The Mediterranean Diet and ADHD in Children and Adolescents

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abstract

OBJECTIVES: Although attention-deficit/hyperactivity disorder (ADHD) has been related to nutrient deficiencies and "unhealthy" diets, to date there are no studies that examined the relationship between the Mediterranean diet and ADHD. We hypothesized that a low adherence to a Mediterranean diet would be positively associated with an increase in ADHD diagnosis.

METHODS: A total of 120 children and adolescents (60 with newly diagnosed ADHD and 60 controls) were studied in a sex- and age-matched case-control study. ADHD diagnosis was made according to the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision*. Energy, dietary intake, adherence to a Mediterranean diet, and familial background were measured. Logistic regression was used to determine associations between the adherence to a Mediterranean diet and ADHD.

RESULTS: Lower adherence to a Mediterranean diet was associated with ADHD diagnosis (odds ratio: 7.07; 95% confidence interval: 2.65–18.84; relative risk: 2.80; 95% confidence interval: 1.54–5.25). Both remained significant after adjusting for potential confounders. Lower frequency of consuming fruit, vegetables, pasta, and rice and higher frequency of skipping breakfast and eating at fast-food restaurants were associated with ADHD diagnosis ($P < .05$). High consumption of sugar, candy, cola beverages, and noncola soft drinks ($P < .01$) and low consumption of fatty fish ($P < .05$) were also associated with a higher prevalence of ADHD diagnosis.

CONCLUSIONS: Although these cross-sectional associations do not establish causality, they raise the question of whether low adherence to a Mediterranean diet might play a role in ADHD development. Our data support the notion that not only "specific nutrients" but also the "whole diet" should be considered in ADHD.

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WHAT'S KNOWN ON THIS SUBJECT: Unhealthy dietary patterns (usually high in saturated fat, refined sugars, and processed food and low in fruit and vegetables) are often associated with attention-deficit/hyperactivity disorder (ADHD).

WHAT THIS STUDY ADDS: A positive relationship between a lower adherence to the Mediterranean diet and ADHD diagnoses has been found. Not only specific nutrients but also the whole diet should be considered in ADHD.

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The etiology of attention-deficit/hyperactivity disorder (ADHD) continues to be debated, although several contributing factors have been acknowledged, including diet.[1,2] However, research on the relationship between ADHD and nutrients and food components thus far has yielded inconsistent results.[3,4] Therefore, a dietary approach to ADHD treatment is still regarded as controversial without a comprehensive evidence base.[5] Some studies have analyzed the association between dietary patterns and ADHD. The common finding is that unhealthy dietary patterns (ie, high in saturated fat and refined sugars and low in fruit and vegetables) are associated with ADHD.[6–9]

The Mediterranean diet is a healthy, well-balanced diet that provides most of the nutrients in their right proportions.[10] However, the Spanish population is moving away from this traditional pattern by increasing their consumption of processed foods and refined sugars, while decreasing vegetable and fruit intakes, consequently losing the benefits of the Mediterranean diet.[11] This eating-pattern change will affect children and adolescents the greatest because they have the highest nutritional needs for optimal growth and development.[8] To our knowledge, there are no studies that examined the potential relationship between adherence to the Mediterranean diet and ADHD.

The worldwide pooled prevalence of ADHD is reported to be 3.4% (95% confidence interval [CI]: 2.6–4.5) in children and adolescents,[12] whereas in Spain it is reported to be 5% to 8% in children and 2.5% to 4% in adolescents.[13] The aim of this study was to compare dietary intake and adherence to a Mediterranean diet in Spanish children and adolescents newly diagnosed with ADHD with that in healthy subjects. We hypothesized that a low adherence to the Mediterranean diet would be associated with an increase in the prevalence of ADHD diagnosis.

METHODS

Subjects

From 130 referrals, 60 children and adolescents (ages 6–16 years) newly diagnosed with ADHD (naive) and 60 sex- and age-matched controls participated in the study (Fig 1). Cases were recruited at the ADHD Unit of the Department of Child and Adolescent Psychiatry and Psychology of the Hospital of Sant Joan de Deu in Barcelona, Spain. The ADHD diagnosis was made according to the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision*.[14] The ADHD Rating-Scale-IV (ADHD RS-IV) for parents was used as screening for the diagnosis of ADHD.[15] The Kiddie Schedule for Affective Disorders and Schizophrenia–Present and Lifetime version (K-SADS-PL) was also used to confirm the ADHD diagnosis and other comorbidities,[16] and the Wechsler Intelligence Scale for Children–IV (WISC-IV)[17] was applied to determine IQ. ADHD diagnosis was made by experienced psychiatrists.

Exclusion criteria were as follows: IQ <70, autism spectrum disorder, psychosis, developmental disorders, and any ADHD drug treatment or nutrient (mineral/vitamin) complement. Subjects in whom the severity of symptoms was significant and in whom a symptomatic treatment was needed urgently (eg, anxiolytic, antipsychotic) before completing the whole evaluation process were also excluded.

Controls were recruited from the ADHD patients' classmates (40%) and from patients attending other hospital services (60%; eg, minor surgery, ambulatory). Controls were screened for the absence of ADHD symptoms and the same exclusion criteria were also applied.

Procedure

The study was approved by the Ethical Committee of the Hospital of Sant Joan de Deu. Written informed consent was obtained from the participants' parents, and verbal assent was obtained from the participants. Demographic and clinical data were obtained from both subjects and parents. Participants underwent a physical examination, including height and weight. BMI was calculated as weight (kg) divided by height (m) squared, and BMI was standardized to BMI *z* score by using age and sex. The whole evaluation, from the first to the last visit, lasted at most 3 weeks (Fig 1).

Assessment of Dietary Intake

Food consumption and nutrient intake were measured by a validated food-frequency questionnaire (FFQ)[18] administered by a trained interviewer. The FFQ comprised 45 items, including foods and beverages. For each food item, participants were asked to record their usual consumption, ranging from never or less than once per month to ≥6 times per day. In addition, a 24-hour recall interview was conducted by telephone. Total energy and nutrient intakes were analyzed by using the nutritional evaluation software program PCN Pro version 1.32.[19,20] According to Willett et al,[21] an adjustment of total energy was made for independent variables by using the nutrient residual model (adjusted for energy), taking into consideration that most nutrients are positively correlated with energy intake, which could introduce a confounding factor. The Willett's methodology allows the calculation of the effect of a specific nutrient beyond any effect due to energy intake.

Assessment of Adherence to the Mediterranean Diet

The KIDMED test[22] was used to evaluate the adherence to the Mediterranean diet. KIDMED test is

based on the principles that sustain Mediterranean dietary patterns and those that undermine it. Items denoting lower adherence were assigned a value of −1 and those related to higher adherence were scored +1. Scores range from −4 to 12, with higher scores indicating greater adherence to the Mediterranean diet.

Physical Activity

Participants used the actigraph ActiSleep (ActiGraph, Pensacola, FL) on their nondominant wrist continuously for 7 days to measure rates of physical activity.

Biochemical Parameters

Fasting blood samples were obtained by venipuncture in the forearm of each participant. Plasma iron, ferritin, transferrin, and zinc were determined in the Laboratory of Biochemistry of the Hospital of Sant Joan de Deu.

Statistical Analyses

Continuous variables were expressed as means (SDs) or medians (interquartile ranges, 25th–75th percentile), whereas categorical variables were expressed as percentages. Differences in normally and nonnormally distributed continuous variables were compared by using the Student's *t* test and the Mann-Whitney *U* test, respectively. Categorical variables were compared by using the χ^2 test. Logistic regression was used to examine associations between the score (after calculating tertiles) of the adherence to the Mediterranean diet and the odds of ADHD diagnosis. In addition, the odds of ADHD diagnosis were estimated according to tertiles of the intake of food groups whose consumption differed between cases and controls, to determine whether any key food group could explain any significant relationship with ADHD. The relative risk (RR) was also computed as the rate for the lowest adherence divided by that for the highest adherence to the Mediterranean diet. Analyses were performed by using the SPSS 21.0 statistical software package (SPSS, Inc, Chicago, IL) and the R package *mmeta* (The R Project for Statistical Computing, The R Foundation). $P \leq .05$ was considered statistically significant.

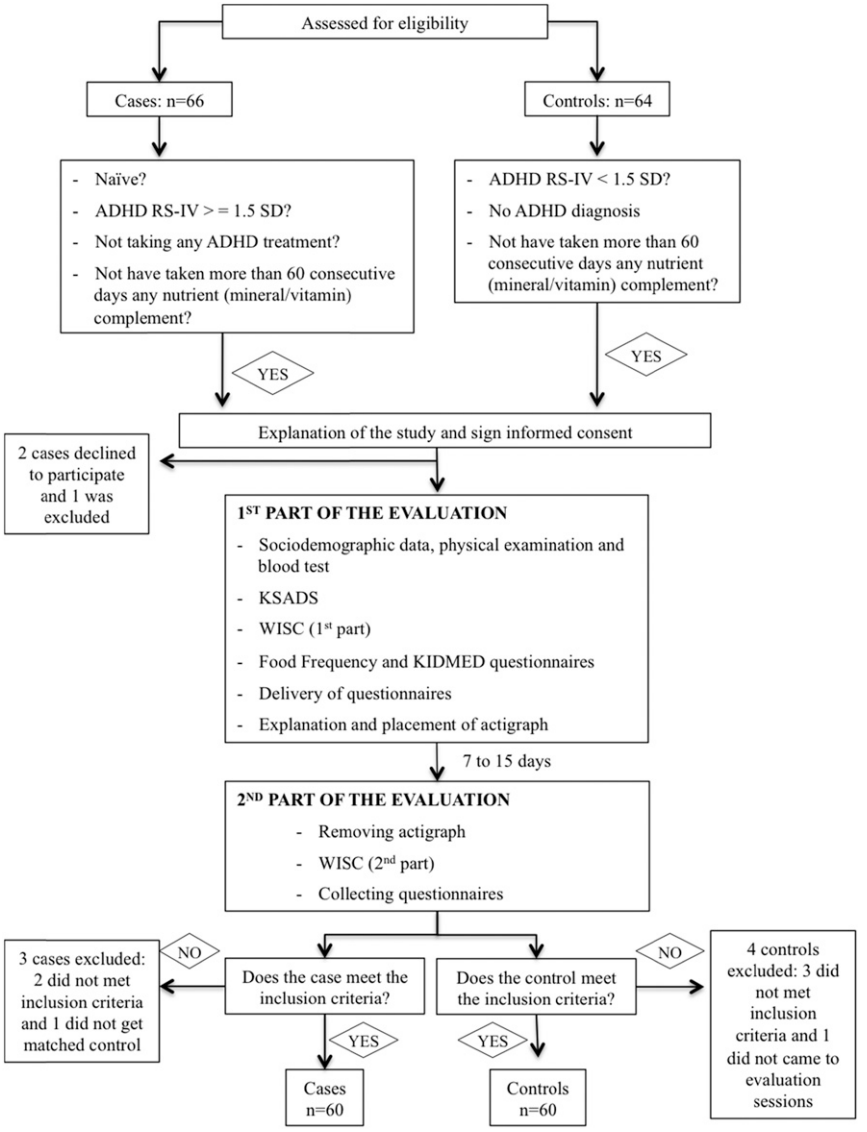

FIGURE 1
Participant flow diagram. ADHD RS-IV, ADHD Rating-Scale-IV; KIDMED, Test to evaluate the adherence to the Mediterranean diet in children and adolescents; KSADS, Kiddie Schedule for Affective Disorders and Schizophrenia–Present and Lifetime version; WISC, Wechsler Intelligence Scale for Children.

RESULTS

General Characteristics

Baseline characteristics of cases and controls are shown in Table 1. There were statistically significant differences associated with ADHD for BMI (and its *z* score) and physical activity but not for body weight at birth. On the other hand, the percentage of subjects with ADHD who were breastfed was lower than of subjects without ADHD; however, the length for those who

were breastfed was the same in both groups. Significant differences were also observed for variables related to familial background. With regard to nutrient plasma levels, no statistically significant differences were found, even though cases showed slightly lower plasma concentrations of iron and ferritin. On the other hand, the cases showed an average value of ADHD-Rating Scale (*Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition*) of 34.2 (9.7), and the K-SADS-PL confirmed the diagnosis of all of the cases. With regard to comorbid diagnoses, 33.3% of patients with ADHD met cutoff criteria for oppositional defiant disorder (ODD), 23.3% for anxiety, 3.3% for conduct disorder, and 1.7% for depression.

TABLE 1 General Characteristics of and Blood Micronutrient Levels in Subjects With ADHD and Control Subjects

	ADHD Cases (n = 60)	Controls (n = 60)	P
Sex, % male (n)	56.7 (34)	56.7 (34)	—
Age, y	9.3 (2.8)	9.3 (2.8)	—
Height, cm	136.5 (16.8)	138.6 (17.3)	.496
Weight, kg	38.1 (16.2)	36.4 (14.5)	.536
BMI	19.6 (4.3)	18 (3.3)	.042*
BMI z score	0.69 (1.1)	0.25 (1.1)	.027*
Body weight at birth, %			
<2.5 kg	13.3	5.0	.114
>2.5 kg	86.7	95.0	
Physical activity,[a] kcal/d	1248.3 (824.6)	861.4 (483.3)	.013*
Maternal smoking pregnancy, %	22.0	8.3	.037*
Breastfeeding, %	66.7	83.3	.035*
Breastfeeding length,[b] mo	5.8 (5.7)	5.7 (5.9)	.931
Maternal educational level,[c] %	63.3	88.3	<.001*
Paternal educational level,[c] %	55.0	76.7	.012*
Biological father living with family, %	81.7	96.7	.008*
Marital status of parents,[d] %	18.3	5.0	.023*
Nutrient plasma levels			
Iron, μg/dL	80.1 (32.5)	85.4 (32.1)	.366
Transferrin, mg/dL	266.2 (29.9)	265.7 (27.9)	.922
Ferritin, μg/L	36.2 (21.0)	42.2 (36.9)	.273
Zinc, μg/L	988.6 (182.0)	975.5 (162.0)	.680

Data are presented as means (SDs) unless otherwise indicated. —, not applicable.
[a] Measured with the actigraphy accelerometer ActiSleep.
[b] Calculated for those who breastfed.
[c] More than primary school.
[d] Separated/divorced.
* P < .05.

ADHD Is Associated With a Lower Adherence to the Mediterranean Diet

Children and adolescents with ADHD showed statistically significant lower scores of adherence to a Mediterranean diet than controls (Table 2). Within the subjects with ADHD, no significant differences in KIDMED scores were observed in those patients with comorbidities such as anxiety (ADHD without anxiety versus ADHD with anxiety: 6.5 [2.0] vs 5.5 [2.0]; P = .096) or ODD (ADHD without ODD versus ADHD with ODD: 6.0 [2.1] vs 6.5 [1.7]; P = .132). When compared with controls, the percentages of subject with ADHD who consume a second serving of fruit every day, of fresh or cooked vegetables daily or more than once a day, and pasta or rice almost every day were significantly lower (Table 2). In addition, the percentage of subjects with ADHD who ate more frequently at a fast-food restaurant was higher than that of controls. In addition, the percentage of subjects who skipped breakfast was significantly higher for the cases. However, no statistically significant differences were observed with respect to the consumption of fish, dairy, and cereal products or baked goods.

Statistical differences were found between children and adolescents with or without ADHD regarding some food group intakes (Table 3). Cases consumed fewer vegetables, citrus fruits, and fatty fish but larger amounts of noncola soft drinks, cola beverages, sugar, and candy than controls. Moreover, individuals with ADHD consumed statistically higher amounts of simple sugars and caffeine and lower amounts of total protein than controls. On the other hand, no significant differences were found for total daily energy intake or other nutrient intakes, including iron and zinc, which are commonly related to ADHD.

We further compared low, medium, and high adherence to the Mediterranean diet with ADHD diagnoses (Table 4). Children and adolescents with a low adherence to the Mediterranean diet were more likely to be associated with an ADHD diagnosis in the crude model (P < .001). The RR was also significant (RR: 2.80; 95% CI: 1.54–5.25). Both odds ratios and RRs remained significant after adjusting for potential confounding variables, such as BMI, level of physical activity, breastfeeding, maternal smoking during pregnancy, maternal educational level, paternal educational level, biological father living with family, and parents divorced. When examining the consumption of specific food groups and ADHD diagnosis, an intake in the low tertile of vegetables, citrus fruit, and fatty fish was associated with ADHD diagnosis in the crude model (Table 4). Further adjustment for potential confounding variables attenuated the association with the exception of fatty fish consumption, which remained statistically significant. On the other hand, subjects with an intake in the highest tertile for

TABLE 2 Mediterranean Diet Quality (KIDMED Score and Index) and Frequencies of Response to Each Item of the KIDMED Test in Subjects With ADHD and in Control Subjects

	ADHD Cases (n = 60)	Controls (n = 60)	P
KIDMED test score total, mean (SD)	6.2 (2.0)	8.1 (1.8)	<.001*
KIDMED index, %			
Poor (≤3 points)	11.7	0.0	
Average (4–7 points)	58.3	36.7	<.001*
Good (8–12 points)	30.0	63.3	
KIDMED test, % yes			
Fruit or fruit juice daily	71.7	78.3	.399
Second serving of fruit daily	20.0	38.3	.027*
Fresh or cooked vegetables daily	35.0	58.3	.010*
Fresh or cooked vegetables more than once a day	31.7	61.7	<.001*
Regular fish consumption (at least 2–3/week)	81.7	86.7	.453
More than once per week at fast-food (hamburger) restaurant	20.0	1.7	<.001*
Pulses more than once a week	68.3	81.7	.092
Pasta or rice almost every day (≥5 times/week)	55.0	85.0	<.001*
Cereals or cereal product (bread) for breakfast	91.7	98.3	.094
Regular nut consumption (at least 2–3 times/week)	33.3	26.7	.426
Use of olive oil at home	98.3	98.3	.999
No breakfast	6.7	0.0	.042*
Dairy product for breakfast (yogurt, milk, etc)	98.3	98.3	.999
Commercially baked goods or pastries for breakfast	61.7	61.7	.999
Two yogurts and/or some cheese (40 g) daily	81.7	90.0	.119
Sweets and candy several times every day	48.3	35.0	.139

KIDMED, Test to evaluate the adherence to the Mediterranean Diet.
* $P < .05$.

sugar and candy, cola beverages, and noncola soft drinks were associated with a higher prevalence of ADHD diagnosis (Table 4). The association remained significant after adjusting for confounding variables.

DISCUSSION

This is the first study to show that low adherence to the Mediterranean diet is associated with odds of an ADHD diagnosis in children and adolescents. This association remained significant after adjusting for confounding variables. Among the habits that characterize a Mediterranean dietary pattern, individuals with ADHD more often missed having a second serving of fruit daily and showed reduced intakes of vegetables, pasta, and rice almost every day when compared with controls. Moreover, subjects with ADHD ate at fast-food restaurants and skipped breakfast more often than controls. In addition, a high consumption of sugar and candy, cola beverages, and noncola soft drinks and a low consumption of fatty fish were also associated with a higher prevalence of ADHD diagnosis.

Several advantages supporting the study of dietary pattern versus single nutrients in health promotion, including mental health, have previously been discussed.[2,23] It seems that in addition to analyzing the impact that a single food component may have on ADHD, the role of dietary patterns as a whole can be more informative. Some studies have analyzed different types of dietary patterns, but none specifically on the Mediterranean diet. In a cohort of Australian adolescents,[6] a dietary pattern identified as the "Western" type was significantly associated with ADHD diagnosis. Similarly, in a cross-sectional study in Iranian children, a greater adherence to fast-food and sweet dietary patterns was associated with a higher prevalence of ADHD.[7] Recently, in a case-control study in Korean children, the traditional-healthy dietary pattern, characterized by high intakes of kimchi, grains, and bonefish and low intakes of fast foods and beverages, was associated with a lower probability of ADHD diagnosis.[9] Moreover, other studies have confirmed that skipping breakfast or substituting it for a sugary drink impairs attention and episodic memory in children.[24] Therefore, low-quality diets are persistently associated with a higher risk of ADHD. Consistent with this finding, a clinical trial examining the effect of overall dietary characteristics in medicated children with ADHD found that a balanced diet, regular meals, and a high intake of dairy products and vegetables were associated with fewer attention and behavioral problems.[25]

Although the mechanisms linking low-quality diet and ADHD are still unknown, an unbalanced diet can lead to deficiencies in essential nutrients or higher intakes of certain food components (ie, food additives).[26] There are numerous potential biological pathways by which diet quality may have an impact on mental health.[2,27] For instance, iron and zinc, which contribute to healthy neurocognitive

TABLE 3 Food Group, Energy, and Nutrient Daily Intakes in Subjects With ADHD and in Control Subjects

	ADHD Cases (n = 60)	Controls (n = 60)	P
Food group intake,[a] g			
Dairy products	296.0 (207.8–331.2)	272.3 (210.3–322.4)	.773
Cereals	161.5 (143.6–188.0)	168.1 (142.9–215.9)	.289
Bakery	6.6 (3.0–10.0)	5.0 (2.9–9.6)	.715
Vegetables	59.6 (25.1–91.0)	81.6 (45.4–110.9)	.018*
Citric fruit	17.8 (3.2–34.5)	26.0 (13.4–53.0)	.031*
Other fruit	53.4 (29.7–95.3)	60.1 (29.9–115.8)	.299
Meat	53.9 (40.4–67.6)	53.3 (40.9–73.2)	.735
Blue fish	7.5 (0.0–11.9)	8.8 (3.9–18.0)	.045*
White fish	12.7 (7.5–18.0)	12.4 (8.8–16.3)	.592
Sugar and candy	4.7 (1.5–11.1)	2.4 (0.6–5.3)	.007*
Noncola soft drinks[b]	41.1 (6.0–98.0)	22.0 (0.0–65.5)	.017*
Cola beverages[c]	17.2 (0.0–50.3)	9.2 (0.0–24.2)	.041*
Energy, nutrient (per 1000 kcal), and caffeine intakes			
Energy, kcal	1609.9 (375.3)	1626.9 (382.8)	.806
Carbohydrates, g	122.7 (10.9)	119.6 (11.0)	.114
Simple sugars	60.4 (16.7)	54.5 (10.5)	.022*
Protein, g	47.3 (7.3)	50.1 (7.0)	.031*
Animal	34.5 (7.1)	36.6 (7.8)	.129
Vegetable	12.8 (2.2)	13.5 (2.6)	.087
Fat, g	35.2 (3.9)	35.4 (4.1)	.780
Saturated fatty acids	14.0 (2.1)	14.2 (2.0)	.448
Monounsaturated fat	11.5 (1.3)	11.5 (1.5)	.793
Polyunsaturated fat	6.1 (1.7)	5.9 (1.6)	.441
Dietary fiber, g	9.4 (2.1)	10.2 (2.5)	.057
Iron, mg	6.1 (1.0)	6.4 (1.1)	.129
Zinc, mg	5.1 (0.8)	5.4 (0.7)	.066
Caffeine, mg	3.8 (5.3)	1.5 (1.9)	.003*

Data are presented as medians (25th–75th percentile) or as means (SDs), as appropriate.

[a] Dairy products include milk, cheese, yogurt, milk/ice cream, and dairy-based desserts; cereals include pasta, rice, potatoes, and breakfast cereals; bakery includes cookies, muffins, donuts, croissants, etc; vegetables (raw and cooked) include salads, tomatoes, spinach, broccoli, green beans, etc; citrus fruit include orange, mandarin, and kiwi; other fruit include apples, bananas, pears, etc; meat includes pork, chicken, beef, lamb, sausages, etc; fatty fish includes sardines, anchovies, tuna, mackerel, salmon, etc; white fish includes hake, codfish, etc; noncola soft drinks include lemon, orange, and other flavors of soda drinks (all caffeine-free); and cola drinks include regular and diet cola drinks.

[b] Seventy-two percent of cases and 80% of controls for noncola soft-drink consumers also drank cola.

[c] Eighty percent of cases and 70% of controls for "cola drinkers" also drank noncola soft drinks.

* $P < .05$.

and physical growth, are cofactors for dopamine and norepinephrine production, both of which play an essential role in the etiology of ADHD. Low plasma levels of iron, ferritin, and zinc[28–30] have been found in children with ADHD. However, in our study, no significant differences regarding the intakes of those nutrients or their serum levels were observed between cases and controls. Donfrancesco et al[31] concluded that normal ferritin levels should not suggest that iron deficiency is not involved in the pathophysiology of ADHD. Indeed, serum ferritin is a marker of peripheral, but not of brain, iron status, in which iron is necessary as a cofactor. The extent to which serum ferritin correlates with iron levels in the brain remains unclear.[32] Omega-3 fatty acids seem also to have a relationship with ADHD. Two recent meta-analyses reported a small but beneficial effect of omega-3 supplementation on reducing symptoms of ADHD.[5,33,34] However, this finding is not entirely supported by the current evidence as a primary treatment of ADHD.[35] In this study, it was not possible to estimate omega-3 intake among controls and cases because the Spanish food-composition tables[20] do not contain information about omega-3 fatty acids. Nonetheless, we found that fatty fish intake, which is the main source of long-chain polyunsaturated omega-3 fatty acids in the Spanish diet, was significantly lower in cases than in controls.

The observed relationship between intakes in the highest tertile of sugary products and increased odds for ADHD is in line with the findings of other studies.[6,9] It is possible that a high intake of these low-nutrient products could indicate a poor micronutrient intake. Two recent studies found that vitamin and mineral supplementation resulted in significant reductions in ADHD symptoms in both children and adults with ADHD.[36,37] In the case of children, these reductions were reversed when the treatment was withdrawn. This kind of approach makes physiologic sense, considering that nutrients are required for many critical biochemical reactions and because it is unlikely that 1 nutrient by itself would resolve all vulnerabilities present in a complex disorder such as ADHD.[38]

We cannot overlook that the relationship found between diet and ADHD could represent reverse causation.[6] Individuals with ADHD are often characterized by impulsivity traits and emotional distress[39] that may lead to poor dietary choices (ie, fat-rich or sugar-rich snack foods) to balance their emotions as a form of self-medication.[27,40] In our population, we found that the intake of sugary beverages and foods was significantly higher in cases than in controls, and those higher intakes were reflected in a larger amount of sugar intake. On the other hand, the role of the family cannot be dismissed considering that a healthy diet is related to a better functioning family.[41,42] Parents of individuals with ADHD often report a more dysfunctional family environment,[39,43,44] so it is plausible that the relationship between low adherence to a healthy diet and ADHD diagnosis may be exacerbated by a dysfunctional

family environment.[6] All of these factors could support a vicious cycle: impulsiveness and family dysfunction could lead to a worse choice of foods, lowering the diet quality, which eventually could lead to a low intake of certain nutrients. This situation may induce certain nutritional subclinical deficiencies and, hence, worsen ADHD symptoms.

The statistical differences in BMI and *z* scores found between cases and controls deserve discussion even though physical activity was higher in cases than in controls, although the energy intake was similar in both groups. Our findings are in line with a recent study, which provided meta-analytic evidence for a significant association between ADHD and obesity/overweight and postulated that the impulsivity and inattention that characterize ADHD might lead to deregulated eating patterns and, consequently, weight gain.[45] Another possible explanation is the "thrifty" phenotype theory, which proposes a mechanism of early programming in which a wide range of environmental conditions before and during pregnancy determine susceptibility to disease later in life.[46] Several studies have shown that children whose mothers smoke during pregnancy are at an elevated risk of being overweight.[46] In our work, we observed a higher percentage of maternal smoking during pregnancy in cases compared with controls.

Finally, the significant differences observed for other indicators of certain social disadvantages (ie, maternal and/or paternal education and single parenthood) or maternal prenatal smoking or insufficient breastfeeding are in accordance with data previously published.[42,47–49] The association between insufficient breastfeeding and ADHD development suggests a "chicken-and-egg" question of which came first, the disorder or the inability to be breastfed, because infants who appear to reject the breast might show an early manifestation of a neuropsychiatric disorder, such as ADHD.[41]

Some limitations of our design and methods should be acknowledged, such as the case-control study design, which prevents our ability to assess cause-and-effect associations. Furthermore, all dietary instruments, such as FFQs, that measure past food intake are vulnerable both to random and systematic measurement errors. Nonetheless, this study has several important strengths, including the fact that all of the cases included were naive, taking no medication. The use of certain drugs might affect the food choices and provoke changes in the child's and adolescent's diet. In addition, well-trained, experienced psychiatrists and psychologists performed the evaluation.

TABLE 4 ORs (95% CIs) for ADHD by Tertile Categories of Mediterranean Diet Score and Consumption of Other Food Groups

	n	Crude OR (95% CI)
Mediterranean diet score		
High adherence	36	1 (reference)
Medium adherence	37	2.84 (1.05–7.67)
Low adherence	47	7.07 (2.65–18.84)
P for linear trend		<.001*
Vegetable consumption		
High	40	1(reference)
Medium	40	1.60 (0.68–4.13)
Low	40	3.85 (1.53–9.75)
P for linear trend		.004*
Citrus fruit consumption		
High	40	1(reference)
Medium	40	1.36 (0.55–3.29)
Low	40	2.68 (1.08–6.65)
P for linear trend		.034*
Fatty fish consumption		
High	40	1 (reference)
Medium	40	1.84 (0.75–4.49)
Low	40	2.50 (1.02–6.15)
P for linear trend		.046*
Sugar and candy consumption		
Low	40	1 (reference)
Medium	42	1.11 (0.45–2.70)
High	38	3.25 (1.28–8.25)
P for linear trend		.014*
Cola beverage consumption		
Low	40	1 (reference)
Medium	40	0.73 (0.29–1.80)
High	40	3.55 (1.40–9.01)
P for linear trend		.008*
Soft-drink consumption		
Low	40	1 (reference)
Medium	40	1.23 (0.50–3.02)
High	40	3.89 (1.53–9.87)
P for linear trend		.004*

OR, odds ratio.
* $P < .05$.

CONCLUSIONS

We found a positive relationship between a lower adherence to the Mediterranean diet and ADHD diagnoses. The current findings suggest that certain dietary habits may play a role in ADHD development, even though further work is required to investigate causality and to determine if dietary manipulation could reverse the symptoms of ADHD, taking into consideration

all potential factors. Therefore, our main recommendation is that clinicians focus on diet not with the expectation of dietary changes improving behavior but with the concern that children with ADHD are more likely to be eating unhealthy diets; this component should therefore be part of the evaluation to improve their health.

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ABBREVIATIONS

ADHD: attention-deficit/hyperactivity disorder
CI: confidence interval
FFQ: food-frequency questionnaire
ODD: oppositional defiant disorder
RR: relative risk

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