

The Mediterranean diet as a nutritional intervention strategy in young adolescents.

La dieta mediterránea como estrategia de intervención nutricional en adolescentes jóvenes.

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Abstract

This systematic review evaluated the Mediterranean diet as a nutritional intervention strategy for young adolescents, with the primary objective of evaluating its effectiveness improving health outcomes among young adolescents. An extensive literature search from 2019 to 2023 across multiple databases identified four eligible randomized controlled trials focused on adolescents aged 12 to 18 years. The findings demonstrated significant improvements after 12 weeks of following a Mediterranean diet compared with a low-fiber diet, including enhanced serum transaminase levels, reduced insulin resistance and hepatic steatosis, increased antioxidant capacity, and improved inflammatory markers. Notably, the Mediterranean diet group exhibited levels of paraoxonase-1 and glutathione peroxidase, along with lower C-reactive protein levels. In addition, benefits were observed in the sleep parameters, including reduced latency, enhanced efficiency, and fewer awakenings. While promoting a holistic approach that emphasizes nutritional intake and the social aspects of eating, widespread adoption faces sociocultural barriers, economic constraints, and a high prevalence of ultra-processed foods. Multifaceted interventions at individual, community, and policy levels, such as nutrition education, marketing regulations, and improved access to affordable fresh produce, are recommended strategies to facilitate adherence to the Mediterranean dietary pattern among adolescents.

Keywords. Mediterranean diet; adolescent nutrition; cardiovascular health; lifestyle intervention; obesity prevention.

Resumen

Esta revisión sistemática evaluó la dieta mediterránea como una estrategia de intervención nutricional para adolescentes, con el objetivo principal de evaluar su efectividad en la mejora de resultados de salud en este grupo etario. Una exhaustiva búsqueda de literatura desde 2019 hasta 2023 en múltiples bases de datos identificó cuatro ensayos controlados aleatorizados elegibles, enfocados en adolescentes de 12 a 18 años. Los hallazgos mostraron mejoras significativas después de 12 semanas de seguir una dieta mediterránea en comparación con una dieta baja en fibra, incluyendo niveles mejorados de transaminasas séricas, reducción de la resistencia a la insulina y esteatosis hepática, aumento de la capacidad antioxidante y mejora en los marcadores inflamatorios. Notablemente, el grupo de la dieta mediterránea exhibió niveles elevados de paraoxonasa-1 y glutatión peroxidasa, junto con niveles más bajos de proteína C reactiva. Además, se observaron beneficios en los parámetros del sueño, como la reducción de la latencia, una mayor eficiencia y menos despertares. Aunque se promueve un enfoque holístico que enfatiza la ingesta nutricional y los aspectos sociales de la alimentación, la adopción generalizada enfrenta barreras socioculturales, restricciones económicas y una alta prevalencia de alimentos ultraprocesados. Se recomiendan intervenciones multifacéticas a nivel individual, comunitario y de políticas, como la educación nutricional, regulaciones de marketing y mejor acceso a productos frescos asequibles, como estrategias para facilitar la adherencia al patrón dietético mediterráneo entre los adolescentes.

Palabras clave. Dieta mediterránea; nutrición adolescente; salud cardiovascular; intervención en el estilo de vida; prevención de la obesidad.

Introduction

A healthy diet is essential for children's physical and mental development and to prevent nutrition-related diseases. Some nutritional patterns associated with both mental and physical health in adults and children have been observed in the Mediterranean diet. The primary components of the Mediterranean diet include a higher intake of fruits, vegetables, whole grains, legumes, nuts, olive oil, fish, and poultry. It involves consuming modest numbers of alcohol and dairy items, and a small amount of red meat. A lower risk of chronic diseases, including diabetes, cancer, cardiovascular disease (CVD), and neurological disorders, has been associated with this eating pattern ¹. The Mediterranean diet captures the synergy between its dietary components and composite scores. Certain nutritional elements are associated with a lower chance of adverse health outcomes ².

Obesity among young adolescents has surged globally, with 340 million overweight or obese individuals in 2016. Low- and middle-income nations have the highest prevalence rates. Adolescent

obesity can lead to metabolic syndrome, cardiovascular disorders, and cancer. The Mediterranean diet is a potential intervention for prevention ³.

The world's top cause of morbidity and death, cardiovascular diseases, have been associated with a lower chance of developing with a Mediterranean diet ⁴. According to the study, the Mediterranean diet and lifestyle more closely had a 29% reduced risk of all-cause death and a 28% lower risk of cancer ⁵.

The Mediterranean diet, which places emphasis on the consumption of foods that are rich in nutrients, such as fruits, vegetables, and whole grains, has proven to be advantageous for adolescents. This dietary approach has been found to have a positive impact on reducing the prevalence of obesity, diabetes, and cardiovascular diseases among this age group ⁶. Moreover, the utilization of olive oil as the primary source of lipid in this dietary regimen furnishes monounsaturated fatty acids and bioactive compounds possessing antioxidant and anti-inflammatory properties, thereby potentially enhancing lipid profiles and mitigating the susceptibility to cardiovascular ailments in adolescents. Furthermore, teenagers adhering to the Mediterranean diet may encounter ameliorated cognitive capabilities and a diminished vulnerability to neurodegenerative disorders owing to the diet's moderate inclusion of fish and poultry, which imparts high-quality protein and vital fatty acids such as omega-3s, indispensable for cerebral development and cognitive function ⁷.

Although numerous benefits can be attributed to the Mediterranean diet, challenges related to cultural inclinations, socioeconomic limitations, and the accessibility of reasonably priced, fresh food items may impede the adoption of this diet by early adolescents. Moreover, the influence of media, peer pressure, and advertising on dietary choices among adolescents cannot be undermined, thereby highlighting the imperative of implementing comprehensive, multi-tiered interventions aimed at promoting wholesome eating habits.

Previous studies have shown that young adolescents are at a critical stage of growth and development and are exposed to unhealthy dietary habits and lifestyle behaviors; hence, Mediterranean dietary patterns may be beneficial ⁸. The primary objective of this systematic review was to evaluate the effectiveness of the Mediterranean diet in improving health outcomes among the young population. It focused on specific parameters such as nutritional status, cardiovascular indicators (including lipid profiles and blood pressure), body mass index (BMI), waist circumference, and dietary intake. The review included randomized controlled trials published between January 2019 and December 2023, following PRISMA criteria.

Materials and methods

This systematic review assessed the efficacy of the Mediterranean diet as a nutritional intervention approach for early adolescents. The review followed the PRISMA guidelines to establish the necessary query specifications and criteria for study inclusion.

Search Strategy: the researchers undertook the implementation of the PRISMA guidelines to establish the requisite query specifications and criteria for the inclusion of studies. Comprehensive searches across multiple electronic databases, such as Google Scholar, PubMed, and research4life, were performed. The search terms included "Mediterranean diet," "young adolescents," "nutrition intervention," "health promotion," and "preventive measures." The investigation encompassed a time frame extending from 2019 to 2024, with the combination of MeSH terms and free text words in the search strategy. Relevant keywords were identified during the initial stages of the search procedure. This involved using synonymous searches and extracting search terms from academic papers that had already been presented. Following an extensive exploration of relevant databases and, employing the designated keywords, a thorough cross-referencing endeavor was initiated to determine mesh terms that corresponded with the pre-established criteria for inclusion. The inquiry was conducted using a range of English-language keywords. Two independent researchers performed comprehensive searches across multiple electronic databases, including Science Direct, PubMed, the Cochrane Library, and CINAHL. In addition, they used the search engine Google Scholar to ensure a thorough exploration of relevant literature. The investigation encompassed a time frame extending from 2019 to 2024, with the primary objective of discerning randomized controlled trials (RCTs) that were conducted solely on human subjects. A thorough analysis was carried out to investigate the references cited in both the primary and secondary publications and, identify any relevant clinical trials that could be of significance. Moreover, diligent efforts were made to acquire gray literature from alternative sources.

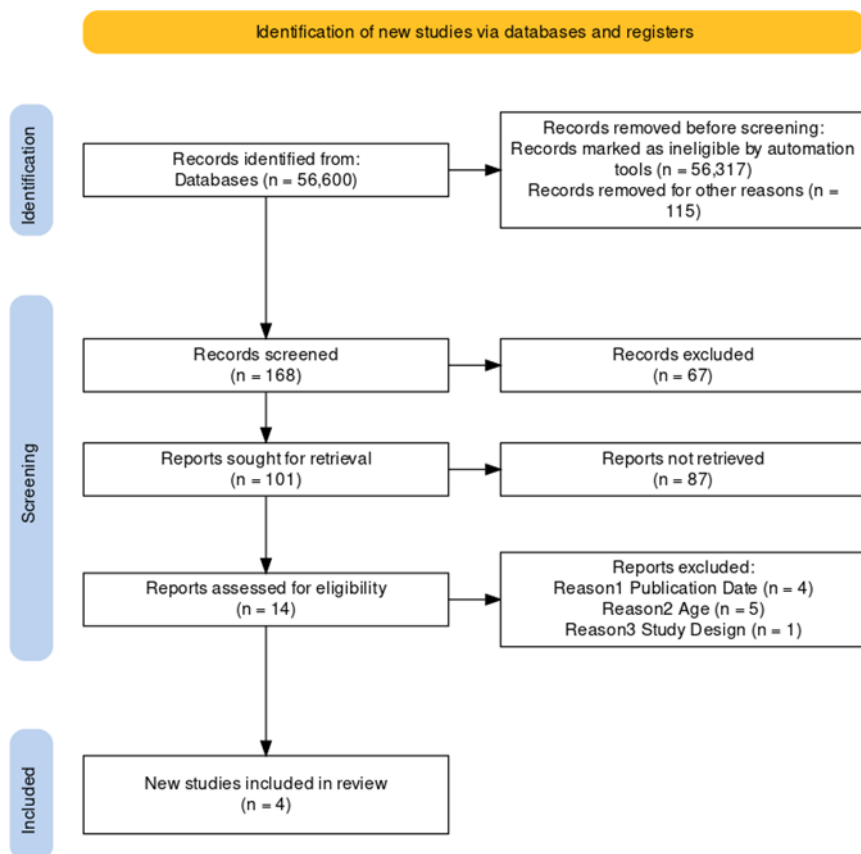


Figure 1. PRISMA flow diagram for identification of studies through databases and registers.

Selection:

The process of selecting studies and the rationale behind exclusions were visually depicted through the use of the PRISMA flow diagram. A comprehensive compilation of 56600 studies was systematically identified from diverse databases, spanning the time frame from January 2019 to 2024. After eliminating 56,432 redundant entries, the remaining studies underwent a meticulous screening process that involved evaluating their titles and abstracts. A comprehensive total of 67 records were determined to be ineligible and subsequently excluded from the study. Subsequently, a detailed assessment was conducted on the remaining 101 full-text articles to determine their suitability for inclusion in the study. A total of 87 additional studies were excluded from the analysis as per the criteria specified in the PRISMA diagram (Figure 1). However, after careful evaluation, 4 studies were found to meet the requirements and were thus considered appropriate for inclusion in the systematic review.

Selection criteria: inclusion criteria: in order to incorporate the studies, the following criteria were utilized as the inclusion criteria.

- i. The selected studies must adhere to the structure of randomized controlled trials (RCTs) or exhibit attributes that are in line with RCTs.
- ii. The target population must include adolescents aged between 12 and 18.

- iii. Studies have implemented a Mediterranean diet as a nutritional intervention strategy.
- iv. Studies reporting outcomes related to overall health, such as the prevention of chronic diseases, and cognitive function.
- v. Studies published in English.

Exclusion criteria: the following criteria were used to include the studies

- i. Studies involving the target population above or below 12 and 18 years
- ii. Studies not implementing a Mediterranean diet as a nutritional intervention strategy
- iii. Studies not reporting outcomes related to overall health, prevention of chronic diseases, and cognitive function
- iv. Studies published before 2019 or in languages other than English.

Outcome: the primary outcomes observed in the conducted studies were the effect of a Mediterranean diet as a nutritional intervention strategy. In addition, individual studies encompassed assessments related to overall health, prevention of chronic diseases such as cardiovascular disease, and cognitive function

Reviewing process: two independent reviewers screened the titles and abstracts of all identified articles based on the inclusion criteria mentioned above. The full texts were then evaluated for biases, examining the impact of information availability and uncertainty on an individual judgment. In instances where conflicts arose, a neutral third author was engaged to serve as an unbiased decision-maker.

Data extraction and analysis: the process of data extraction was performed by two review authors stringently and systematically, employing carefully crafted data retrieval forms. Data about the participants were collected, encompassing key demographic variables such as age and sex. In addition, information regarding the study setting will be documented. Furthermore, the number of individuals randomized will be recorded for analysis. Furthermore, meticulous accounts of the interventions used will be documented. The outcome measures will be meticulously recorded, alongside the findings, encompassing point estimates and measures of variability. This study will provide frequency counts for dichotomous variables and report, the total number of patients included in the research. A specifically assigned reviewer undertook the responsibility of compiling and inputting all the data into an Excel file. In the event of disagreements, the resolution was facilitated through the implementation of open dialog and the subsequent achievement of consensus among the parties involved

Data synthesis: each study was synthesized using a narrative synthesis approach, and data were extracted. The findings are presented in a tabular format, highlighting the intervention characteristics, outcome measures, and study limitations and strengths. The results were analyzed

qualitatively, and the findings were discussed about the research question.

Quality assessment: the risk of bias in randomized controlled trials (RCTs) was evaluated using a method developed by the Cochrane Collaboration. To evaluate the standard of observational research, the Newcastle Ottawa Scale was used. Two independent reviewers conducted a quality assessment, and discrepancies were resolved through discussion and consensus.

Risk of bias assessment: every study had its bias evaluated by two review authors. The review included several methodological issues, including the creation of random sequences, hiding the allocation, putting staff, participants, and outcome assessors in the dark, providing insufficient outcome data, disclosing only certain results, and possibly having additional biases. The evaluation was performed using the standards set by the Cochrane Collaboration. Various evaluative judgments, such as low, high, and uncertain assessments, were used in this study. The current study assessed biases by examining how people's judgments were impacted by information availability and uncertainty. When disagreements surfaced, an impartial third party was consulted to act as an arbiter.

Risk of bias assessment: the method of randomization used in each study was recorded, and the adequacy of the randomization process was assessed based on the study description. The randomization method used in each study was categorized as "adequate" if it was clearly described as a random process, such as computer-generated random numbers or a randomization table. If the study did not provide sufficient detail about its randomization process, it was categorized as "unclear." If the study did not use a randomization process, it was categorized as "inadequate."

Results

The four studies met the requirements for inclusion in this systematic review. A total of 755 young adolescents from several nations, including Spain, Italy, Greece, and Portugal, participated in the study. There was a range of 12 to 2 years for the interventions. Numerous outcomes were reported in the research, including blood pressure, lipid profiles, waist circumference, body weight, BMI, and food consumption. Table 1 presents the detailed demographic and metabolic characteristics of the participants by gender.

Table 1. Demographic and Metabolic Characteristics of Participants by Gender.

Characteristic	Girls	Boys
No. of participants	401	354
Age (year)	10-18 years	10-18 years
Weight (kg)	53.4 + 11.1	56.8 +14.1
Height (cm)	157.7 + 6.68	162.9 +11.3
BMI (kg/m ²)	21.4+ 3.9	21.2 + 3.7

Adiponectin, mg/mL	12.9 5.7	10.2 4.8
HOMA-IR	3.5 1.8	3.3 7.4

Note. Body mass index (BMI) is referred to as BMI, and the homeostasis model evaluation of insulin resistance is known as HOMA-IR.

Four selected articles demonstrated significant improvements in serum transaminase levels, insulin resistance, and the degree of hepatic steatosis in both groups after 12 weeks on a low-fiber diet (LFD) or a Mediterranean diet (MD). All groups showed similar results, but no significant differences were observed for aspartate aminotransferase (AST). AST levels decreased more in the MD group than in the LFD group ($p < 0.05$). Blood total antioxidant capacity, paraoxonase-1, and glutathione peroxidase levels in the Mediterranean diet (MD) group were higher ($p < 0.05$) than those in the low-fiber diet (LFD) group at baseline. C - reactive protein (CRP) levels only decreased in the MD group ($p = 0.008$), whereas interleukin-6 (IL-6) levels only increased in the LFD group ($p = 0.031$). To determine how the Mediterranean Diet (MD) affects different health outcomes in early adolescents, 44 individuals participated in the study.

Serum transaminase levels, insulin resistance, and hepatic steatosis all significantly declined in the low-fat diet (LFD) and Mediterranean diet (MD) groups. AST, glutathione peroxidase, paraoxonase-1, and serum total antioxidant capacity were all significantly lower in the MD group than in the LFD group. In both groups, interleukin-6 (IL-6) levels also decreased. After 12 weeks, the group following the Mediterranean diet was smaller than the control group in terms of weight, waist circumference, and body mass index (BMI). In comparison to the control group, the MD group's systolic blood pressure was considerably lower. The homeostatic model evaluation of insulin resistance revealed a substantial rise in HDL levels but a significant decrease in triglycerides, low-density lipoprotein (LDL), and fasting blood glucose levels in the MD group.

Serum concentrations of inflammatory markers, including IL-6 and high-sensitivity C-reactive protein, were considerably lower in the MD group.

Another study investigated the impact of anthropometric measures and sleep patterns in children and adolescents with abdominal obesity. The study comprised 529 adolescents between the ages of 12 and 18, and measurements of body adiposity and anthropometry were performed. All adiposity variables showed a linear rise in HOMA-IR across quartiles ($p < 0.001$), independent of age, sex, pubertal stage, socioeconomic position, cardiovascular health, or adherence to the Mediterranean diet. Following the Mediterranean diet (MD) for twelve weeks resulted in significantly lower weight, waist circumference, and body mass index (BMI) than the control group ($p < 0.001$). Furthermore, there was a significant difference ($p < 0.001$) in the systolic blood pressure between the control and Mediterranean diet (MD) groups. Compared with low-density lipoprotein (LDL), triglycerides (TG),

fasting blood glucose (FBS), and the homeostatic model assessment of insulin resistance (HOMA-IR), there was a significant increase ($p < 0.001$) in the levels of HDL. A significant reduction ($p < 0.02$) in the blood levels of inflammatory markers, such as IL-6 and high-sensitivity C-reactive protein (hs-CRP), was linked to the Mediterranean diet (MD). Table 2 outlines how the Mediterranean diet influences inflammatory biomarkers and elements of metabolic syndrome among adolescent girls.

Table 2. Effect of the Mediterranean diet on inflammatory biomarkers and components of metabolic syndrome in adolescent girls.

Parameter	Result
Weight	Lower (Ptime*group $\leq 0/001$)
BMI	Lower (Ptime*group $\leq 0/001$)
Waist Circumference	Lower (Ptime*group $\leq 0/001$)
Systolic blood pressure	Significantly reduced (Ptime*group $\leq 0/001$)
Fasting blood glucose	Significantly decreased (Ptime*group $\leq 0/001$)
Triglycerides	Significantly decreased (Ptime*group $\leq 0/001$)
LDL	Significantly decreased (Ptime*group $\leq 0/001$)
HOMA-IR	Significantly decreased (Ptime*group = 0/02)
HDL	Increased (Ptime*group $\leq 0/001$)
IL-6	Significantly reduced (Ptime*group = 0/02)
hs-CRP	Significantly reduced (Ptime*group = 0/02)
TNF- α	No significant effect (Ptime*group = 0/43)

Research with 529 adolescents aged 12–18 years discovered that HOMA-IR increased linearly across all adiposity measure quartiles. Age, sex, pubertal stage, socioeconomic status, Mediterranean diet adherence, and cardiovascular health were not associated with this increase. In all cases, the p-value was less than 0.001. When compared with the low adiponectin group, adolescents in the upper quartile of adiposity for body fat percentage (BF%), body mass index (BMI), waist circumference (WC), and skinfold sum (Q4) had substantially lower HOMA-IR. This difference was observed for possible confounders and was detected at a significance level of $p < 0.01$. Children with higher levels of physical activity compared with those with lower levels showed considerably reduced triglyceride levels ($p = 0.001$), according to another study including 529 adolescents.

A multidisciplinary investigation observed that the intervention group significantly reduced sleep latency at 12 and 24 months in children and adolescents with abdominal obesity. When compared with the group receiving normal treatment, they also demonstrated enhanced sleep efficiency at 2 and 12 months. The intervention group woke up after sleep had started at 24 months, and they woke up far less frequently.

All subject's leptin levels and wakefulness following the onset of sleep showed a favorable correlation. Following the 2-month intervention, total sleep time showed an inverse relationship with triglycerides and metabolic score and a negative correlation with leptin, triglycerides, and metabolic score. At one year, the metabolic score was negatively connected with efficiency and positively correlated with the frequency of awakenings and wakefulness after sleep onset, whereas triglyceride levels were adversely correlated with the total amount of time spent in bed and sleep.

Discussion

The Seven Countries Study had an observational design and possessed restricted capability to establish a cause-and-effect relationship. The link between total blood cholesterol levels and the dietary variables manipulated was the main area of study for Keys and his team. They were more focused on investigating the potential of the Mediterranean diet, which may be advantageous for cardiovascular health overall. Until the early 1990s, the notion of the "Mediterranean diet" was primarily unheard of, although the Seven Countries Study demonstrated the links between dietary practices and cardiovascular risk ¹⁰.

Nonalcoholic fatty liver disease (NAFLD) has been recognized as the most common liver disease among adolescents in the United States because of its significant association with obesity. NAFLD may cause progressive fibrosis over time, which may lead to severe liver disease. It has been one of the main causes of adult liver transplants throughout the last decade ¹¹.

Chronic hepatic fat buildup in children aged 18 years is known as pediatric nonalcoholic fatty liver disease (NAFLD). Cases associated with infections, fatty liver-inducing drug usage, malnourishment, genetic or metabolic abnormalities, or alcohol intake were not included ¹². The results of subsequent liver biopsies performed as standard clinical treatment for children with nonalcoholic fatty liver disease (NAFLD) were reported in two small retrospective studies. After an average of 28 months, the first trial found that 11 of 18 patients had either stable or better fibrosis ¹³. In a retrospective study, fibrosis deteriorated over an average of 41 months in 4 of 5 individuals investigated ¹⁴.

Numerous authors have reported obesity as a major risk factor for nonalcoholic fatty liver disease (NAFLD). Body mass index (BMI), weight, and obesity have been associated with an elevated risk of NAFLD ¹⁵.

Four studies were reviewed to investigate the effects of the Mediterranean diet (MD) on early adolescents in this systematic review. By the time the trial ended, the evaluation showed that both groups of participants implementing a low-fiber diet (LFD) and the group following a Mediterranean diet (MD) had significantly lower levels of insulin resistance, serum transaminase, and severity of

hepatic steatosis. However, aspartate aminotransferase (AST) levels were significantly reduced in the Mediterranean Diet (MD) group than in the low-fiber diet (LFD) group. Additionally, the Mediterranean Diet (MD) group showed improvements in blood levels of glutathione peroxidase, paraoxonase-1, and total antioxidant capacity in addition to a decrease in C - C-reactive protein (CRP). The group on the reduced fiber diet (LFD) exhibited a decrease in interleukin-6 levels. There was a decrease in waist circumference, body mass index (BMI), and weight in both groups.

HOMA-IR levels were consistently elevated by all markers of adiposity, including age, sex, pubertal stage, socioeconomic status, adherence to the Mediterranean diet, and cardiovascular health. Higher adiponectin and lower HOMA-IR levels were observed in obese adolescents. This implies that adiponectin, insulin resistance, and obesity are related. Higher levels of physical activity were related to decreased triglyceride levels.

Accordingly, in ¹⁶, low adiponectin levels at baseline and a reduction in adiponectin levels throughout the 10-year ten-year follow-up period are predictive of developing metabolic syndrome. In addition, adipocyte dysfunction is triggered by dietary habits such as excessive eating, inactivity, and low respiratory health. Defensive adipocytokines such as adiponectin are also dysregulated by these conditions, which results in radiotoxicity ¹⁷. In obese populations, obesity is linked to further metabolic conditions ¹⁸. According to the research, a prominent level of insulin resistance has been associated with an increase in the adipose depot, especially in the visceral area ¹⁹.

Correlation between insulin resistance and normal body mass index, glucose tolerance, waist circumference, and body fat mass in males ¹⁹. The relationship between insulin resistance, anthropometric measures, and the buildup of abdominal fat in those classified as obese or diabetic was explained by the results of a cross-sectional study ²⁰. Therefore, insulin resistance (IR) may serve as a trigger for the development of several maladies, such as metabolic syndrome, non-alcoholic fatty liver disease (NAFLD), and progressive liver fibrosis, all of which are common liver disorders in obese people.

Research has focused on nutritional and pharmaceutical approaches that block many inflammatory pathways that cause metabolic problems associated with obesity. A lower incidence of cardiovascular diseases and death from all causes has been associated with strict adherence to a Mediterranean diet ²¹. Cardiorespiratory health, which is indicated as a strong predictor of health outcomes in adolescents, is another essential component of health in addition to food ²². Circulating adiponectin levels and cardiorespiratory fitness correlate negatively with some studies ²³. Because adolescence is an essential stage for developing lifestyle patterns, the importance of nutrition and cardiorespiratory fitness in reducing the risk of cardiometabolic disease is significant.

The effects of a multidisciplinary intervention on sleep patterns in children and adolescents with abdominal obesity were investigated in a different study that was included in the systematic review. The intervention group showed significant increases in sleep efficiency at 2 and 12 months, as well as improvements in sleep latency at 12 and 24 months when compared with the control group. The frequency of awakenings and waking after sleep began was significantly lower in the intervention group at 24 months. Each participant's leptin level and sleep latency showed favorable correlations. Furthermore, inverse relationships were found between the metabolic score, triglycerides, and overall amount of time spent in sleep. Moreover, inverse relationships between total sleep duration and triglycerides, leptin, and metabolic score were noted after the 2-month intervention.

A recent study found that many variables, including sex, food, fasting, sleep, and hormonal changes, affect the control of diurnal blood leptin levels²⁴. The data indicate that leptin levels and sleep duration correlate in both directions²². The loss of fat mass in the selected study was the main cause of the decrease in leptin levels. Evaluating the levels in obese adolescents would be useful.

An investigation measuring the concentration of melatonin in the saliva of obese children found that 1 h after sleep, their levels were more than twice as high as those of control children²⁵. It was further shown after a year that there was a negative correlation between total sleep time in bed and triglyceride levels. The metabolic score revealed an inverse relationship with sleep efficiency and a direct relationship with waking after sleep initiation and the frequency of awakenings. In addition, the study discovered that teenagers' HOMA-IR values were lower in the top quartile than in the lower quartile of adiposity measures. This conclusion was reached after adjusting for potential confounding variables such as age, sex, pubertal stage, socioeconomic status, Mediterranean diet adherence, and cardiovascular health. Teenagers who engaged in more physical exercise had lower triglyceride levels than those who did not engage in as much physical activity.

Numerous studies have researched the relationship between the number of sleep and metabolic risk factors in addition to weight status. Strong evidence points to the fact that children who sleep for longer periods are more likely to be overweight or obese, which is consistent with our results on triglycerides and metabolic status²⁶. We observed a clear correlation between waking after sleep onset (WASO) and both metabolic scores and leptin levels along with our lifestyle modification. In a case-control study, children with obesity linked to metabolic syndrome exhibited increased waking after sleep onset (WASO)²⁷. Studies have shown a negative association between metabolic score and sleep efficiency.

A significant negative relationship was observed between better sleep efficiency and unfavorable anthropometric results in other research that employed objective techniques to quantify sleep efficiency²⁸. The number of awakenings was found to be a significant predictor of obesity in two studies including adolescents. Liu et al. found a significant difference in children's sleep maintenance between overweight/obese and normal weight, specifically if it came to night awakenings as reported by parents²⁸.

This study provides important new information on the possible benefits of lifestyle modifications on the quality of sleep in obese children and adolescents. The relationship between children's sleep habits and their metabolic health is being clarified because of these discoveries. However, we understand that there are still several limitations to that study.

First, the participants span a wide variety of ages and pubertal phases. The statistical models incorporated age, pubertal stage, and sex to reduce the impact of any confounding variables. One potential drawback of the research might be the diminished statistical power to compare sleep metrics between the two groups at follow-up, which could be linked to a decline in sample size because of dropouts. Furthermore, the particular characteristics of the individual and the tool may impact sleep measures.

The additional research and systematic review provide evidence in favor of the benefits of lifestyle modifications and the Mediterranean diet for early adolescents. Studies have indicated that the Mediterranean diet improves several inflammatory and metabolic parameters and sleep habits. Furthermore, it has been shown that modifying a person's lifestyle, such as increasing physical activity, can improve cholesterol levels. Implementing a Mediterranean diet and lifestyle changes at an early age could have a substantial impact on lowering the prevalence of obesity-related disorders such as type 2 diabetes, heart problems, and cancer.

Additional studies are needed to confirm these results in broader population samples and to explore the long-term effects of these treatments on early adolescent health outcomes. Numerous health indicators, including hepatic function, metabolic profile, inflammatory markers, anthropometric parameters, and sleep patterns, have been found to improve with the Mediterranean diet. These results highlight the Mediterranean diet's ability to protect the population against obesity and related metabolic diseases. Further longitudinal studies and additional investigations are necessary to validate these findings and gain a more comprehensive understanding of the underlying mechanisms involved.

Conclusions

The four studies reviewed showed that the Mediterranean diet improves several anthropometric, metabolic, inflammatory, and antioxidant capacity markers compared to a low-fiber diet. The

Mediterranean diet achieved significant reductions in insulin resistance, hepatic steatosis, waist circumference, blood pressure, weight, BMI, triglycerides, fasting glucose, and inflammatory biomarkers like IL-6 and CRP. It also increased HDL levels. These findings suggest that the Mediterranean diet could be an effective nutritional intervention to prevent obesity, type 2 diabetes, cardiovascular disease, and other metabolic conditions in early adolescence.

Conflicts of Interest: the authors declare no conflict of interest.

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