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Meta-analyses

Is higher adherence to the mediterranean diet associated with greater academic performance in children and adolescents? A systematic review and meta-analysis

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SUMMARY

Objective: The aim of the present study was to synthesize the available evidence from the relationship between adherence to the Mediterranean diet (MedDiet) and academic performance in children and adolescents.

Methods: A systematic review and meta-analysis was conducted, which adhered to the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. Four electronic databases (PubMed, Scopus, Web of Science, and the Cochrane Library) were examined from inception to April 8th, 2024.

Results: Eighteen studies were included in the current systematic review and sixteen in the meta-analysis. The relationship between adherence to the MedDiet and academic performance among children and adolescents was statistically significant (Pearson's correlation coefficient [r] = 0.17, 95% confidence interval [CI]: 0.14 to 0.21, $p < 0.001$; inconsistency index [I^2] = 56.7%). The influence analysis revealed that removing individual studies one at a time did not result in any changes to the overall results ($p < 0.05$ in all cases).

Conclusions: A higher adherence to the MedDiet could play a relevant role in academic performance among children and adolescents.

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1. Introduction

Academic performance is a crucial measure of student, school, curriculum, and instructor proficiency, assessed through various formal evaluations alongside daily tests and classwork [1]. During childhood and adolescence, academic performance plays a crucial role in the future trajectory of life [2]. It serves as a foundation for their cognitive development, critical thinking skills, and overall academic aptitude [3]. Academic performance goes beyond school achievements, influencing long-term goals, career success, and overall well-being [4]. Furthermore, early academic success boosts confidence, widens career opportunities, and instills a love for learning [4]. Hence, providing guidance and support during formative academic years leads to enduring benefits in personal, professional, and intellectual development [5].

Diet is a lifestyle behavior that can be modified and has the potential to impact brain maturation, cognition, and ultimately, academic performance [6]. The Mediterranean diet (MedDiet) is notable for its health benefits [7,8]. It emphasizes olive oil, seasonal fruits, vegetables, legumes, whole grains, and nuts [9], while limiting red and processed meats, ultra-processed foods, sweets, and pastries [9]. Studies show that the MedDiet enhances cognitive functions, including memory [10], executive function, and visual constructs [11], improving cognitive performance in adults [11] and older individuals [12].

A systematic review including 40 studies (most of the cross-sectional) revealed associations of higher overall diet quality and healthier eating habits (including regular breakfast consumption and reduced intake of energy-dense and nutritionally poor foods) with greater academic performance among children and adolescents [13]. This notion is further supported by a previous study

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among Icelandic children and adolescents, which showed that participants with healthy diets (e.g., high fruit and vegetables consumption, low fast-food consumption) tend to achieve greater academic and cognitive performance [14]. Likewise, a low consumption of healthy foods like vegetables, fish, and fruits, as well as a high consumption of unhealthy foods such as fast and ultra-processed foods, have both been associated with lower academic performance in children and adolescents [15]. Regarding MedDiet, some studies have indicated a relationship between having a high adherence to this eating pattern and the academic performance of children and adolescents [16,17]. Moreover, this association appears to be consistent irrespective of body mass index [18]. Furthermore, higher consumption of nuts (one of the key foods in the MedDiet) has also been associated with greater academic performance in adolescents [19].

No previous systematic review or meta-analysis has investigated the relationship between adherence to the MedDiet and academic performance in children and adolescents. Existing studies often focus on specific dietary behaviors rather than broader dietary patterns [13]. Understanding this link is crucial due to its implications for individual well-being [20] and broader societal [21] and economic factors [22]. Therefore, the aim of the present study was to synthesize the available evidence from the association between adherence to the MedDiet and academic performance in children and adolescents.

2. Material and methods

The protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) with the registration number CRD42022354924 and carried out in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2021 checklist [23].

2.1. Information sources and search strategy

Four electronic databases (PubMed, Scopus, Web of Science, and the Cochrane Library), from inception to April 8th, 2024, were examined by two independent researchers (DV-M and JFL-G). The research strategy was based on the following groups of search terms: (a) preschool*, early*, child*, young*, adolesc*, student*, youth, and teena*; (b) “Mediterranean diet”, “Mediterranean eating pattern”, and “Mediterranean dietary pattern”; and c) academic, “academic performance”, “academic achievement”, “academic behaviour”, “academic behavior”, “academic grades”, “school achievement”, “school performance”, “school grades”, and “grade point average”. The search terms utilized for each of the mentioned databases can be found in Supplementary Table 1, which outlines the specific terms employed during the search process. In addition, a manual search of the reference lists of the studies incorporated in this meta-analysis and relevant review studies was conducted to guarantee that no eligible studies were overlooked.

2.2. Selection criteria

To be considered eligible for inclusion in this meta-analysis, each study was required to meet the next criteria: (a) population: children and adolescents up to 19 years of age; (b) exposure: adherence to the MedDiet; (c) outcome: academic performance of the subjects which the students had taken during their academic year; and (d) study design: observational and experimental studies, with the exception of gray literature (such as editorials, abstracts, or congress communications), systematic reviews and/or meta-analyses, narrative reviews, and qualitative studies. Studies were excluded if they (a) were only carried out among children and adolescents living with any disability; or (b) were conducted during the COVID-19 lockdown.

EndNote (version 21.0.1) was utilized to remove duplicate studies after identifying eligible studies in each database. Two researchers (JFL-G and DV-M) evaluated the titles and abstracts of the studies to recognize potentially pertinent articles. The complete texts of the final studies selected by both authors were independently assessed for eligibility. In case of any disagreement, a consensus was reached between the two researchers, or a third researcher (AG-H) was involved to resolve it.

For the three studies in which data of interest was not available, the corresponding authors were contacted. A 100% response rate was achieved in obtaining the requested information [24–26].

2.3. Data collection process and data items

One researcher (DV-M) performed the data extraction process, and a second researcher (JFL-G) verified its accuracy. In cases of disagreement, the two investigators reached a consensus, or a third researcher (AG-H) intervened to resolve any discrepancies. The data presented below was derived from studies that satisfied the specified selection criteria: author(s), year of publication, country, sample size, mean age, age range, study design, adherence measurement method for the MedDiet, and academic performance indicators investigated. Supplementary Table 2 displays the excluded studies and reasons for exclusion.

2.4. Outcome measures

Academic performance was computed as follows: The average score obtained in all school subjects which the students had taken during their academic year on a scale of 0–10 points was chosen as the indicator “grade point average (GPA)”. Furthermore, when this information was reported in the studies, the score obtained in language or maths (on a scale of 0–10 points) was also chosen for additional analyses. To avoid repetition, a single correlation coefficient was selected from each study using the following hierarchy: (a) all school records (i.e., GPA), (b) combination of language, math, and other subject (i.e., foreign language, science); (c) combination of language and math; (d) language only, (e) math only, (f) foreign language only, and (g) other individual subjects.

2.5. Study quality assessment in individual studies

The quality of the study was evaluated using the Quality Assessment Tool for Observational Cohort and Cross-sectional Studies developed by the National Heart, Lung, and Blood Institute (NHLBI) [27]. This tool consists of 14 items that are classified as “yes”, “no”, or “not reported”, with higher scores indicating higher methodological quality. Two authors (DV-M and JFL-G) assessed all the studies independently, and if needed, a third author (AG-H) was consulted.

2.6. Meta-analysis

All analyses were conducted using the software R (Version 4.3.0) (R Core Team, Vienna, Austria) and RStudio (Version 2023.03.1) (Posit, Boston, Massachusetts, USA). For this meta-analysis, the Pearson's correlation coefficient (r) was used as the main effect size. We applied various formulas [28–30] to convert other statistics, such as unstandardized regression coefficients, standardized regression coefficients, and standardized mean differences, to r. A random-effects inverse variance model with restricted maximum likelihood estimator was applied to calculate the overall effect size estimate and its corresponding 95% confidence intervals (CIs).

Additionally, based on the available information, combined analyses were conducted separately for the different academic performance indicators chosen, including GPA, only language, or only math. We further examined language and math as individual indicators of cognitive control, as these subjects rely heavily on inhibition and working memory [31].

To address the expected inconsistency between studies, the total variance (Q) and the inconsistency index (I^2) [32] were considered. The I^2 values were classified into three groups: 0%–40%: might not be important; 30%–60%: may represent moderate heterogeneity; 50%–90%: may represent substantial heterogeneity; 75%–100%: considerable heterogeneity [33].

To evaluate small-study effects and publication bias, we employed Doi plots and calculated the Luis Furuya-Kanamori (LFK) index. The asymmetry of the LFK index was categorized as follows: a value > 1 or < −1 suggests minor asymmetry, and a value > 2 or < −2 suggests major asymmetry [34]. In addition, pooled estimates were calculated omitting one study at a time to analyze how the outcomes of each study influence the overall correlation coefficients that have been combined (i.e., influence analysis). Furthermore, a subgroup analysis was conducted according to age group (i.e., children [<10 years], adolescents [10–19 years], or both children and adolescents). To perform this analysis, the cut-off point for the age groups was established based on World Health Organization criteria (i.e., children aged <10 years; adolescents: aged 10–19 years) [35]. Finally, meta-regression analyses with mixed-effects models were conducted to test whether mean age, mean body mass index, or the percentage of girls included in the study modified the estimates.

3. Results

3.1. Study selection

The PRISMA flow diagram in Fig. 1 shows how many studies were removed at each stage of the systematic review and meta-analysis. The initial search of the databases yielded 359 studies. Following the process of identifying and removing duplicate entries, as well as considering other relevant factors during screening, 205 studies remained. After titles and abstracts were reviewed, 170 papers were excluded, and 35 full-text articles were assessed for eligibility. Finally, 18 studies were included in the current systematic review (Table 1) and 16 in the meta-analysis, as they met the inclusion and exclusion criteria. Table S2 provides a list of the reasons for excluding certain items or elements from consideration during the full-text screening.

3.2. Study characteristics

The main characteristics of the 18 studies included in this systematic review [16–18,24,25,36–46] are shown in Table 1. Ten studies were conducted in Spain [16,18,36,37,39–43,47], three in Italy [38,44,45], two in Greece [17,46], one in Portugal [24], one in Chile [26], and one in Lebanon [25]. Regarding the measurement of adherence to the MedDiet, the Mediterranean Diet Quality Index in children and adolescents (KIDMED) was the tool most used in 16 out of the 18 studies [16–18,24–26,36,37,39–46]. Only two studies used a tool other than KIDMED (i.e., the Mediterranean Diet Score (MDS) [38], and a modified version of KIDMED [47]). Concerning academic performance indicators, most of the studies reported the average of all school records (i.e., GPA) [16,17,25,36–47]. Nine studies reported specific information about both language and maths [16,18,24,26,36,38–40,42]. Five studies offered specific information about foreign languages [18,38–40,42], and four studies offered specific information about other subjects [26,38–40]. Furthermore, most of the studies reported academic performance with data provided by the schools [16–18,24–26,36,37,39–44,46,47] rather than reported by the participants [45]. Most of the studies reported information about adherence to the MedDiet as a continuous variable [16–18,24,25,36,38–43,45,46] rather than a categorical variable [26,37,44]. Moreover, most of the studies presented information about academic performance by continuous variables [16–18,24–26,36,38–44,46,47] instead of categorical variables [37,45]. Regarding the study design, all studies were cross-sectional, with the exception of one longitudinal study (with 12 months of follow-up) [25]. In this case, we select the most recent information (i.e., at the end of the follow-up). Concerning sex, all the studies included both boys and girls.

Regarding the meta-analysis, a total of 16 studies including 9691 children and adolescents aged 6–18 years (49.3% girls) were included. Sample sizes across studies ranged from 129 [43] to 1371 participants [16]. Two studies were excluded from the meta-analysis: the study by Santomauro et al. [45] because it assessed academic performance in a self-reported manner by adolescents, and the study by Alfonso Rosa et al. [37] because it reported academic performance categorically (i.e., pass, good, merit) rather than continuously. Twelve of the 16 studies showed results adjusted for other covariates [16–18,25,26,36,39–42,46,47], while four studies showed unadjusted results [24,38,43,44].

3.3. Study quality assessment in individual studies

The results of the quality assessment are presented in Fig. S1. All studies met the criteria for questions one (i.e., research question), two (i.e., study population), three (i.e., study population), four (i.e., groups recruited from the same population and uniform eligibility criteria), six (i.e., exposure assessed prior to outcome measurement), seven (i.e., sufficient timeframe to see an effect), eight (i.e., different levels of the exposure of interest), nine (i.e., exposure measures and assessment), thirteen, and fourteen. Seven out of 18 studies (38.9%) did not meet the criteria for question five (i.e., sample size justification). Regarding both criteria 10 (i.e., repeated exposure assessment) and 12 (i.e., blinding of outcome assessors), eleven out of 18 (61.1%) did not meet the criteria. Furthermore, seven out of 18 studies (38.9%) did not meet criteria 11 (i.e., outcome measures).

3.4. Synthesis of results of the meta-analysis

The association between adherence to the MedDiet and academic performance is shown in Fig. 2. Higher adherence to the MedDiet was associated with greater academic performance among children and adolescents (r = 0.17, 95%CI 0.14 to 0.21, p < 0.001). However, the effect size observed was weak. The inconsistency observed for this result was moderate (I^2 = 56.7%; p = 0.003). The LFK index in the Doi plots revealed no asymmetry, confirming that there was no publication bias (LFK index = −0.01) (Fig. S2). Furthermore, the influence analysis revealed that removing individual studies one at a time did not result in any changes to the overall results (p < 0.001 in all cases) (Fig. S3). Finally, further analyses examining only all the averages of school records, only language, and only maths are shown in Figs. S4–S6. Overall, the results were similar regardless of the academic-related outcome examined (p < 0.05 for all).

According to age group (i.e., only adolescents or both children and adolescents), the results were consistent with no significant differences identified among these groups (p = 0.175) (Fig. S7). Additionally, meta-regression analyses did not show a moderating effect as a function of mean age (B = 0.009, p = 0.382), mean body

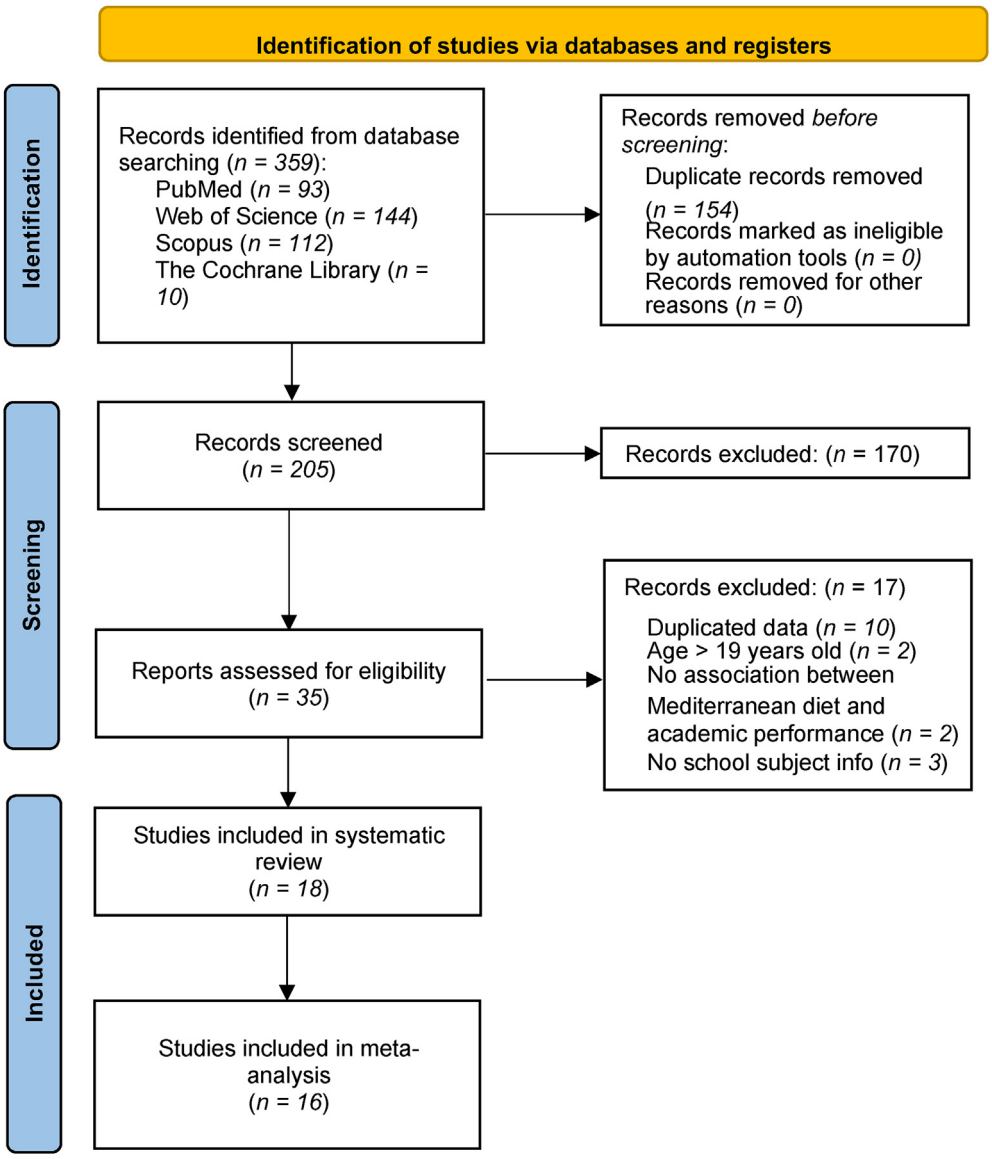

Fig. 1. PRISMA 2020 flow chart for systematic reviews that included database searches. MedDiet, Mediterranean diet.

mass index ($B = 0.008$, $p = 0.336$) or percentage of girls included in the study ($B = -0.00003$, $p = 0.714$) (Table 2).

4. Discussion

Overall, our findings showed that greater adherence to the MedDiet was associated with greater academic performance among children and adolescents. The observed effect sizes for the association between adherence to the MedDiet and academic performance were weak, with substantial inconsistency in results. One possible explanation could be the different tools used to assess MedDiet adherence and academic performance measures, such as GPA or specific subjects. Additionally, biases in teacher grading and heterogeneity in measurement methods may have influenced the precision of the effect estimates. Further studies with rigorous designs and control of biases and confounding variables are needed to confirm and refine these associations.

On the other hand, subgroup and meta regression analyses displayed that these results still remained significant regardless of the indicator evaluated (i.e., the average score of GPA, only language, or only maths), age group (i.e., only children, only adolescents, both children and adolescents), mean age, mean body mass index, and the percentage of girls included in the studies, which confers robustness to the obtained findings. These results are in line with a previous systematic review which emphasized that certain eating habits (such as eating breakfast regularly, consuming fewer nutrient-poor and energy-dense foods, and maintaining overall dietary quality) were significant behaviors and changeable factors associated with higher academic performance [13]. In general, the MedDiet encompasses a unique set of dietary patterns (e.g., high consumption of fruits and vegetables, emphasis on whole grains and legumes, regular consumption of olive oil) that distinguish it from other dietary approaches. These distinctive patterns likely contribute to the results observed in our study. More specifically, there are several potential mechanisms underlying these observed results that can be attributed to the components and characteristics of the MedDiet.

The higher academic performance observed in children and adolescents may be explained by the potential cognitive benefits of the MedDiet. Studies have shown that high adherence to the

Table 1
Main characteristics of the studies included in the systematic review (N = 18).

Authors (year)	Country	Sample (N)	Girls (%)	Mean age (years)	Age range[a]	Academic grades	MedDiet indicator
Santomauro et al. (2014) [45]	Italy	N = 1290	44.9	16.8	14 to 20 (adolescents)	GPA[d]	KIDMED
Vassiloudis et al. (2014) [17]	Greece	N = 520	51.5	NR	10–12 years (adolescents)	GPA[b]	KIDMED
Esteban-Cornejo et al. (2016) [16]	Spain	N = 563	50.0	12.0	6–18 years (children and adolescents)	GPA[b]	KIDMED
Vassiloudis et al. (2017) [46]	Greece	N = 269	50.8	NR	15–18 years (adolescents)	GPA[b]	KIDMED
Adelantado-Renau et al. (2018) [36]	Spain	N = 50	48.0	13.9	14–18 years (adolescents)	GPA[b]	KIDMED
Alfonso Rosa et al. (2018) [37]	Spain	N = 213	49.5	NR	9–10 years (children and adolescents)	GPA[c]	KIDMED
Barchitta et al. (2019) [38]	Italy	N = 244	52.0	16.0	15–18 years (adolescents)	GPA[b]	MDS
Marques et al. (2021) [24]	Spain	N = 129	48.9	9.2	9–11 years (children and adolescents)	Combined language and math[b]	KIDMED
Jiménez Boraita et al. (2022) [41]	Spain	N = 757	49.7	14.5	12–17 years (adolescents)	GPA[b]	KIDMED
Rosi et al. (2020) [44]	Spain	N = 1127	52.8	12.5	11 to 14 (adolescents)	GPA[b]	KIDMED
Carrillo-López et al. (2021) [39]	Spain	N = 1371	45.3	8.8	8–13 years (children and adolescents)	GPA[b]	KIDMED
Hayek et al. (2021) [25]	Lebanon	N = 761	49.9	15.8	15–18 years (adolescents)	GPA[b]	KIDMED
Peláez Barrios & Vernetta (2021) [43]	Spain	N = 354	43.4	13.6	12–14 years (adolescents)	GPA[b]	KIDMED
Tapia-Serrano et al. (2021) [18]	Spain	N = 528	44.7	13.1	12–14 years (adolescents)	Language, math and foreign language[b]	KIDMED
Carrillo-López (2023) [40]	Spain	N = 181	53.7	10.8	10–12 years (adolescents)	GPA[b]	KIDMED
López-Gil et al. (2023) [19]	Spain	N = 891	55.6	14.0	12–17 years (adolescents)	GPA[b]	KIDMED
Villodres et al. (2023) [47]	Spain	N = 269	46.5	11.3	10–12 years (adolescents)	GPA[b]	Modified KIDMED
Peña-Jorquera et al. (2024) [26]	Chile	N = 1296	50.0	11.9	10–14 years (adolescents)	Language, math and science[b]	KIDMED

GPA, grade point average; KIDMED, Mediterranean Diet Quality Index in children and adolescents; MDS: Mediterranean Diet Score, MedDiet, Mediterranean diet; NR: Not reported.
[a] Participants were considered children when they were under 10 years old and adolescents when they were 10 years old or older.
[b] Academic performance of all the subjects which the students had taken during their academic year on a scale of 0–10 points.
[c] Academic performance reported with categorical variables (i.e., pass, good, merit).
[d] Academic performance was self-reported.

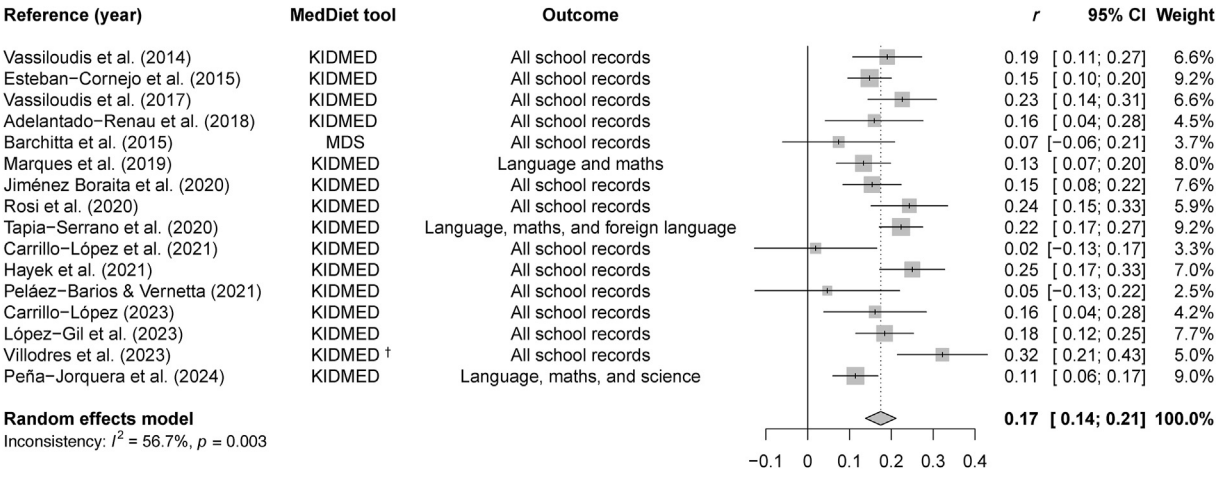

Fig. 2. Meta-analysis of the association between adherence to the Mediterranean diet and academic performance indicators in children and adolescents. CI, confidence intervals; KIDMED, Mediterranean Diet Quality Index in children and adolescents; MDS, Mediterranean Diet Score; MedDiet, Mediterranean diet; *r*, Pearson's correlation coefficient. † Modified KIDMED.

Table 2
Meta-regression analyses by mean age, mean body mass index, and percentage of girls.

Variables	#	*B*	SE	LLCI	ULCI	*p*
Mean age (years)	14	0.009	0.009	−0.010	0.026	0.382
Mean body mass index (kg/m^2)	13	0.008	0.010	−0.010	0.029	0.336
Number of girls (%)	16	−0.00003	0.0001	−0.0002	0.0001	0.714

#, number of studies; LLCI, lower limit confidence interval; MedDiet, Mediterranean diet; SE, standard error; ULCI, upper limit confidence interval.

MedDiet is associated with greater working memory scores [48,49] and cognitive strategies (e.g., organization and critical thinking [50]), which seems to have a crucial role in achieving higher academic performance [51]. Additionally, the MedDiet's emphasis on fruits and vegetables [13,53], rich in antioxidants and micronutrients, may contribute to improved academic performance [52–56]. These findings suggest that the MedDiet could positively impact cognitive function and academic outcomes in young populations [57].

While the precise mechanism for the relationship between monounsaturated and polyunsaturated fats and academic performance is not completely clear, the literature suggests that consuming some high-fat foods leads to higher academic performance. For instance, compared to Spanish adolescents who did not consume any serving of nuts, those who consumed three or more servings/week had higher academic performance (e.g., GPA) [19]. Similarly, a longitudinal study reported a dose–response relationship between fish consumption and cognitive ability among Chinese children [58]. Furthermore, a randomized controlled trial showed a small beneficial effect of fatty fish compared to meat meals and supplements on processing speed [59]. One noteworthy aspect is that nuts and fatty fish are a good source of essential fatty acids, such as omega-3 fatty acids [60]. These fatty acids have been linked to enhanced cognitive function, improved learning abilities [61,62], and higher relational memory in the young population [63]. Lastly, the consumption of olive oil (i.e., the main liquid fat in the MedDiet) has been found to improve cognitive functioning and to reduce cognitive decline (in adults older than 55 years old) [64]. Although specific studies in children are needed, the possibility that olive oil consumption may be associated with higher academic performance cannot be ruled out.

Breakfast consumption, an important component of the KIDMED score, may contribute to the higher academic performance seen in children and adolescents. Previous studies have suggested that regular breakfast consumption is consistently linked to higher academic performance, cognitive function, and school attendance [65–72]. Adolescents who regularly eat breakfast before mentally demanding tasks tend to have higher cognitive performance. Moreover, skipping breakfast is associated with higher rates of depression, anxiety, and stress, which could negatively impact academic performance [69]. Additionally, school breakfast programs have been shown to improve school attendance and subsequently academic performance, especially when provided free of charge to all students [70]. These factors could partially explain the relationship between breakfast consumption and academic success in children and adolescents.

The results from the present study must be interpreted considering the study's limitations. Due to the cross-sectional design of the studies included in this meta-analysis, it is not possible to establish causal inferences. Furthermore, other factors related to greater adherence to the MedDiet (e.g., socioeconomic status, parental practices) were not considered in most included studies, which could affect the results obtained. Similarly, the utilization of questionnaires (such as KIDMED) to gather information on adherence to the MedDiet may introduce potential biases due to differential desirability and information recall. On the other hand, a noteworthy strength of the study is that, in the meta-analysis, academic performance was evaluated in a more objective manner rather than relying on self-reported information provided by the children and adolescents [45,73]. Moreover, we also analyzed overall academic performance, incorporating results from all subjects. Conventionally, studies of academic performance have assessed maths, language, and English [16,18]. However, this approach may result in an inadequate representation of other academic disciplines. By concentrating solely on a limited number of subjects, it is possible to overlook the assessment of academic performance in other equally significant subjects, such as science, history, art, or physical education. Each of these subjects encompasses its own unique set of skills and knowledge, which are equally valuable in evaluating overall academic performance [74]. Another notable strength is that, to our knowledge, this study presents the first-ever evidence of the link between the MedDiet and academic performance in children and adolescents using a comprehensive meta-analytical approach.

In conclusion, a higher adherence to the MedDiet could play a relevant role in academic performance among children and adolescents. Given the psychological, societal, and economic implications of academic performance during childhood and adolescence, encouraging the adoption of this eating pattern (e.g., using a multifaceted approach) might be important among this population. However, given the weak effect sizes and moderate inconsistency observed for this association, caution is required when interpreting these findings.

Ethics approval and consent to participate

Not applicable.

Funding

Not applicable.

Authors' contributions

JFL-G and DV-M designed the study. JFL-G contributed to the interpretation and analysis of the data. JFL-G wrote of the initial draft. DV-M and AG-H contributed to the revision of the manuscript. All authors approved the final version of the manuscript.

Consent for publication

Not applicable.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interest

All authors disclose no conflict of interest for this work.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnu.2024.05.045.

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