Mediterranean diet and adiposity in children and adolescents: a systematic review

Camille Lassale[a,b,c], Montserrat Fíto [a,b], Maria Morales-Suárez-Varela[d,e], Andres Moya[e,f,g], Santiago F. Gomez*[h,i], Helmut Schröder*[a,e]

[a] Hospital del Mar Medical Research Institute (IMIM), Barcelona, Spain
[b] CIBER of Pathophysiology of Obesity and Nutrition (CIBEROBN), Instituto de Salud Carlos III, Madrid, Spain
[c] Department of Epidemiology and Public Health, University College London, UK
[d] Unit of Public Health and Environmental Care, Department of Preventive Medicine, University of Valencia, Valencia, Spain
[e] CIBER of Epidemiology and Public Health (CIBERESP), Institute of Health Carlos III, Madrid, Spain
[f] Institute of Integrative Systems Biology, Universitat de València and Spanish Research Council (CSIC), Valencia, Spain
[g] Fundación para el Fomento de la Investigación Sanitaria y Biomédica de la Comunitat Valenciana (FISABIO), Valencia, Spain[h] Gasol Foundation, Sant Boi de Llobregat, Spain
[i] GREpS, Health Education Research Group, Nursing and Physiotherapy Department, University of Lleida, Lleida, Spain

*Authors contributed equally

Address for correspondence

Lassale C and Schröder H; Hospital del Mar Medical Research Institute, Carrer Doctor Aiguader 88, 08003, Barcelona, Spain
Telephone:
Email: classale@imim.es; hschroeder@imim.es

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Abstract

Aim: Our aim was to summarize, through a systematic review, the current evidence from dietary intervention and observational studies on the impact of adherence to the Mediterranean diet on adiposity markers and obesity in children and adolescents.

Methods: We searched Medline up to May 11th 2020 for the identification of intervention and observational studies meeting the inclusion criteria, following the PRISMA statement.

Results: We included 55 articles: 8 intervention studies and 47 observational studies. Three trials report a beneficial effect of the dietary intervention, whereas 2 did not, and 3 did not compare to a control. All observational studies were cross-sectional, and only 5 studies also included a longitudinal analysis. More than half of the cross-sectional studies found no significant association between adherence to Mediterranean diet and adiposity. Three out of the 5 longitudinal studies found a negative association. The majority of both observational and intervention studies was of low quality.

Conclusions: Despite a large number of published studies, overall there is only limited evidence of a beneficial effect of following a traditional Mediterranean diet to maintain a healthy body weight in childhood. More high-quality intervention and longitudinal data is needed to form the base of large-scale health programs to prevent childhood obesity.

Introduction

A healthy balanced diet is imperative for healthy physical and mental development in children and helps to prevent nutrition related diseases [1]. It has been shown that some nutritional patterns, such as the Mediterranean diet, are associated with both mental and physical health in adults and children [2]. The Mediterranean diet traditionally includes abundant plant foods such as vegetables and fruits, whole grain products, legumes, nuts and seeds; daily dairy products are consumed in small quantities; some portions of poultry or fish weekly; and olive oil is the main source of fat intake. Several of these foods have been associated with a reduced risk of the incidence of chronic diseases [3-6]. Composite scores of adherence to the Mediterranean diet, which can best capture the synergy between these dietary components, have been associated with lower risk of adverse health outcomes, with a greater magnitude than individual food components [7].

Obesity prevalence has increased across countries and continents over the last decades [8], and not only in adults. The NCD Risk Factor Collaboration group reported a worldwide increase of the standardized child BMI from 1975 to 2016 [9]. The prevalence and trends of childhood overweight and obesity is particularly worrying in Iberian countries [8]. Current data show that Spain is one of the European countries with the highest prevalence of childhood overweight and obesity with 32.2% of children aged 7-13 years [8]. The economic burden of obesity and its related comorbidities consumes a large part of societal resources [10]. The fact that excessive weight in childhood tend to track into adulthood [11,12] make childhood obesity prevention a primary public health, social and economic challenge.

Obesity is a multidimensional health problem with a complex interplay among environmental, microbial, genetic, and psychosocial risk factors [13] [14]. One of the main drivers of the obesity pandemic are unhealthy dietary habits [15,16]. Results from clinical randomized trials (RCTs) provide promising evidence on the efficacy of the Mediterranean diet on long term weight loss in adults [17]. Recent data from the interim analysis of the PREDIMED-Plus trial [18] showed a significant and clinically meaningful reduction of more than a 5% in several anthropometric variables in the intervention compared to the control group. A review of Iaccarino Idelson and colleagues [19], which included a literature search up to December 2015, reported conflicting results on the association between adherence to the Mediterranean diet and obesity. However, this evidence was based largely on cross-sectional observational data. Less is known on the potential impact on adiposity of adhering to a traditional Mediterranean diet in early life, and no systematic review has summarized the existing evidence.

Therefore, the objective of the present systematic review was to summarize the current evidence from dietary intervention and observational studies on the impact of adherence to the Mediterranean diet on adiposity markers and obesity in children and adolescents.

Methods

Search strategy

This systematic review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analyses statement [20]. Two investigators (HS and CL) independently searched for the relevant studies on Medline from 1st January 2010 up to 1st June 2021. The following keywords, index terms and Boolean operators were used for the literature search: (Mediterranean diet [title/abstract] OR Mediterranean style diet [title/abstract] OR Mediterranean dietary pattern [title/abstract]) AND (child* [title/abstract] OR adolescent* [title/abstract] OR teenage* [title/abstract] OR youth [title/abstract]) AND (obes* [title/abstract] OR abdominal obes* [title/abstract] OR body mass index [title/abstract] OR BMI [title/abstract] OR waist [title/abstract]).

The search was limited to articles published in the English or Spanish language and to full-text journal articles. We scrutinized the references sections of the retrieved articles and systematic reviews to search for any article not picked up by the search (snowball strategy). Disagreements were discussed and resolved by consensus between the two investigators.

Study selection

We aimed to include both intervention and observational studies. To be eligible, a study had to meet the following criteria: 1) Exposure / intervention: Mediterranean diet adherence; 2) Outcome: markers of body size / adiposity (weight, body mass index, waist circumference, body fat) in continuous or grouped in predefined categories of overweight or obesity; 3) Design: intervention or observational study (cross-sectional, case-control, longitudinal); 4) Population: children and / or adolescents from 2 to 18 years of age, free-living.

We excluded studies with the following characteristics 1) Exposure: other markers of diet quality; 2) Outcome: metabolic syndrome or other cluster of cardiometabolic health not separating body size; 3) Population: adults aged 18 years and older; 4) No statistical test performed.

Data extraction

After study selection, we extracted the following information from each retrieved article: first author's surname, journal, year published, geographical location, study design, follow-up time (if applicable), sex and mean age, sample size, dietary score used to measure adherence to MedDiet, anthropometric variable assessed, method of collection (measure or self-report), statistical model used, covariates included, main findings including mean differences between groups, regression coefficients, or odds ratio / risk ratios for binary outcomes (obesity). When a study provided several estimates, we chose to use those from the most complex model (that is, the one including the largest number of confounders).

Assessment of study quality

For intervention trials, we assessed if the study was 1) randomized, 2) included a control group, 3) if appropriate statistical tests and adjustment for confounders was conducted. A study was considered of high quality if all 3 criteria were met, medium if 2, poor if 0 or 1. For observational studies, we adapted the Newcastle-Ottawa checklist [21] to assess:1) whether cohorts were representative of the wider population; 2) if diet was ascertained by means of a validated dietary assessment tool (e.g. FFQ); 3) if the dietary score used was validated; 4) whether follow-up was sufficient to preclude reverse causation (≥1 year), and; 5) if appropriate statistical adjustment was made (age, sex, markers of socioeconomic status, physical activity, total energy intake, etc.). If at least four of the five of the above criteria was met, the study was considered of high quality, medium if 3 criteria were met, poor if 2 or less.

Results

The search yielded 246 records. As seen on Figure 1, after screening titles and abstracts, we excluded 141 records and assessed 105 full text articles. A total of 48 studies did not match the inclusion criteria, therefore we included 57 articles. Of them, there were 8 intervention studies [22-29], and 47 observational studies. All observational studies were cross-sectional, except one that only included a longitudinal analysis, and only 5 studies included a longitudinal analysis [30-34].

Intervention studies

Characteristics and results of the 8 intervention studies are presented in Table 1. The Mediterranean diet interventions lasted from 8 weeks to 3 years in children aged 3 to 16 years. Six studies [22,23,26-29] report a test of the before/after difference in the intervention group, but 3 of them did not compare it to a control group [22,26,27]. Most before/after comparisons in children who had the intervention yielded statistically significant reductions over time in continuous BMI [26,28,29], overweight or obesity category defined by BMI [23,27] or waist to height ratio [22,26]. However, when a comparison with a control group was performed, three studies found a statistically significant difference between the intervention and control group in terms of obesity [23,24] or BMI [28], but two other studies did not report significant differences [25,29]. There was no evidence of an effect of the intervention on markers of abdominal obesity in the two studies that measured it [24,25]. The quality of the trials was on average poor, with 3 out of 8 studies that did not include a control group, and even in the presence of a control, reporting of results was only appropriate in 3 studies: comparison of the difference before/after between the two groups [25,29], or incidence of overweight/obesity [23].

Observational studies

For the 47 observational studies described in Table 2, 42 carried out a cross-sectional analysis, 4 a cross-sectional analysis combined with a longitudinal and one a longitudinal analysis only. The cross-sectional studies examined the association of an anthropometric measure with a score of adherence to the Mediterranean diet. The score most commonly used was the 16-item KIDMED index (ranging -4-12) or one of its variation, and only 6 studies [30,31,34-37] used another score such as the MDS. The majority of studies included BMI as the main anthropometric marker, except three: waist circumference [38], abdominal obesity [39], or body fat percentage [40]. In cross-sectional studies, regarding general adiposity expressed by BMI, continuous or in categories (overweight/obesity), a total of 27 studies [31,32,34-36,39,41-61] found non statistically significant associations, 16 a negative association [30,37,62-75], and one a positive association [76] with greater adherence to the Mediterranean diet. Regarding central adiposity, 11 studies found no significant association [30,32,34,36,39,46-49,52,56], whereas 5 found an inverse association [37,38,61,74,77], and two a positive association [74,76]. Regarding the statistical approaches, 17 studies only performed simple chi-square, ANOVA or Pearson correlation tests without adjustment [40,44-50,53-56,62,63,66,71,75], of which only 5 found statistically significant differences in anthropometric markers according to Mediterranean diet adherence [62,63,66,71,75]. The other 30 studies either used linear or logistic regressions, with various levels of adjustment, and 16 of these found non-significant results.

Of the 5 longitudinal studies (4 also included a cross-sectional analysis), three found a negative association with BMI [30,33,34] and two with other markers of adiposity [30,34], whereas the other two report non-significant associations [31,32].

The majority of observational studies were ranked of low or medium quality, and only 10 reached the quality criteria to be of high quality [30,32-34,36-38,59,61,69].

Discussion

With this systematic review we show that, despite having been the object of a reasonably large number of studies, there is only limited evidence of a beneficial effect of following a traditional Mediterranean diet to maintain a healthy body weight in childhood. Most studies retrieved were of observational nature, of which the majority were cross-sectional, and deemed of low quality, therefore providing a low level of evidence. There were eight intervention studies, but they presented methodological limitations. To summarize, out of 8 intervention studies, 5 actually compared to a control group, of which 3 found significant reductions in body weight in the intervention group. Out of 47 observational studies, only 5 were longitudinal: 3 showed a negative association between Mediterranean diet adherence and change in BMI, 2 found non-significant results. Out of the 42 cross-sectional studies, 38% of the studies found a negative association with general adiposity, and 28% with markers of central adiposity.

Intervention studies

The interpretation of the current evidence from intervention studies included in this review is somewhat problematic. This is mainly due to methodological limitations of the majority of these studies. Four out of eight intervention studies either did not include a control group or appropriate comparisons of change over time between groups [22,26-28], which provide only a low level of evidence. Moreover, adjustment for potential confounders - even a minimal set of factors, was only used in two studies [23,25]. Pre-post within group comparisons suggest overall a favourable impact of the Mediterranean diet intervention on anthropometric surrogates of body fat in these studies. This contrasts with the evidence coming from studies showing no or little effect of other dietary intervention programs, alone or in combination with physical activity, on BMI and zBMI in children aged 0 to 13 years, as reviewed[78]. One explanation might be the superiority of an intervention with the Mediterranean diet regarding weight management compared to other healthy dietary intervention programs. In adults, weight loss interventions including a Mediterranean diet are showing promising results [18]. However, the low quality of the design of most intervention studies included in this review prevents drawing any firm conclusion. It should also be noted that all but one studies were conducted in Mediterranean countries (Spain, Italy, Greece), with only one trial of low quality with 49 participants in Mexico[28], that shows promising results but no comparison with the control group was provided. Therefore, the results reported here cannot be generalized to non-Mediterranean countries.

Four studies which compared changes in anthropometric markers [25,29] or the reversion of the prevalence of obesity [22,23] at the end of the intervention showed mixed results with 2 studies reporting a favourable impact [22,23], whereas 2 studies did not find any significant difference between intervention and control group [25,29]. Again, methodological issues might explain this. The intervention programs of these studies were implemented in various settings: primary care [29], school [22,23], and community [29]. It is still an open question whether these settings are equally appropriate for the implementation of childhood obesity preventative programs. Furthermore, only one of these studies was of high quality [25] and included paternal educational level as a potential confounder in the analysis. This is especially important for studies without randomization at the individual level. It is known that parental socioeconomic level is a crucial factor for child weight status [79] and for adherence to the Mediterranean diet [80]. Therefore, the lack of adjustment for parental socioeconomic level likely flaws the evidence of these studies.

Observational studies

We retrieved a total of 47 observational studies looking at Mediterranean diet and body size in children or adolescents, and only five of them included longitudinal analysis. Results were mixed as two out of the five longitudinal studies found no evidence of an association with BMI change. All longitudinal studies were of high quality with appropriate statistical modelling and adjustment for confounders, including indicators of socioeconomic status of the family, except for one [33]. There was no clear pattern on age of children, or duration of follow-up in explaining presence or absence of association, although the two studies that did not find significant results were of lower sample size (<1000). Longitudinal studies with the strongest design and pooling results from various countries, namely the IDEFICS and INMA cohorts, in younger children (2-9 years and 4 years respectively), [30,34], as well as a study in the USA with over 10,000 children [33]. Interestingly, in the IDEFICS and INMA studies, a cross-sectional analysis was also performed and did not show significant associations with waist to height ratio [30] or with any anthropometric marker [34]. These encouraging results do not seem to be confined to Mediterranean countries.

The results from cross-sectional studies do not form a convincing body of evidence: of the 39 cross-sectional studies, more than half did not report any significant association between adherence to a Mediterranean diet and anthropometric markers, may it be markers of total or abdominal adiposity. This can be a result of an interplay of biases, including reverse causality bias, social desirability, and conscious or unconscious dietary misreporting [81]. In concrete terms, parents of children who have overweight or obesity may tend to report a healthier diet as a result of being made aware by the study team of the weight status of their child. Feeding practices are perceived as clearly essential for parents and for this reason the social desirability of answers would be strongly determined.

For both intervention and observational studies, besides the aforementioned limitations specific to each study design, publication bias likely occurs. Due to the heterogeneity in design and reporting, we could not meta-analyse the results, neither draw a meaningful funnel plot, so we cannot assess it formally. A substantial number of observational studies reported null results, but those results tended to be presented alongside others. Therefore, some studies for which the primary objective was the association between Mediterranean diet and anthropometrics markers in children may not have been published due to null results, or the papers reframed to study another outcome and the results on anthropometrics not reported. The implication of this, is that the number of studies failing to find an association between Mediterranean diet and childhood obesity is likely greater than what reported in this review.

Biological mechanisms

Despite the low quality of evidence shown in this review, there is an array of plausible mechanisms through which adhering to a Mediterranean diet can help maintain a healthy body weight and prevent obesity in the first developmental phases of life. The high content in fibre-rich, nutrient-dense and energy-poor food (fruit, vegetables, whole grain, nuts and seeds) are optimal to not overconsume calories, as well as having meals together as a family, which is a pillar of the Mediterranean diet [82]. Moreover, specific compounds such as phenolic compounds from olive oil, omega 3 polyunsaturated fatty acids, vitamins and trace elements, as well as polyphenols, and dietary fibre, are found in abundance in a traditional Mediterranean diet. They have been shown to modulate and maintain a healthy gut microbiota, as well as a better intestinal barrier integrity, which have been shown to be disturbed in the presence of obesity and metabolic syndrome [83,84].

To conclude, more randomized clinical trials with the promotion of the Mediterranean diet as one part of an innovative multilevel and multicomponent, medium- to long-term, intervention program are needed [85]. The current evidence from largely poor-quality trials makes it impossible to draw conclusions on the efficacy of the adherence of the Mediterranean diet on weight management in children. The implementation of health programs to prevent childhood obesity at large scale should be based on robust evidence coming from RCTs.

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Figure 1. Flow diagram of study selection

Table 1. Summary of intervention studies with a Mediterranean diet intervention on markers of adiposity in children and adolescents

Author year	Country	N, age	Comparator	Duration	Outcome	Statistical analysis	Results	Quality
Bibiloni et al, 2019 [24]	Spain, ACTIVAT	96 8-14y	Intervention vs control; before/after	6 months	BMI categories, WHtR	Chi-square	Intervention vs control **Categories of BMI p=0.001** Abdominal obesity p= 0.260 Presentation of proportions before/after without p values.	Low
Ojeda-Rodriguez et al, 2018 [29]	Spain, IGENOI	107 7-16y	Intervention vs control (Intensive care vs usual care)	8 week	BMI continuous	t-test	Difference of changes between groups: -0.1 (-0.6, 0.3) NS. BMI change in control group -1.4 (-1.8, -0.9) BMI change in intervention group -1.5 (-1.7, -1.3)	High
Gomez et al, 2018 [25]	Spain, POIBC	2086 8-10y	Intervention vs control	15 monts	zBMI, WHtR, general and abdominal obesity	Generalized estimating equation models. Adjusted for age,sex, mother's educational level, adherence to the Mediterranean diet, PA, and the corresponding anthropometric variable	NS differences between intervention and control group for changes in zBMI and the proportions of incidence of general obesity and abdominal obesity. WHtR decreased significantly in the control group compared to the intervention group	High
Roccaldo et al, 2017 [27]	Italy	494 8-10y	Before vs after	6 weeks	Obesity categories	McNemar test	**Before vs after p=0.001** n=395; no data control n=99	Low
Ranucci et al, 2017 [26].	Italy	74 5-17y	Before vs after	6 months (5-12y); 3 months (13-17y)	BMI, WC, WHtR and body fat	Student's t-test	**In children aged 5-12y** **Decrease in BMI p<0.001, WC p<0.001, WHtR p=0.002; body fat p=0.005)** **In adolescents 13-15y BMI, WC, body fat p<0.001; WHtR p=0.012.**	Low

Bibiloni et al, 2017 [23]	Spain, INFADIMED	1199 3-7y	Intervention vs control	3 years	Overweight or obesity (age and gender specific cut off)	Logistic regression. Adjusted for sex, educational level, origin	113 new cases, 97 in the control and 16 in the intervention group. **OR=0.45 (0.26, 0.78)**	Medium
Bacopoulou et al, 2017 [22].	Greece	1032 12-17y	Before vs after	6 months	WC	Comparison pre-post t-test	**71.1 +-9.1 vs 70.3 +- 9.0 cm p<0.001**	Low
			Before vs after	6 months	WHtR		**0.44+-0.05 vs 0.43 +-0.05 p<0.001**	
Velazquez-Lopez et al, 2014 [28]	Mexico	49 11y	Before vs after	16 weeks	BMI	Comparison pre and post BMI, separately for each group	Mean difference **In intervention group -1.10 (-1.4, -0.7) p=0.001**, In control standard diet group: +0.1 (-0.2, 0.6) p=0.374	Low

Abbreviations: BMI, body mass index; WC, waist circumference; WHR, waist to hip ratio; WHtR, waist to height ratio

Values in bold are statistically significant

Table 2. Summary of observational studies on adherence to Mediterranean diet and anthropometric markers in children and adolescents

Author Year	Country	N, age	Study design	Obesity measure	MedDiet score	Model	Adjustment	Results	Quality
George et al. 2021 [61]	The Healthy Growth Study ,Greece	1972 9-13y	Cross-sectional	BMI categories and abdominal obesity (WC>90th percentile)	KIDMED	Logistic regression	Sex, age, Tanner stage, maternal education, and energy intake.	**Poor (≤3) vs high (≥8) adherence** OR=1.16 (0.85, 1.59) for obesity **OR=1.31 (1.01-1.73) for abdominal obesity.**	High
Jiménez Boraita et al. 2021 [57,58]	Spain	761 12-17y	Cross-sectional	BMI	KIDMED	Correlation coefficient Stepwise backwards logistic regression	Age, sex, nationality, sleep hours, academic performance, physical activity	Unadjusted correlation KIDMRD-BMI r= -0.007, p>0.05 for all r= -0.029, p>0.05 for boys r= 0.016, p>0.05 for girls Mediterranean Diet not selected as a predictor of overweight/obesity	Low
Peng et al. 2021[73]	Israel Mabat Youth II	3906 11-19y	Cross-sectional	BMI categories	KIDMED	Logistic regression outcome=high KIDMED	School level, socioeconomic status, physical activity, dieting, daily screen time, alcohol, sleeping hours, read food labels. Stratified by sex, population group and age group.	OR of high KIDMED **(≥8)** in overweight /obesity vs normal weight **OR= 0.72 (0.53, 0.98) p= 0.038** for Jewish boys only (n=895)	Medium
Caamano-Navarrete et al. 2020[74]	Chile and Colombia	969 Girls:5.24 ± 0.80y Boys: 5.10 ± 0.78 y	Cross-sectional	BMI categories, WC, and WHtR	KIDMED	Logistic regression	-	**Low vs medium/high adherence to the KIDMED** **BMI≥85th OR=1.43 (1.00,2.05) p=0.018 for 4-5y old Chilean boys (n=611)** **WC≥85th OR=0.44 (0.23,0.88) p=0.010 for 4-5y old Colombian girls (n=353)** **WHtR≥85th OR=0.37 (0.14-0.95) p=0.040 for 6-7y old Colombian girls (n=353)**	Low

								NS for all other groups	
Manzano-Carrasco et al. 2020 [59]	Spain	1676 6-17y	Cross sectional	BMI	KIDMED	Linear regression	Sex, age, fat mass, physical fitness and pubertal status	Association between KIDMED and BMI: β= 0.01 (SE 0.02). NS	High
Kanellopoulou et al. 2020 [60]	Greece	1142 10-12y	Cross-sectional	BMI categories	KIDMED	Logistic regression	Sex, age, physical activity, and screen-time	OR of overweight and obesity versus normal weight per 1 unit increase of KIDMED OR= 0.96 (0.90, 1.02)	Low
Fernández-Álvarez, et al. 2020 [75]	Spain	303 13-16y (Boys only, football players)	Cross-sectional	BMI categories.	KIDMED	ANOVA	-	**In normal weight KIDMED score=6.90 vs 6.24 in overweight boys, p=0.032**	Low
Notario-Barandiaran et al, 2020 [34]	Europe, INMA Cohort	1801 4y	Longitudinal 4 years follow-up (from age 4 to age 8)	BMI categories, abdominal obesity based on WC	rMDP	Cox proportional hazards	Region, child age, sex, maternal social class, mother's prepregnancy BMI, smoked during pregnancy, second-hand smoking, parity, breastfeeding duration, small child for gestational, at baseline (4 years): TV watching, sleep, sweetened beverages consumption	**High vs low adherence HR=0.38 (0.21, 0.67) for overweight, HR=0.16 (0.05, 0.53) for obesity HR=0.30 (0.12, 0.73) for abdominal obesity**	High
			Cross-sectional	BMI, WC		Poisson regression to estimate prevalence ratio		High vs low adherence PR= 1.01 (0.96–1.05) for overweight, PR= 0.99 (0.96–1.02) for obesity, PR= 1.01 (0.96–1.08) for abdominal obesity	

De Santi et al, 2020 [71]	Italy (Sicily)	239 11-13y	Cross-sectional	BMI categories	KIDMED	Chi square and correlation coefficient	-	**p=0.018 across BMI categories Correlation coefficient -0.207 p<0.001**	Low
Rosi et al 2020 [72]	Italy	409 11-14y	Cross-sectional	BMI	KIDMED	Stepwise linear regression	sex, age, KIDMED score, physical activity, sleep time, daytime sleepiness	**Association between 1 KIDMED unit and BMI Beta = -0.133; p=0.042**	Medium
Rosa Guillamon et al, 2019 [54]	Spain	520 8-17y	Cross-sectional	BMI categories	KIDMED	Chi square	-	Chi square NS cross-tabulation KIDMED score category vs normal, overweight, obesity	Low
Obradovic Salcin et al, 2019 [52]	Croatia	260 5-6y	Cross-sectional	zBMI, WC, WHR	KIDMED	Mixed effects logistic regression	Sex	Low+moderate vs high KIDMED: OR=1.37 (0.86, 2.00) for BMI, 0.95 (0.90, 1.01) for WC and 0.49 (0.12, 2.13) for WHR	Medium
Mounayar et al, 2019 [68]	Lebanon	600 15-18y	Cross-sectional	BMI percentiles	KIDMED	Linear regression	Sex, age, school type, education, school grades, breakfast quality	**Beta=-0.101 p=0.044**	Medium
Katsagoni et al, 2019 [37]	Greece, National Action for Children's Health (EYZHN) program	174,209 6-18y	Cross-sectional	BMI categories, WC and WHtR	Medlife index	Logistic regression	Sex, age	**T3 vs T1: OR=0.70 (0.67, 0.75) for Obesity, OR=0.94 (0.91, 0.98) for overweight and OR=0.83 (0.80, 0.77) for WHtR≥0**	High
Galan-Lopez et al, 2019 [49]	Spain	991 13-16y	Cross-sectional	BMI, WC, body fat	KIDMED	GLM	-	NS all anthropometric variables across KIDMED categories	Low
Galan-Lopez et al, 2019 [48]	Spain, Estonia, Iceland	1717 13-16y	Cross-sectional	BMI, WC, body fat	KIDMED	Not specified	-	NS all anthropometric variables	Low

Galan-Lopez et al, 2019 [46]	Estonia	431 13-16y	Cross-sectional	BMI, WC, body fat	KIDMED	MANOVA	-	NS all anthropometric variables across KIDMED categories	Low
Tambalis et al, 2018 [76]	Greece, National Action for Children's Health (EYZHN) program	336,014 4-17y	Cross-sectional	BMI, WC	KIDMED	Logistic regression	-	**Boys: OR=1.15 (1.09, 1.29) for obesity, 1.05 (1.00, 1.09) for WHtR>0.5. Girls: OR=1.12 (1.04, 1.20) and 1.07 (1.02, 1.12)**	Low
Labayen Goni et al, 2018 [77]	Spain	619 3-5y	Cross-sectional	zBMI, WC	KIDMED	Linear regression	age, sex, socioeconomic variables	beta=-0.011 p=0.676 for zBMI, beta=-0.055, p=0.020 for zWC	Medium
Grammatikopoulou et al, 2018 [64]	Greece	319 10-18y	Cross-sectional	BMI categories	KIDMED	Logistic regression	sex, age, residence status	**Low vs high KIDMED OR=4.20 (1.54, 11.4) for obesity, 0.76 (0.29, 1.96) for overweight**	Medium
Galan-Lopez et al, 2018 [47]	Spain	439 13-16y	Cross-sectional	BMI, WC, body fat	KIDMED	ANOVA	-	NS all anthropometric variables across KIDMED categories	Low

Archero et al, 2018 [42]	Italy	669 6-16y	Cross-sectional	Obesity	KIDMED	Logistic regression	Sex, school level, ethnicity	Moderate+high vs low KIDMED: OR=0.87 (0.50, 1.50)	Medium
Sedaghat et al, 2017 [56]	Iran	300 15-18y girls only	Cross-sectional	BMI, WC, waist to hip	KIDMED	Chi square	Age, duration residence in Theran, SES, energy kcal, physical activity	NS difference for BMI, WC and WHR	Medium
Rosi et al, 2017 [55]	Italy	690 9-11y	Cross-sectional	BMI categories	KIDMED	Chi square	-	p= 0,087 cross-tabulation of KIDMED and BMI categories	Low
Peng et al, 2017 [70]	Israel Mabat Youth I	5268 11-19y	Cross-sectional	Obesity categories	KIDMED	Logistic regression	-	Only significant OR of poor KIDMED was for underweight (vs normal weight) in Jewish boys (but not girls, nor arab children)	Low
Novak et al, 2017 [69]	Lituania, Serbia	3071 14-18y	Cross-sectional	Overweight or obesity	KIDMED	Logistic regression	Sex, age, psychological distress, self related health, SES, physical activity, sedentary behaviours	**OR for high adherence: overweight/obesity 0.74 (0.59, 0.92)**	High
Mistretta et al, 2017 [67]	Sicily, Italy	1643 11-16y	Cross-sectional	Overweight and obesity (age and gender specific cut off points)	KIDMED	Logistic regression	Sex, age, SES, BMI, physical activity, energy intake, blood pressure, parents education, parents occupation	**High vs low KIDMED: OR=0.70 (0.56, 0.87)**	Medium

Arriscado et al, 2017 [43]	Spain	613 11-12y	Cross-sectional	Overweight and obesity (age and gender specific cut off points)	KIDMED	Linear regression	-	No significant difference in continuous KIDMED score	Low
Martin-Calvo et al, 2016 [33]	USA	10918 (3942 included in multivariate analysis) 8-15y	Longitudinal 7 years follow-up	BMI	modified KIDMED (mKM)	Generalized estimating equation	Sex, age, BMI at baseline, physical activity, sedentary time, time of follow-up and total energy intake	**Q4 vs Q1 m-KM: 2-year relative BMI change -0.11(−0.19 to −0.03). 2-year change in the m-KM Score and simultaneous relative change in BMI -0.30 (-0.40 to -0.20)**	High
Zhong et al, 2016 [32]	US, SEARCH study	793 13.7y mean	Cross-sectional and Longitudinal 5 years	BMI z-score and WC	modified KIDMED (mKM)	Linear regression	age, sex, race, diabetes duration, parental education, family income, parental history of diabetes, clinical site, physical activity, sedentary behavior, smoking, total calories, insulin regimen, daily insulin dose per kg, HbA1C	Continuous m-KM with BMI z-score and WC, all NS for both Cross-sectional and longitudinal. Cross-sectional beta=0.06, SE=0.04, p=0.19 for BMI, beta=0.33, SE=0.48, p=0.50 for WC. Longitudinal 5-year analysis : beta=0.02, SE=0.02, p=0.44 for BMI, beta=0.18, SE=0.24, p=0.46 for WC	High
Voltas et al, 2016 [31]	Spain (Reus)	241 12-15y	Cross-sectional and Longitudinal 3 study phases	Underweight vs normal weight	Krece score	Logistic regression models to predict risk of low MD adherence	gender, age, birthplace, family type, school type, SES, risk/control, total SCARED, total CDI	NS difference in Cross-sectional and longitudinal analysis (over 3 study phases): 0.97 (0.89, 1.06)	Medium
Garcia-Pastor et al, 2016 [40]	Spain	1389 14-17y	Cross-sectional	Body fat percentage quartiles	KIDMED	ANOVA across quartiles of body fat percentage	-	NS difference in KIDMED across quartiles of body fat percentage	Low

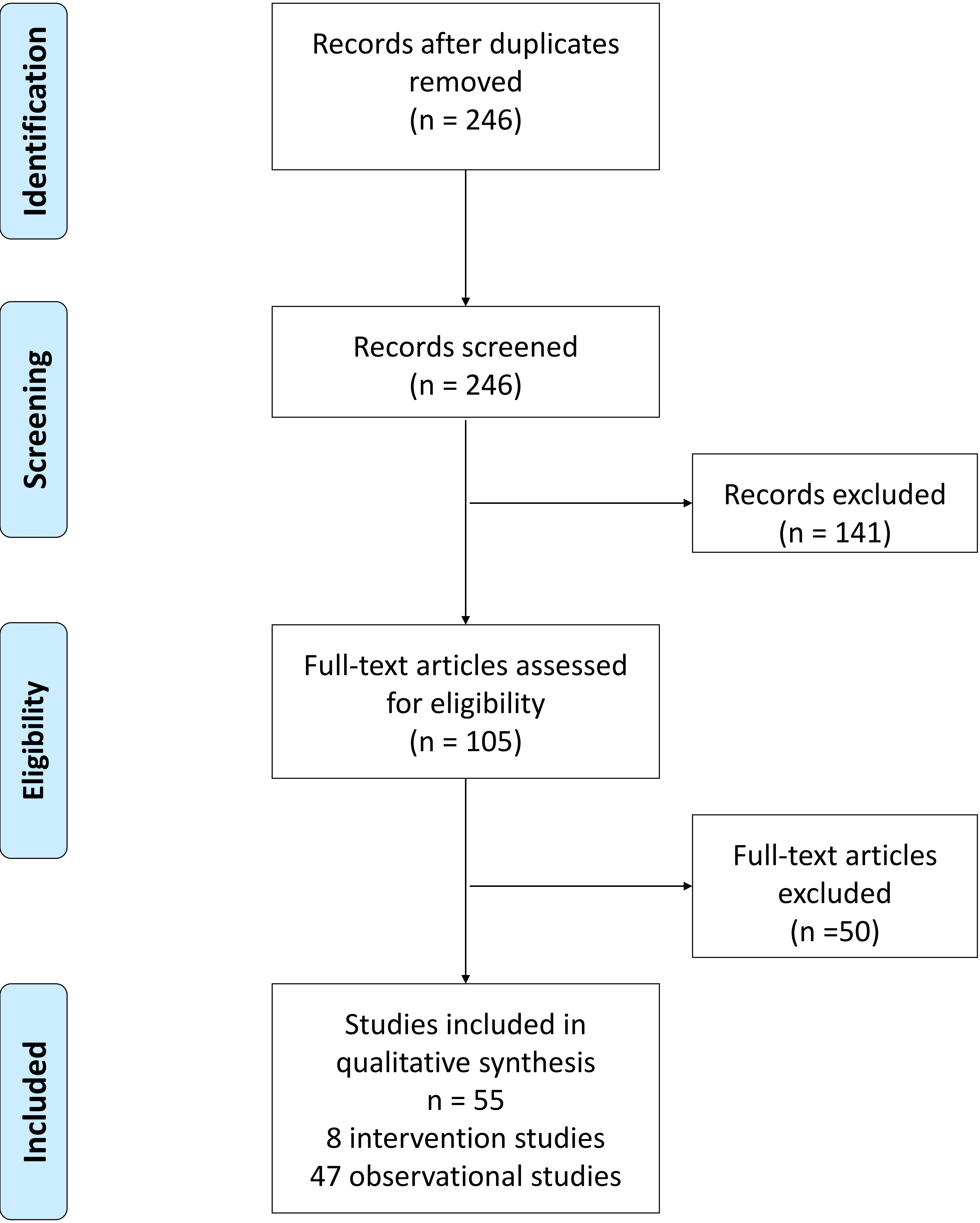
Ferranti et al, 2016 [63]	Sicily, Italy	1586 11-14y	Cross-sectional	BMI categories	KIDMED	Chi square	-	**p=0.003 of KIDMED score category vs normal, overweight, obesity, lower proportion of high adherence score in overweight and obesity**	Low
Eloranta et al, 2016 [35]	Finland, PANIC study	204 6-8y	Cross-sectional	BMI	MDS 8 items without alcohol + poultry	Linear regression	age, physical activity, electronic media time, household income	Association between BMI and MDS continuous: borderline positive in boys beta=0.12 (-0.02, 0.26) p=0.096, NS in girls beta=-0.01 (-0.15, 0.13), p=0.858	Medium
Cakir et al, 2016 [62].	Turkey, Black sea	181 11-12y	Cross-sectional	BMI	KIDMED	Correlation coefficient	-	**Negative correlation between KIDMED and BMI r=-0.53, p<0.05**	Low
Tognon et al, 2014 [30]	8 European countries, IDEFICS study	13,256 2-9y	Cross-sectional	Overweight (Cole definition), WC, WHtR, body fat %	fMDS	Logistic regression	age, sex, study center, parental education, high parental income	**fMDS>3 vs <=3** **OR=0.85 (0.77, 0.97) overweight,** OR=1.00 (0.89, 1.12) WtHR>0.5, beta=-0.20 (-0.46, 0.06) WC **beta=-0.22 (-0.43, -0.01) body fat %**	High
		9196	Longitudinal 2 years follow-up	Highest quintile of BMI, WC, WHtR, body fat z-score change	fMDS	Logistic regression	age, sex, study center, parental education, high parental income	**OR=0.87 (0.78, 0.98) BMI** **OR= 0.88 (0.78, 0.99) WtHR** **OR=0.87 (0.77, 0.98) WC** **OR= 0.89 (0.78, 1.00) body fat %**	
Roccaldo et al, 2014 [53]	Italy, ZOOM8 study	1740 8-9y	Cross-sectional	Overweight and obesity Cole definition	KIDMED	Comparison across 3 categories of KIDMED	-	NS difference in normal, overweight and obesity proportions across KIDMED categories	Low
Arriscado et al, 2014 [44].	North Spain	321 11-12y	Cross-sectional	Overweight and obesity Cole definition	KIDMED	Correlation coefficients	sex	Correlation coefficient: r=0.035 with BMI NS, r=0.033 with WC NS	Low
Grosso et al, 2013 [65]	Sicily, Italy	1135 13-16y	Cross-sectional	Obesity Cole definition	KIDMED	Logistic regression modelling odds of medium-high tertile vs low adherence to KIDMED	sex, socioeconomic status, physical activity level, place of living (urban/rural)	**OR of high MED adherence in obesity vs normal weight 0.59 (0.37, 0.94)**	Medium

Grao-Cruces et al, 2013 [50]	South Spain	1973 11-18y	Cross-sectional	BMI, body fat	KIDMED	ANOVA	-	Across categories of KIDMED: p=0.11 for BMI, p=0.241 for % body fat	Low
Antonogeorgos et al, 2013 [41]	Greece	1125 10-12y	Cross-sectional	Overweight and obesity (adult cutoffs)	KIDMED	Logistic regression	Urban/rural, parental obesity	High vs low/medium adherence OR of overweight/obesity: 0.76 (0.45, 1.29)	Medium
Bibiloni et al, 2011 [39]	Spain Balearic islands	362 12-17y	Cross-sectional	Abdominal obesity	MD	Logistic regression	sex, age, parental educational level, parental socioeconomic status, physical activity	High vs low (Q4 vs Q1) MD adherence: OR of abdominal obesity 1.31 (0.59, 2.89)	Medium
Jennings et al, 2011 [36]	UK	1700 9-10y	Cross-sectional	BMI	MDS	Linear regression	sex, parental education, underreporting, energy density, physical activity	1SD increase in MDS: -0.03, SE=0.08 NS for BMI, -0.18, SE=0.22 NS for WC	High
Farajian et al, 2011 [45]	Greece, GRECO Study	4786 10-12y	Cross-sectional	BMI	KIDMED	ANOVA comparison across 3 KIDMED categories <03, 4-7, >=8	-	No difference BMI across KIDMED categories p=0.32	Low
Schroder H et al, 2010 [38]	Spain, EnKid study	2153 10-24y	Cross-sectional	Waist circumference cm	KIDMED	Linear regression	sex, age, energy intake, leisure time physical activity, low energy reporting, maternal educational level	**Beta=-0.176, CI -0.269, -0.097, p=0.001**	High
Lazarou et al, 2010 [51]	Cyprus, CYKIDS study	823 9-13y	Cross-sectional	Overweight or obesity	KIDMED	Logistic regression	age, sex, parental educational level, 3factors of dietary beliefs and behaviors, parental obesity status, physical activity levels	High (>=8) vs Low (<4) KIDMED OR= 0.20 (0.02, 1.86)	Medium

Kontogianni et al, 2010 [66]	Greece	1170 3-18y	Cross-sectional	BMI	KIDMED	Correlation coefficient	-	**Correlation coefficient BMI and KIDMED score r=-0.14, p<0.001**	Low

Abbreviations: BMI, body mass index; WC, waist circumference; WHR, waist to hip ratio; WHtR, waist to height ratio; MDS, Mediterranean Diet Score; MDP, Mediterranean Dietary Pattern; OR, Odds ratio; 95% CI, 95% confidence interval

Values in bold are statistically significant


Identification
Records after duplicates removed (n = 246)
Screening
Records screened (n = 246)
Records excluded (n = 141)
Eligibility
Full-text articles assessed for eligibility (n = 105)
Full-text articles excluded (n =50)
Included
Studies included in qualitative synthesis
n = 55
8 intervention studies
47 observational studies