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ORIGINAL CONTRIBUTION

Adherence to the Mediterranean diet and academic performance in youth: the UP&DOWN study

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Abstract
Purpose To examine the association between adherence to the Mediterranean diet and academic performance in children and adolescents.
Methods This is a cross-sectional study conducted with 1371 youth aged 12.04 ± 2.50 years (685 girls) in Spain during 2011–2012. Adherence to the Mediterranean diet was assessed using the KIDMED index (Mediterranean Diet Quality Index in children and adolescents), which includes 16 questions on specific dietary patterns. Levels of adherence were classified into three groups: poor adherence (0–3), average adherence (4–7), and good adherence (8–12). Academic performance was assessed through school records using four indicators: math, language, an average of math and language, and grade point average score.
Results Adherence to the Mediterranean diet was related to academic performance (β ranging from 0.107 to 0.148; all $P < 0.001$) after adjusting for confounders. The group of good adherence to the Mediterranean diet had significantly higher scores in all of the academic indicators compared with the poor group (ranging from +0.429 to 0.464; all $P \leq 0.001$); as well as the group of average adherence to the Mediterranean diet had significantly higher scores in all of the academic indicators compared with the poor group (ranging from +0.292 to 0.344; all $P \leq 0.06$). There were no differences between the groups of good and average adherence to the Mediterranean diet.
Conclusions Adherence to the Mediterranean diet may have a beneficial influence on academic performance in youth. Importantly, the benefits of adherence to the Mediterranean diet on academic performance may be stronger as youth adhered to the optimal Mediterranean diet levels.

Keywords Mediterranean diet · Academic performance · Children and adolescents

Introduction

The Mediterranean diet (MeD) is characterized by an elevated consumption of plant based foods (e.g., fruits, nuts, and vegetables), a moderate-to-high consumption of fish and seafood, a low intake of red meat and dairy products, and the use of olive oil as the main source of fat [1]. There are numerous benefits of adherence to the MeD for cardiovascular diseases, some cancers, and chronic degenerative diseases [2]. In addition, the MeD has been associated with brain health (i.e., Alzheimer's disease) and cognitive improvement in middle and older ages [3, 4]. Little is known, however, about the influence of the MeD on academic performance during childhood and adolescence, key periods to adopt healthy patterns, in which actually adherence to the MeD is low [5, 6].

On behalf of UP&DOWN Study Group.
Please see the "Appendix" for The UP&DOWN Study Group.

Electronic supplementary material The online version of this article (doi:10.1007/s00394-015-0927-9) contains supplementary material, which is available to authorized users.

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Previous studies in youth have focused on the association of individual food included into the MeD (e.g., vegetables, fruits, fish, or nuts) with academic indicators [7–15]. Intake of fish was related to higher academic performance in adolescents [14, 15], whereas the benefits of fruit and vegetable consumption on academic indicators were found in both children and adolescents [7–13]. However, beyond the influence of individual components on academic performance, a joined approach of the MeD, considering the synergistic effects of each food component, has been broadly recommended due to the high-quality properties of this diet [16]. For example, olive oil and nuts have antioxidant properties and, together with other polyphenol-rich foods in the MeD, are suggested to improve cognitive function, which in turn may influence academic performance at school age [17]. To date, there is only one study examining the influence of adherence to the MeD on academic performance, indicating that poor adherence to the MeD seems to negatively affect academic performance in 10- to 12-year-old Greek children [18]. Therefore, it is necessary to expand knowledge on the role that adherence to the MeD may play on academic performance among both children and adolescents.

The aim of this study was to examine the association between adherence to the MeD and academic performance in a large sample of children and adolescents.

Materials and methods

Participants

Participants selected for this study were enrolled in the UP&DOWN study. Detailed information about the study methods is available elsewhere [19]. In brief, the UP&DOWN study is a 3-year longitudinal study designed to assess the impact over time of physical activity and sedentary behaviors on health indicators as well as to identify the psychoenvironmental and genetic determinants of physical activity, in a Spanish sample of children and adolescents. Data were collected from September 2011 to June 2012. Children and adolescents were recruited from schools in the Cadiz and Madrid regions, respectively. A total of 2225 youth aged 6–18 years participated in the UP&DOWN study. The 6-year-old children did not complete dietary patterns questionnaire due to possible bias. Thus, the present analysis included 1371 youth aged 12.04 ± 2.50 years (685 girls) with complete data at baseline on dietary patterns and academic performance.

Parents and school supervisors were informed by letter about the nature and purpose of the study, and written informed consent was provided. The study protocols were approved by the Ethics Committee of the *Hospital Puerta de Hierro* (Madrid, Spain), the Bioethics Committee of the National Research Council (Madrid, Spain), and the Committee for Research Involving Human Subjects at University of Cádiz.

Adherence to the Mediterranean diet

Adherence to the MeD was assessed using the KIDMED index (Mediterranean Diet Quality Index in children and adolescents). The KIDMED index was based on principles sustaining Mediterranean dietary patterns, as well as those that could potentially impair the MeD [5]. This questionnaire consists of 16 yes/no questions, 12 denoting positive connotation and four with negative aspect with respect to the MeD. Positive questions were assigned a value of +1: (1) fruit or fruit juice daily, (2) second fruit every day, (3) fresh or cooked vegetables daily, (4) fresh or cooked vegetables more than once a day, (5) regular fish consumption at least 2–3 times per week, (6) pulses more than once a week, (7) pasta or rice consumption five or more times per week, (8) cereals or grains for breakfast, (9) nuts consumption at least 2–3 times per week, (10) use of olive oil at home, (11) dairy product for breakfast, and (12) two yoghurts and/or 40 g cheese daily. Negative questions were assigned a value of −1: (1) consumption of fast foods more than once a week, (2) skipping breakfast, (3) commercially baked goods or pastries for breakfast, and (4) sweets and soft candy several times a day. The index of adherence to the MeD was calculated as the sum of each answer and ranged from 0 to 12. Levels of adherence were classified into three groups: poor adherence (0–3), average adherence (4–7), and good adherence (8–12) to the MeD [5].

Academic performance

School records at the end of the academic year were provided for every school. Academic performance was based on four indicators: math, language, an average of these two core subjects, and grade point average (GPA) score. GPA score was calculated as a single average for the examinable subjects in each grade (e.g., natural sciences, social sciences, and English). We used math and language as individual indicators due to the important role that cognitive control (i.e., inhibition and working memory) plays in these areas [20]. In addition, we used an average of specific subjects (i.e., math and language). Passing both subjects is taken to indicate good academic performance due to according to the Spanish educational system (www.educacion.es); the minimum requirement for passing grade is fail in no more than two subjects, whenever these two subjects are not math and language. Other previous studies have also used these indicators to assess academic performance [21–24]. For standardized purposes, individual letter grades

were converted to numeric data as follows: $A = 5$, $B = 4$, $C = 3$, $D = 2$, and $F = 1$.

Covariates

Participants' age, sex, and city (Cadiz/Madrid) were recorded. Gestational age at time of delivery (weeks), birth weight (kg), and maternal education level (below university education and university education) were reported by parents [25].

Anthropometric and physical fitness measurements were assessed with the ALPHA health-related fitness test battery for youth [26]. Body mass index was calculated as weight in kilograms divided by height in meter-squared (kg/m^2). A fitness score was calculated as the mean of the two z-standardized scores of the cardiorespiratory and motor fitness tests [21]. Physical activity and sedentariness were measured by the ActiGraph accelerometer models GT1M, GT3X, and GT3X+ (Actigraph TM, LLC, Fort Walton Beach, FL, US). Each participant wore the accelerometer at the lower back for seven consecutive days, removing it during sleep hours and water-based activities. The inclusion criteria were an activity monitor recording of at least 10 h per day for 3 days [27, 28]. Moderate-to-vigorous physical activity and sedentary time were estimated by using the cut-point values of 2000 counts per minutes (cpm) and <100 cpm, respectively [29, 30]. Neonatal, anthropometric, fitness, physical activity, and sedentariness variables were included as covariates because we found that these characteristics were associated with academic performance in previous studies with the present sample [21–23].

Statistical analysis

The characteristics of study sample are presented as means (SD) or percentages. Differences between sexes were determined by *t* tests and Chi-squared tests for continuous and nominal variables, respectively. Since preliminary analyses showed no significant interactions between sex, age, and adherence to the MeD (all $P > 0.1$), all analyses were performed with the whole sample.

Partial correlations controlling for sex, age and city were used to analyze the relationships of gestational age, birth weight, body mass index, moderate-to-vigorous physical activity, sedentary time, fitness with adherence to the MeD.

The association of adherence index to the MeD (ranged from 0 to 12) with academic performance was assessed by linear regression using three separate models: Model 1 was controlled for age, city, and maternal education; model 2 was additionally controlled for gestational age, birth weight, and body mass index; and model 3 was further adjusted for moderate-to-vigorous physical activity, sedentary time, and fitness. Additionally, we examined the association between the MeD components and academic performance using linear regression controlling for all previous covariates.

We also examined differences in academic performance variables among the three groups of adherence to the MeD (poor, average and good) using one-way ANCOVA adjusted for the previous covariates. All statistical analyses were performed using the SPSS version 18.0 for Windows (IBM, Armonk, New York), and the level of significance was set at $P < 0.05$.

Results

Table 1 shows the descriptive of study sample. Overall, boys were heavier and taller than girls (both $P < 0.01$). Boys also had higher birth weights than girls ($P < 0.001$). Moreover, boys spent more time in moderate-to-vigorous physical activity than girls ($P < 0.001$). However, girls spent more time in sedentary behavior ($P < 0.001$). The level of adherence to the MeD was greater in boys than in girls ($P = 0.041$). Girls had higher scores than boys in language ($P < 0.001$), the average of math and language ($P = 0.043$), and GPA ($P = 0.001$).

Table S1 (supplementary file) shows the partial correlations between exposures after adjustments for sex, age, and city. Adherence to the MeD was only correlated with gestational age ($r = 0.055$; $P = 0.044$); however, it was not associated with birth weight, body mass index, moderate-to-vigorous physical activity, sedentary time, or fitness (all $P > 0.05$).

Table 2 displays the associations between adherence index to the MeD and academic performance. In model 1, adherence to the MeD was associated with all academic performance indicators after controlling for sex, age, city, and maternal education (β ranging from 0.115 to 0.157; all $P < 0.001$). In model 2, the associations remained significant after further adjustments for birth weight, gestational age, and body mass index (β ranging from 0.110 to 0.152; all $P < 0.001$). Finally, in model 3 (additionally including moderate-to-vigorous physical activity, sedentary time, and fitness), adherence to the MeD was related to academic performance (β ranging from 0.107 to 0.148; all $P < 0.001$). In addition, table S2 (supplementary file) presents the associations between components of the MeD and academic performance.

Figure 1 shows the differences in academic performance between groups of adherence to the MeD, after adjusting for potential confounders. Significant differences in all academic performance variables were found across the groups (all $P \leq 0.002$). Indeed, the group of good adherence to the MeD had significantly higher scores in all of the academic indicators compared with the poor

Table 1 Descriptive characteristics of study sample

	All	Boys	Girls	$P_{\text{for sex}}$
n	1371	686	685	
Physical characteristics				
Age (year)	12.04 ± 2.50	12.00 ± 2.47	12.08 ± 2.53	0.537
Weight (kg)	48.52 ± 13.95	49.62 ± 15.55	47.42 ± 12.04	**0.003**
Height (cm)	152.79 ± 13.61	154.29 ± 15.22	151.28 ± 11.58	**<0.001**
Maternal education level university (%)	29	31	27	0.159
Birth weight (kg)	3.22 ± 0.53	3.28 ± 0.54	3.16 ± 0.52	**<0.001**
Gestational age (week)	38.44 ± 2.56	38.42 ± 2.48	38.47 ± 2.64	0.724
Body mass index (kg/m^2)	20.39 ± 3.55	20.35 ± 3.63	20.43 ± 3.48	0.671
Fitness (z-score)[a]	0.41 ± 0.70	0.42 ± 0.71	0.40 ± 0.69	0.705
Moderate-to-vigorous PA (min/day)	65.79 ± 22.53	68.77 ± 22.06	62.82 ± 22.63	**<0.001**
Sedentary time (min/day)	620.11 ± 108.99	607.03 ± 111.20	633.21 ± 105.19	**<0.001**
Adherence index to the MeD (0–12)	6.66 ± 2.29	6.79 ± 2.30	6.53 ± 2.27	**0.041**
Adherence to the MeD (%)				
Poor (≤3)	8	8	9	
Average (4–7)	55	52	57	
Good (≥8)	37	40	34	0.057
Academic performance				
Math (1–5)	3.08 ± 1.33	3.10 ± 1.32	3.06 ± 1.35	0.585
Language (1–5)	3.18 ± 1.33	3.02 ± 1.36	3.33 ± 1.28	**<0.001**
Math and Language (1–5)	3.13 ± 1.24	3.06 ± 1.26	3.20 ± 1.21	**0.043**
Grade point average (1–5)	3.44 ± 0.97	3.35 ± 0.99	3.53 ± 0.93	**0.001**

Statistically significant values are in bold

Values are mean ± SD or percentages

PA physical activity, *MeD* Mediterranean diet

[a] z-score computed from the 20-m shuttle-run test and the 4 × 10 m shuttle-run test

Table 2 Associations of adherence to the Mediterranean diet and academic performance in youth ($n = 1371$)

	Adherence index to Mediterranean diet (0–12)					
	Model 1		Model 2		Model 3	
	β	*P*	β	*P*	β	*P*
Math	0.119	**<0.001**	0.115	**<0.001**	0.111	**<0.001**
Language	0.115	**<0.001**	0.110	**<0.001**	0.107	**<0.001**
Math and Language	0.126	**<0.001**	0.121	**<0.001**	0.117	**<0.001**
Grade point average	0.157	**<0.001**	0.152	**<0.001**	0.148	**<0.001**

Statistically significant values are in bold

Values are standardized regression coefficients (β). Model 1: Analyses were adjusted by sex, age (year), city (Cadiz/Madrid), and maternal education (university level/below university level). Model 2: Adjustments for model 1 plus birth weight (kg), gestational age (week), and body mass index (kg/m^2). Model 3: Adjustments for model 2 plus moderate-to-vigorous physical activity (min/day), sedentary time (min/day), and fitness (z-score)

group (ranging from +0.429 to 0.464; all $P \leq 0.001$); as well as the group of average adherence to the MeD had significantly higher scores in all of the academic indicators compared with the poor group (ranging from +0.292 to 0.344; all $P \leq 0.06$). There were no differences between the group of good and average adherence to the MeD. Analyses were also performed including waist circumference and body fat percentage instead of body mass index in separate models, and results were virtually similar (data no shown).

Discussion

The main finding of this study indicated that adherence to the MeD was positively associated with academic

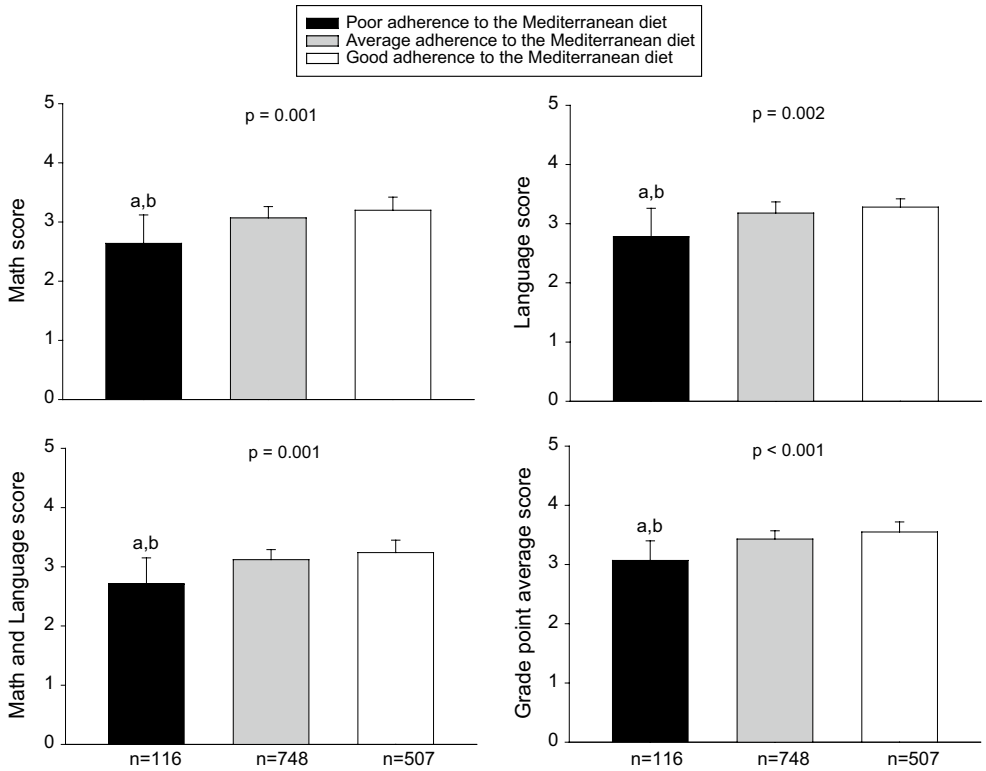


Fig. 1 Differences in academic performance between adherence to the Mediterranean diet groups in youth. *Error bars* represent 95 % confidence interval. Analyses were adjusted by sex, age (year), city (Cadiz/Madrid), maternal education (university level/below university level), birth weight (kg), gestational age (week), body mass index (kg/m^2), moderate-to-vigorous physical activity (min/day), sedentary time (min/day), and fitness (z-score). *a* Significant differences between the poor and the average adherence groups (all $P < 0.05$). *b* Significant differences between the poor and the good adherence groups (all $P < 0.05$)

performance in youth, independent of potential confounders, including body mass index, physical activity, fitness, and sedentary behavior. Importantly, we found that the higher the adherence to the MeD, the better the academic performance scores in youth. These results contribute to the current knowledge by suggesting that adherence to the MeD may have a beneficial influence on academic performance in youth.

Several plausible mechanisms can explain the protective effect of adherence to the MeD on cognition, including antioxidative and anti-inflammatory effects and reduced vascular comorbidities. Higher adherence to the MeD is associated with lower levels of C-reactive protein and interleukins; thus an underlying neuroprotective effect could be due to its vascular properties and its ability to reduce inflammation and oxidative stress, which are also associated with neurodegeneration [31]. Other mechanisms could be due to the joined beneficial effect of the individual components of the MeD. For example, olive oil and nuts have antioxidant properties and, together with other polyphenol-rich foods in the MeD, are suggested to improve cognitive function [32]. Polyphenols from fruits and vegetables seem to influence and modulate several cellular processes in brain; in particular, the α-tocopherol form of vitamin E might exert regulatory effects on cell proliferation and beneficial effects in improving glucose transport and insulin sensitivity [31]. Lastly, fish contains abundant n-3 polyunsatured fatty acids, such as docosahexaenoic acid and eicosapentaenoic acid. These two n-3 polyunsatured fatty acids are major components of neuronal membranes and perform several brain functions [i.e., modulating synaptic plasticity and neurochemistry, neuroimmune modulation, and neuroprotection], which may influence cognition [32].

To our knowledge, there is only one previous study that examined the association of adherence to the MeD with academic performance in a sample of 528 Greek children aged 10–12 years [18]. This study found that good adherence to the MeD was related to academic performance independently of socioeconomic status, self-esteem, body mass index, and some energy balance behaviors (i.e., physical activity, television viewing, and sleep time). Present findings also highlighted the importance of adherence to the MeD on academic performance and expand the previous study by (1) examining this association in a relatively large and heterogeneous sample of both children and adolescents aged 8–18 years and (2) improving several methodological

aspects. First, we used school grades, which are socially valid measures of academic performance, and included four academic indicators (i.e., math, language, an average of math and language, and GPA), whereas the study conducted in Greece assessed children's academic performance using a questionnaire completed by teachers, which may have potential limitations of bias, and included only an overall academic indicator. Second, our study included additional covariates such as physical fitness, birth weight, and gestational age, characteristics that have previously shown to influence academic performance [21–23]. Lastly, we accurately measured energy balance behaviors by accelerometry (e.g., physical activity and sedentary time), while in the study from Vassiloudis et al. [17], these behaviors, used as confounders, were self-reported. Therefore, further studies in youth using standardized tests and measures of brain function and taking into account present confounders are needed.

The typical MeD is characterized by high intakes of vegetables, fruits and nuts, legumes, cereals, and fish; relatively low intakes of meat and dairy products and the use of olive oil as an important fat source [1]. Previous studies have examined the association of individual foods with academic performance in youth [7–15]. For example, intake of fruits and vegetables was related to higher academic performance in both children and adolescents [7–13]. Additionally, few studies in adolescents found a beneficial influence of fish consumption on academic indicators [14, 15]. Even, a longitudinal study of 9-year-old children whose mothers had consumed fish during the early pregnancy period had an increased verbal intellectual quotient compared with those whose mothers never ate fish [33]. However, an integrative approach of the MeD considering the synergistic effects of each food component have been broadly recommended [16]. Therefore, beyond the study of individual MeD components in relation to academic performance, it is necessary for further research to examine the influence of the MeD on academic performance in youth.

Although the MeD is a healthy pattern culturally rooted in the countries of the Mediterranean basin, there is an increasing prevalence of poor adherence to the MeD among Spanish youth. A previous study conducted between 1998 and 2000 in a Spanish sample aged 2–24 years reported poor adherence to the MeD for 4.2 % of participants [5]. However, the prevalence of poor adherence to the MeD in the present study was twofold (8 % of the sample). It is possible that youth are moving away from the MeD to adopt a less healthy diet (e.g., junk diet), which may negatively affect academic performance. For example, a longitudinal study found that children who adopted a junk diet, which is characterized by high-fat processed foods, snack foods high in sugar, and fizzy drinks had lower academic performance [34]. This information is important, because the MeD-based interventions are effective and easily to implement among children and adolescents within the school context, as a recent study indicated with regard to health outcomes [35]. Therefore, from a public health perspective, there would be a need to implement MeD-based interventions among children and adolescents to achieve both physical and cognitive benefits.

Limitations of the present study included its cross-sectional design, which precludes drawing conclusions on the direction of the associations; thus, more prospective and experimental studies are warranted to confirm the association between adherence to the MeD and academic performance in youth. A second limitation was that we did not have information about energy intake; however, we included objective measures of physical activity, sedentary behavior, and body mass index as a proxy of the energy balance. Lastly, some confounding variables that may influence the findings (e.g., family structure, conscientiousness, or self-discipline) were not available. The strengths of this study were the relatively large sample of children and adolescents as well as the inclusion of other relevant confounders, such as body mass index, birth weight, physical activity, fitness, and sedentary behavior, which have not all been included in previous research on this topic.

In conclusion, our results suggest that adherence to the MeD was positively related to academic performance in youth, independent of potential confounders. In addition, we found that the benefits of adherence to the MeD on academic performance were stronger as youth adhered to the optimal MeD levels.

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Conflict of interest The authors declare that there are no conflicts of interest.

Ethical standard Parents and school supervisors were informed by letter about the nature and purpose of the study, and written informed consent was provided prior to their inclusion in the study. This study followed the ethical standards recognized by the Declaration of Helsinki (reviewed in Seoul, Republic of Korea in October 2008) and the EEC Good Clinical Practice recommendations (document 111/3976/88, July 1990), and current Spanish legislation regulating clinical and biomedical research in humans, personal data protection and bioethics (Royal Decree 561/1993 on clinical trials and 14/2007, 3rd July, for Biomedical research).

Appendix: The UP&DOWN study group

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