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Review Article

Dietary patterns associated with obesity outcomes in adults: an umbrella review of systematic reviews

Canaan Negash Seifu[1,*], Paul P Fahey[2,3], Tewodros G Hailemariam[4], Steven A Frost[1,5,6] and Evan Atlantis[1,3,7]

[1]School of Nursing and Midwifery, Western Sydney University, 48-52 Warby St, Campbeltown, Sydney, NSW 2560, Australia: [2]School of Health Sciences, Western Sydney University, Sydney, NSW, Australia: [3]Translational Health Research Institute, Western Sydney University, Sydney, NSW, Australia: [4]School of Public Health and Community Medicine, University of New South Wales, Sydney, NSW, Australia: [5]Department of Intensive Care, Liverpool Hospital, Sydney, NSW, Australia: [6]Centre for Applied Nursing Research & Ingham Institute for Applied Medical Research, South Western Sydney Local Health District, South Western Sydney Clinical School, University of New South Wales, Sydney, NSW, Australia: [7]School of Medicine, The University of Adelaide, Sydney, NSW, Australia

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Abstract

Objective: The aim of this umbrella review was to summarise the evidence from existing systematic reviews on the association between different dietary patterns (DP) and overweight or obesity outcomes in adults.

Design: We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and searched the MEDLINE, EMBASE, CINAHL, Cochrane, Scopus, and Web of Science for systematic reviews reporting on DP and weight gain or overweight/obesity outcomes.

Result: We identified 16 systematic reviews with 143 unique studies published between 2001 and 2019. Overall quality scores ranged from 4 to 10. Six reviews in 2/11 cohort and 6/19 cross-sectional studies reported (statistically significant) decreased OR for obesity (range: 0·53 to 0·73 and 0·35 to 0·88, respectively) associated with the Mediterranean diet. Five reviews in 5/15 cohort and 10/45 cross-sectional studies reported an inverse association between diet quality and weight gain or BMI (β range: –1·3 to –0·09). Two reviews in 1/3 cohort and 1/2 cross-sectional studies reported a decreased risk of obesity (OR = 0·76) and weight gain (OR = 0·26), respectively, with fruit and vegetable intake. Five reviews of mixed DP in 3/40 cross-sectional studies reported an increased prevalence of obesity (OR = 1·19) or abdominal obesity (OR range: 1·07 to 1·27) with the Korean diet pattern.

Conclusions: Our umbrella review confirms the hypothesis that Mediterranean-type DP reduce the risk of obesity in adults. Although population-specific evidence of effective interventions is needed, characteristics of Mediterranean-type DP are important considerations for national obesity prevention strategies.

Keywords
Dietary pattern
Obesity
Mediterranean diet
Umbrella review

Public Health Nutrition

Obesity and overweight, defined as a BMI greater than or equal to 30 kg/m^2 and 25 kg/m^2, respectively, are global health challenges(1). Worldwide, it is estimated 1·9 billion adults were in the overweight range(1), while 390 million women and 281 million men had obesity in 2016(2) and that the prevalence of obesity has tripled since the 1970s(3). It is one of the leading risk factors contributing to the total non-fatal and fatal disease burden in high-income countries worldwide(4). A recent systematic review found that obesity is also associated with a substantial economic burden in

*Corresponding author: Email c.seifu@westernsydney.edu.au

both developed and developing countries[5]. Improving our understanding of the effect of dietary patterns (DP) on the course of obesity could lead to the development of new obesity prevention strategies and management interventions and yield substantial health and economic benefits in affected societies.

Although the origins of the obesity epidemic are not entirely clear[6], the effects of globalisation resulting in 'obesogenic' environments since the 1970s are believed to be the most plausible explanation for the population-wide imbalance between energy intake and expenditure in most societies worldwide[7,8]. Unhealthy DP associated with excess energy intake, especially from energy-dense and nutrient poor foods, have likely played a major role in the development of obesity[9]. A DP is broadly defined by the quantity, variety, or combination of different foods and beverage in a diet and the frequency with which they are habitually consumed[10]. Evidence from some systematic reviews have shown that the risk of weight gain and obesity are associated with 'Western' diets typically high in energy and nutrient poor[11], high intake of refined grains, red meat and sugar-sweetened beverages[12]. Conversely, observational research has shown that both dairy consumption[13] and Mediterranean diets (MD), mostly composed of olive oil, fruits, vegetables, bread and cereals, legumes or nuts[14], may have a protective effect against developing obesity, but methodological differences between studies weaken the strength of this evidence[15]. Despite this uncertainty, the overall body of evidence suggests that public health strategies warning against established unhealthy DP could help reverse population levels of obesity[16].

Because of the variability in published systematic reviews on this topic regarding DP and their association with obesity[11–13,15,17–20], a summary and grading of this evidence is needed and timely. Following a thorough scoping of the published literature and electronic databases, we found no evidence of an existing or ongoing umbrella review on the above topic. Therefore, to address this knowledge gap, we aimed to summarise the evidence from existing systematic reviews on the association between different DP and overweight/obesity outcomes in adults.

Method

We reported the findings of our umbrella review according to the Preferred Reporting Items of Systematic Reviews and Meta-analyses statement (PRISMA checklist)[21].

Protocol and registration

Our protocol is registered with the International Prospective Register of Systematic Reviews hosted by the Centre for Reviews and Dissemination (PROSPERO) (CRD42020165391).

Inclusion criteria

To address the broad aim of this systematic review, we developed our research question and selected our specific inclusion and exclusion criteria using the Population, Interventions, Comparators, Outcomes and Study designs (PICOS) framework (Table 1)[22]. Our broad research question is 'are DP associated with obesity outcomes according to systematic reviews?' We included systematic reviews (with or without meta-analysis) of observational (cohort, case–control or cross-sectional) studies investigating the association of DP (exposure) on obesity incidence, or weight gain (change in weight, change in BMI and change in waist circumference (WC)), as primary outcomes in adult populations. In this study, a DP can be combination of foods consumed and assessed '*a priori*' or '*a posteriori*' (derived from cluster analysis or factor analysis). Unhealthy DP, consisting of foods high in energy such as heavily processed and animal source foods, are associated with excessive energy intake and have undoubtedly played a major role in the development of obesity[9]. Furthermore, components in food such as refined grains and processed meats as well as an excess of sugary drinks have been classified as detrimental to health[23]. Moreover, high consumption of saturated fats and low consumption of fruits and vegetables have been described as unhealthy dietary practices[24].

The focus of the review includes the following categories: (i) unhealthy *v.* healthy DP associated with overweight/obesity incidence and (ii) unhealthy *v.* healthy DP associated with weight gain.

Exclusion criteria

We excluded studies not meeting our inclusion criteria (Fig. 1). For systematic reviews that included both children and adult study populations, we reviewed the results pertaining to adults only where possible. If children could not be excluded or if ages were not specified, the review was excluded. Also, we did not consider studies of meal replacements (low- or very-low energy diet products). If systematic reviews included both observational and intervention studies, we reviewed the observational studies only.

Search strategy

Our search strategy was developed in consultation with a university librarian. We considered reviews written in English and published after 1990 because of limited publications before that[25]. Also, since then, high BMI became one of the top five risk factors contributing to deaths and disability-adjusted life-years[26]. We searched electronic databases up to February 2020. In the current review, a three-step search process was carried out. First, initial keywords were identified in MEDLINE, then text words included in the title and abstracts were documented followed using index terms to describe related reviews. Second, a search was undertaken in MEDLINE, EMBASE, CINHAL, Cochrane, Scopus

Table 1 PICOS criteria for including reviews

Parameter	Criteria
Participants	1. Adults (study population aged 18 years and over)[2]. 2. For systematic reviews that included both children and adult study populations, we reviewed the results pertaining to adults only if possible. 3. If children could not be excluded or if ages were not specified, the review was excluded.
Phenomena of interest	1. A DP determined *a priori* based on a combination of food groups or derived *a posteriori* from DP analysis methods such as factor analysis, cluster analysis or dietary indices[64]. 2. We did not consider studies of meal replacements (low- or very-low energy diet products).
Types of comparisons or control groups	1. Systematic reviews in which study populations did not have an outcome at baseline or were not exposed to the dietary risk factor (for longitudinal studies) as controls 2. The study population with lower DP scores as comparisons
Outcomes	1. Weight gain measures: change in weight, change in BMI, change in waist circumference 2. Obesity-related measures: weight, BMI, waist circumference, waist-to-hip ratio, adiposity (body composition), and incidence or risk of overweight or obesity
Types of studies	1. Systematic reviews (with or without meta-analysis) of quantitative studies that used observational study designs 2. If systematic reviews included both observational and intervention studies, we reviewed the observational studies only

DP, dietary pattern.

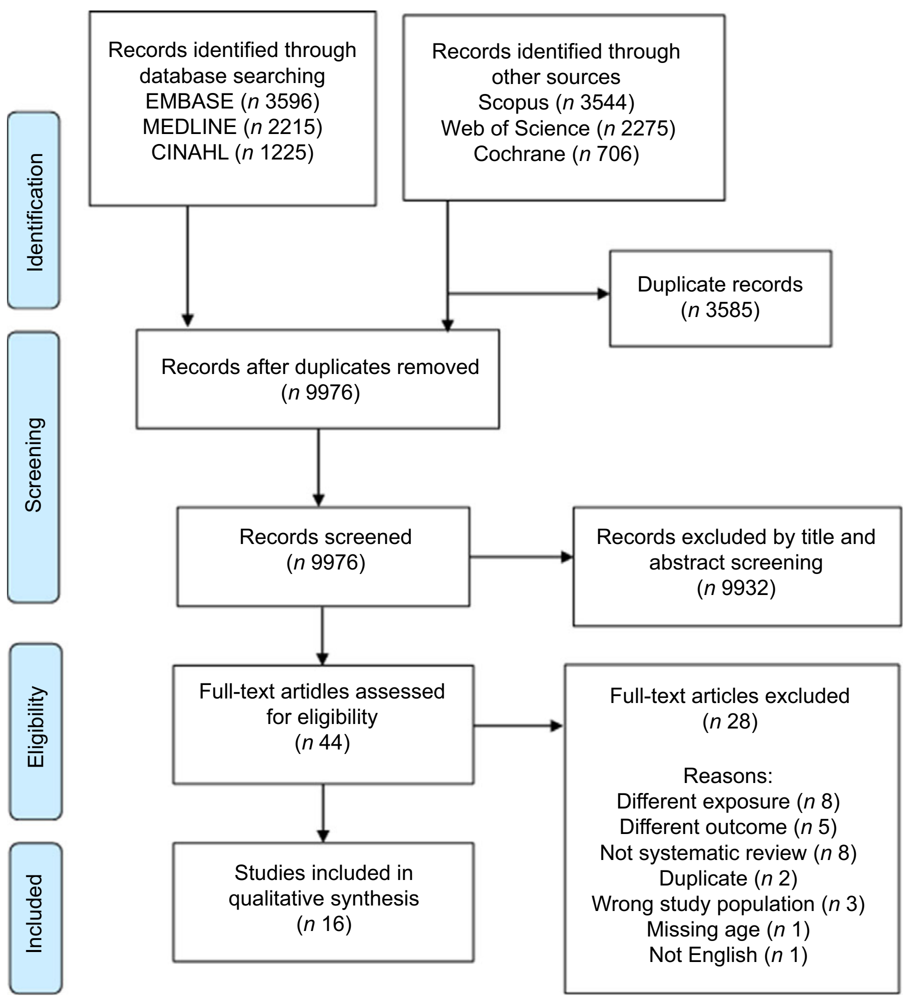

Fig. 1 (colour online) Preferred reporting items for systematic review and meta-analysis flow diagram of the study selection process

and Web of Science using a search strategy, which used subject headings and free texts such as diet, feeding behaviour, plant-based diet, prudent diet, Western diet, overweight, obesity, BMI, and systematic review were used after an academic librarian evaluated them. Third, we searched the reference lists of selected reviews for other potentially eligible reviews. The full search strategy on MEDLINE is available (Appendix S1).

Study selection

Two reviewers (CNS and TGH) assessed the titles and abstracts of systematic reviews against the inclusion criteria and completed the data extraction and quality assessments. First, titles and abstracts were screened and then full-text articles were screened (Fig. 1). We resolved any discrepancies through discussion with a third author (EA) to achieve a consensus.

Data extraction

Two reviewers (CNS and EA) reached a consensus on items such as search databases, source of funding, number of studies, types of studies, exposure and outcome to extract from eligible studies. We created a data extraction template on Microsoft Excel based on items from the Joanna Briggs Institute (JBI) data extraction tool and other items from a literature search.

Quality assessment

We used the JBI critical appraisal checklist for systematic reviews and research syntheses[27] (Appendix S2) to assess the quality of included systematic reviews. We assessed the overall quality score of the included reviews using eleven items (Appendix S3), including the clarity of research question, inclusion criteria, search strategy, critical appraisal of individual studies and ways to minimise error and publication bias. Responses were 'yes', 'no', 'unclear'or 'not applicable'; a score of 1 was given for a 'yes' response while 0 was given for a 'no' response. The overall quality score was sum of score for each item.

Data synthesis

Because of the diverse types of systematic reviews selected, we present the findings in narrative form only with summary tables to aid in data presentation, where appropriate. We defined 'overlapping studies' for primary studies reviewed in more than one of the included systematic reviews.

Results

Identification of relevant systematic reviews

A flow diagram of the study selection process appears below (Fig. 1). Our search strategy identified 9976 records after 3585 duplicates were removed. Of these, 9932 records were excluded after the first screening, leaving 44 full-text articles for the second screening. After further assessment, sixteen articles[15,28–42] met our eligibility criteria for inclusion and narrative synthesis. We summarised the reasons for excluding the twenty-eight full-text articles below (Fig. 1) and in detail in supporting information (Appendix S4). The reasons included not meeting the inclusion criteria such as different exposure, not a systematic review or, missing age. The review of the reference lists added no further eligible articles. The overlapping studies ranged from one to eight in thirteen systematic reviews (Appendix S5)[15,28–30,32,33,36–39,41–43].

Characteristics of included systematic reviews

The characteristics of the review papers included are presented below (Table 2). In total, there were sixteen systematic reviews published between 2001 and 2019. They reviewed a total of 201 studies published between 1975 and 2015, of which 143 were unique while 58 were duplicates. The studies were conducted in Europe 85 (42·3 %), North America 61 (30·3 %), Asia 21 (10·4 %), Middle East 14 (7·0 %), South America 10 (5·0 %), Africa 6 (3·0 %) and Oceania 4 (2·0 %) in study participants aged 18 years and beyond. The number of individual studies who met the eligibility criteria ranged from 1[40] to 32[42], and sample sizes ranged from 11 040[31] to 946 977[32]. Six reviews assessed the relationship between adherence to MD or Mediterranean diet score (MDS) and overweight/obesity outcomes[15,29,30,32,35,36]. Of these, five reported obesity[15,29,30,32,35], four reported abdominal obesity[29,30,32,35] and one reported WC[36]. Four reviews focused on different diet quality measures and overweight/obesity outcomes[28,39,41,42]. Of these, three reported overweight/obesity outcomes[39,41,42] and two reported abdominal obesity[39,42]. Two reviews assessed if fruit and vegetable (FV) consumption was associated with risk of obesity or weight gain[34,40]; they reported effect estimates of obesity or weight gain. Five reviews assessed other DP and obesity or weight gain[29,31,33,37,38]. They reported outcomes such as BMI, obesity, abdominal obesity or WC[29,31,33,37,38]. As presented in Table 2, the overall quality score ranged from 4 to 10. The most frequent quality items lacking in the systematic reviews were for item 6: critical appraisal done in duplicate (*n* 14); item 5: appropriateness of criteria for critical appraisal (*n* 11); and item 7: methods to minimise errors in data extraction (*n* 9) (Appendix S3).

Findings of systematic reviews

We summarised the findings of all systematic reviews included in our umbrella review (Table 3). The findings are presented first by DP and then by study design.

Mediterranean diet pattern

Six out of sixteen systematic reviews included eleven cohort and nineteen cross-sectional studies that reported associations between the MD and overweight/obesity-related outcomes or weight gain (Table 3)[15,29,30,32,35,36]. The reviewers generally concluded that the MD was associated with a decreased risk of overweight/obesity outcomes.

Cohort studies

Out of the eleven cohort studies, two reported a decreased incidence of obesity (OR ranging from 0·53 to 0·73) associated with adherence to the MD or higher MDS. One out of the six reviews reported a lower risk of weight gain in two cohort studies with higher MDS ($\beta = -20{\cdot}16$ kg and

Table 2 Characteristics of included reviews

First author, year	Location: countries or group of countries	Electronic database, search time frame	Number of studies	Types of studies included	Range (years) of included studies	Publication bias	Source of funding	Sample characteristics	Exposure	Dietary assessment method	Comparator	Outcome (measure)	Follow-up period	Quality score	Conclusions
Aljadani, 2013	Spain, USA, Denmark, France, Germany, Greece, Italy, the Netherlands, Norway, Sweden and UK	MEDLINE, CINAHL, EMBASE and Scopus Date: From 1970 to March 2011	13 out of 37	Cohort	2002 to 2010	Not reported	Haya Aljadani is supported by the King Abdul-Aziz University and Ministry of Higher Education, Kingdom of Saudi Arabia	515 492, aged ≥ 18 years, general population (*n* 515 492), sex distribution: females only 23·08 % and both 76·92 %	Dietary intake high score: (1) DQI (2) Factor analysis (3) Cluster analysis	FFQ, 24-h recall, diet history, and estimated record	Dietary intake low score: (1) DQI (2) Factor analysis (3) Cluster analysis	Changes in body weight, weight gain, obesity (not defined), overweight (not defined), BMI and WC	28 months to 12 years	10	Lower weight gain was associated with more frequent consumption of a variety of foods high in nutrients and lower in energy density, such as vegetables, fruit, whole grains and lower amounts of energy-dense foods such as sweetened desserts, and red meat. Consuming nutritionally poorer diets was associated with overweight/obese
Asghari, 2017	North America, Iran, Australia, France, Canada, Spain, Brazil, Guatemala, Sri Lanka and Denmark	MEDLINE and EMBASE Date: From January 1990 to January 2016	32 out of 34	Cross-sectional (*n* 371 252)* Cohort (*n* 21 769)	2000 to 2014	Not reported	Supported by the Research Institute for Endocrine Sciences, Shadid Beheshti University of Medical Sciences, Tehran, Iran	390 309, aged ≥ 18 years†, community-based (*n* 19 813), general population (*n* 87 335), nurses and health professionals (*n* 282 988), and post-menopausal (*n* 173), sex distribution: females only 9·38 % and both 90·63 %	Highest score of: (1) HEI (2) DQI (3) Variety score (4) DGAI (5) Dietary Guideline Index (6) Other dietary indices	FFQ, 24-h recall, and diet history	Lowest score of: (1) HEI (2) DQI (3) Variety score (4) DGAI (5) Dietary Guideline Index (6) Other dietary indices	Overweight (BMI), obesity (BMI), overweight and/or obesity (BMI), % BF, and abdominal obesity (WC)	18 months to 20 years	7	HEI, DGAI, DGI and FNRS had inverse association, DQI had conflicting associations based on sex and design and, and variety scores mostly had positive associations with obesity
Buckland, 2008	Italy, Spain, Cyprus, Greece, Germany, Canada, USA and Hong Kong	MEDLINE Date: Up to July 2007	10 out of 21	Cross-sectional (*n* 34 656) Cohort (*n* 35 156)	2000 to 2007	Not reported	Supported by Spanish Ministry of Health	69 812, aged 18–100 years, university graduates (*n* 6319), nurses (*n* 660), general population (*n* 56 214), patients or individuals with risk factors (*n* 6619), sex distribution: females only 10 % and both 90 %	High MD adherence	24-h recall and diet record‡	Low MD adherence	Overweight/obesity (not defined), obesity (not defined) and BMI	2·4 to 9 years	5	Adherence to the MD was inversely associated with obesity

Table 2 *Continued*

First author, year	Location: countries or group of countries	Electronic database, search time frame	Number of studies	Types of studies included	Range (years) of included studies	Publication bias	Source of funding	Sample characteristics	Exposure	Dietary assessment method	Comparator	Outcome (measure)	Follow-up period	Quality score	Conclusions
Choi, 2019	Korea, Italy, Spain, Cyprus, Morocco, Greece, Iran, China and Brazil	MEDLINE and EMBASE Date: 23 November to 27 December 2018	20 out of 27	Cross-sectional (*n* 76 705) Cohort (*n* 30 137)	2004 to 2015	Not reported	Not reported	106 842, aged ≥ 18§ years, community-based (*n* 57 639), general population (*n* 39 680), and with chronic diseases (*n* 3204), sex distribution: males only 5 %, females only 15 %, and both 80 %	(1) Highest score category Korean diet pattern (2) Highest score category MDP	Not reported	(1) Lowest score category of Korean diet pattern (2) Lowest score category of MDP	Obesity (BMI)‖ and abdominal obesity (WC)	Not reported	5	Most studies reported no significant association between the KDP and obesity. There was inverse association between the MDP and obesity
Garcia-Fernandez, 2014	Spain, European countries, Greece, Canada and Cyprus	PubMed, MEDLINE, and National Library of Medicine Date: Up to September 2013	9 out of 37	Cross-sectional (*n* 528 018) Cohort (*n* 412 006)	2004 to 2010	Not reported	Not reported	940 024, aged 18–100 years†, sex distribution: 100 % both	High Mediterranean diet score	Not reported	Low Mediterranean diet score	Body weight, BMI, weight gain, overweight, obesity and abdominal obesity	2–8 years	5	Majority of the included studies showed strong inverse association between MD and obesity
Green, 2016	North, South, East, and West regions of India	EMBASE, EThoS, Global Health, IndMED, MEDLINE, PubMed, Scopus, and ISS Web of Science databases; other sources Google Scholar, FAO, the World Bank and the International Food Policy Research Institute Date: Up to 10 July 2015	3 out of 8	Cross-sectional	2011 to 2015	Not reported	Supported by the Wellcome Trust Our Planet, Our Health programme (103 932)	11 040 adults, sex distribution: females only 33·3 % and both 66·7 %	Models consisting different DP: (1) Model 2 (DP-1 fruit, dairy products,and snacks) (2) Model 3 (DP-2 sweet and snack) (3) Model 4 (DP-2 snacks and meat) (4) Model 5 (DP-2 butter, oil and ghee) (5) Model 8 (DP-3 red meat, poultry, fish and eggs)	FFQ and 24-h recall	Models consisting of different DP (1) Model (2) (DP-2 vegetable and pulses) (2) Model 3 (DP-1 pulses and rice) (3) Model 4 (DP-1 fruit and vegetable) (4) Model 5 (DP-1 vegetable, sweet, fruit, pulses, nuts, poultry and eggs) and (DP-3 red meat, dairy product and cereals) (5) Model 8 (DP-1 rice and nuts) and (DP-2 other cereals,	BMI, abdominal adiposity (not defined) and WC	Not applicable	7	Association was limited, but patterns characterised by sweets, savoury snacks and meat were associated with obesity

Table 2 *Continued*

First author, year	Location: countries or group of countries	Electronic database, search time frame	Number of studies	Types of studies included	Range (years) of included studies	Publication bias	Source of funding	Sample characteristics	Exposure	Dietary assessment method	Comparator	Outcome (measure)	Follow-up period	Quality score	Conclusions
											vegetable, fruit, dairy products, snacks and sweets)				
Grosso, 2014	Greece, Spain, Italy, France, UK and China	PubMed Date: From 2001 to August 2010	16 out of 58	Cross-sectional (*n* 407 294) Cohort (*n* 539 683)	2001 to 2010	Not reported	Not reported	946 977, aged 18–89 years, sex distribution: both 100 %	Adherence to or high Mediterranean diet score	FFQ, 24-h recall, and Mediterranean diet score	Non-adherence to or low Mediterranean diet score	Obesity (not defined), overweight (not defined), BMI, WC, WHR, change in weight and central obesity (not defined)	2·4–9 years	4	Several of included studies found an inverse relation between MD and BMI
Hsiao, 2011	USA, Europe, England, Scotland and Greece	PubMed Date: Up to November 2010	10	Cross-sectional	1992 to 2010	Not reported	Funded in part by USDA #1950–51 530–010–02G	116 627, aged ≥ 59 years, community-based (*n* 150), general population (*n* 116 477), sex distribution: males only 10 %, and both 90 %	Food intake patterns (1) Priori (2) Principal component analysis (3) Cluster analysis	FFQ, 24-h recall, and diet history	Food intake patterns (1) Priori (2) Principal component analysis (3) Cluster analysis	BMI, WC, WHR, obesity (not defined)¶, and central obesity (not defined)¶	NA	5	HDI and modified DQI-R had an inverse association with obesity; low-nutrient-dense patterns were inversely associated with central obesity and; no consistent relationship between food intake patterns and BMI or WC in older adults was observed
Hutfless, 2013	USA, Spain, Germany and Canada	MEDLINE, EMBASE, the Cochrane Central Register of Controlled Trials, CINAHL, PsycINFO and ClinicalTrials.gov Date: Up to June 2012	4 out of 22	Cross-sectional (*n* 5974) Cohort (*n* 317 464)	2005 to 2011	Not reported	Agency for Healthcare Research and Quality (AHRQ)	323 438, aged (mean) 37·5 to 52·2 years, general population (*n* 33 522), health professional (*n* 289 916), sex distribution: both 100 %	High-fibre/low-fat DP, healthy eating pattern, high fruit and vegetable consumption	Not reported	Low fruit and vegetable consumption	Weight gain	Not reported	10	Eating more fruits and vegetables may prevent weight gain.

Table 2 *Continued*

First author, year	Location: countries or group of countries	Electronic database, search time frame	Number of studies	Types of studies included	Range (years) of included studies	Publication bias	Source of funding	Sample characteristics	Exposure	Dietary assessment method	Comparator	Outcome (measure)	Follow-up period	Quality score	Conclusions
Kastorini, 2011	Spain, Italy, USA and Europe	PubMed, EMBASE, Scopus, and the Cochrane Central Register of Controlled Trials databases Date: Up to 30 April 2010	4 out of 15	Cross-sectional (*n* 499 196) Cohort (*n* 2563)	2006 to 2009	Not reported	Not reported	501 759, aged 20–90 years, without CVD risk factor (*n* 2563), diabetic (*n* 1888), and general population (*n* 497 308), sex distribution: females only 25 % and both 75 %	(1) High Mediterranean diet score (2) High Mediterranean diet scale	Not reported	(1) Low Mediterranean diet score (2) Low Mediterranean diet scale	WC	Not reported	10	Not all studies show a protective effect of the MD on obesity, but evidence suggests a possible beneficial role of the MDP
Kastorini, 2010	USA, Cyprus, Canada and Europe	PubMed, Scopus and EMBASE Date: Up to December 2009	12 out of 35	Cross-sectional (*n* 541 313) Cohort (*n* 34 146)	2004 to 2009	Not reported	Not reported	575 459, aged > 18 years, community-based (*n* 10 540), general population (*n* 561 025), nurses (*n* 690), and with risk for CVD (*n* 3204), sex distribution: not reported 16·67 % and both 83·33 %	(1) High Mediterranean diet score (2) High adherence to MD	Not reported	(1) Low Mediterranean diet score (2) Low adherence to MD	Obesity (not defined), central obesity (not defined), BMI and WHR	2 to 3 years	5	Greater adherence to the MDP was associated with favourable effects on the WC
Ledoux, 2011	Spain, USA and Denmark	PsychInfo and PubMed Date: From 1980 to January 2009	1 out of 23	Cohort	2004	Not reported	Supported by federal funds from the USDA/ARS under Cooperative Agreement 58–6250–6001	74 063, female nurses	High fruit and vegetable consumption	FFQ	Low fruit and vegetable consumption	Obesity (not defined) and weight gain	12 years	7	Combined high fruit and vegetable consumption was associated with less or slower weight gain over lengthy time intervals
Rezagholizadeh, 2017	Iran, Canada, Mexico, Germany, Korea, Lebanon, USA, Poland, Thailand and Brazil	MEDLINE, EMBASE and Google Scholar Date: Up to December 2015	13	Cross-sectional (*n* 26 974) Case–control (*n* 174)	2007 to 2015	Egger and Begg tests ($P=$ 0·068 and $P=$ 0·048) for healthy DP, and ($P=$ 0·56 and $P=$ 0·691) for unhealthy DP	No funding	27 148, age 30–55 years, sex distribution: not reported**	(1) Highest score category healthy DP (2) Highest score category unhealthy DP	FFQ and 24-h recall	(1) Lowest score category of healthy DP (2) Lowest score category of unhealthy DP	Central obesity (not defined)	Not applicable	10	Healthy DP are inversely associated with central obesity

Table 2 *Continued*

First author, year	Location: countries or group of countries	Electronic database, search time frame	Number of studies	Types of studies included	Range (years) of included studies	Publication bias	Source of funding	Sample characteristics	Exposure	Dietary assessment method	Comparator	Outcome (measure)	Follow-up period	Quality score	Conclusions
Salehi, 2016	South Africa, Uganda, Nigeria, Iran, Burkina Faso, Sri Lanka, China, Taiwan, Brazil, Bolivia, Mexico and USA	PubMed, ISI Web of Science, Scopus and Google Scholar Date: Up to December 2013	14 out of 16	Cross-sectional	2005 to 2013	Egger and Begg tests (*P* = 0·850 and *P* = 1·0) for odds of overweight/obesity, and (P = 0·819 and P = 0·835) for mean difference in BMI	Not reported	27 179, *n* 33 93††, age ≥ 18 years‡‡, sex distribution: females only 35·71 % and both 64·29 %	High Diet Diversity Score	FFQ, Food Diversity Score Kyoto, 24-h recall, and diet record	Low Diet Diversity Score	Overweight/obesity (BMI) and BMI	Not applicable	9	Few studies reported positive, while majority showed inverse or no association between DDS and BMI or obesity
Togo, 2001	USA, Switzerland, Canada, Italy, the Netherlands, UK, Belgium, Denmark, France, Portugal, Spain and Poland	MEDLINE Date: Up to February 2001	21 out of 30	Case–control (*n* 8804) Cross-sectional (*n* 263 636)	1975 to 2001	Not reported	Supported by the University of Copenhagen, DK (no. 301–116–5 = 99); the establishment of the Research Unit for Dietary Studies was financed by the FREJA programme from the Danish Medical Research Council (no. 9 801 037)	272 440, aged ≥ 18, community-based (*n* 7713), general population (*n* 113 492), health professional (*n* 151 235), sex distribution: males only 23·81 %, females only 14·29 %, and both 61·9 %	Food intake pattern (1) Diet index (2) High factor score (3) Cluster analysis	FFQ, 24-h recall, diet record and diet history	Food intake pattern (1) Diet index (2) Low factor analysis score (3) Cluster analysis	Obesity (BMI) and BMI	NA	5	No consistent associations could be identified between food intake patterns and BMI or obesity; one study observed a high-fat/sugar dairy factor associated with lower BMI while a 'Western' factor (with many high-fat foods) associated with higher BMI

Table 2 *Continued*

First author, year	Location: countries or group of countries	Electronic database, search time frame	Number of studies	Types of studies included	Range (years) of included studies	Publication bias	Source of funding	Sample characteristics	Exposure	Dietary assessment method	Comparator	Outcome (measure)	Follow-up period	Quality score	Conclusions
Vadiveloo, 2013	Iran, Australia, China, Guatemala, USA, Brazil, Mexico, Canada and Hong Kong	MEDLINE and Web of Science Date: From January 1999 to June 2012	19 out of 26	Cross-sectional (*n* 47 817) Cohort (*n* 101 896)	2002 to 2011	Not reported	Not reported	123 971, aged ≥ 18 years‡‡, community-based (*n* 5297), general population (*n* 17 788), health professionals (*n* 100 886), households (*n* 3393), sex distribution: females only 5·3 % and both 94·7 %	High: (1) Overall diet variety (2) Diet variety in recommended foods (3) Diet variety in non-recommended foods	FFQ, 24-h recall, an open list of foods including amount, and diet variety questionnaire	Low: (1) Overall diet variety (2) Diet variety in recommended foods (3) Diet variety in non-recommended foods	BMI, abdominal adiposity, overweight, overweight/obesity, WC, WHR and % body fat§§	8 to 12 years	8	Dietary variety within recommended and low-energy foods alone do not increase the odds of overweight and obesity; greater variety within less healthful, energy-dense foods increases the odds of overweight and obesity and; the association between total dietary variety and adiposity is mixed and accurate evaluation of this association requires a consistent and theoretically valid measurement tool

DQI, Diet Quality Index; WC, waist circumference; WHR, waist to hip ratio; BF, body fat; HEI, Healthy Eating Index; DGAI, Dietary Guidelines for Americans Index; DGI, Dietary Guideline Index; FNRS, Framingham nutritional risk score; MD, Mediterranean diet; KDP, Korean dietary pattern; MDP, Mediterranean diet pattern; DP,dietary pattern; NA, not applicable; HDI, Healthy Diet Indicator; DQI-R, Diet Quality Index-International; DDS, Dietary Diversity Score; USDA, United States Department of Agriculture.

*There was double counting of study participants because two studies had both cross-sectional and cohort designs.

†One study had only a population of ≥ 65 years.

‡Only two studies reported their diet assessment method.

§Three studies had only participant who are ≥ 55 years of age.

||Different BMI cut-offs were used to define obesity.

¶A cut-off of BMI > 30 kg/m^2 for obesity and WC of > 102 cm in men and > 88 cm in women for abdominal obesity was used for one study.

**Sex distribution was reported for both pattern; healthy DP four studies on women and twelve studies on both; unhealthy DP five studies on women and eighteen studies on both.

††Primary sampling units were households, and analysis is based on that.

‡‡Two studies included only participants who are above 60 years of age.

§§WHO cut-offs were used to define obesity.

Table 3 Summary of findings

Author, year	Types of DP	Summary of findings by study designs
Aljadani, 2013		Cohort studies (*n* 13)
	DQI – highest *v.* lowest quintile	The mean ± SD of weight gain was lower 3·3 ± 17·4 lb *v.* 8·0 ± 13·0 lb in females and 2·7 ± 10·1 lb *v.* 5·1 ± 13·3 lb in males
	DQI – highest MDS	1 study associated with decreased incidence of 'obesity' among overweight subjects at baseline (OR = 0·69, 95 % CI 0·54, 0·89) in females and (OR = 0·68, 95 % CI 0·53, 0·89) in males
	DQI – MDS	1 study associated with decreased mean weight gain –0·077 (–0·131, –0·022), –0·102 (–0·194, –0·009), –0·061 (–0·116, –0·006) (by three MDS methods)
	DQI – MDS	1 study reported no significant association with obesity
	DQI – MD adherence	1 study reported no significant association with overweight
	DQI – MDS	1 study reported no significant association with weight gain in females
	DQI – MDS	2 studies reported no significant association with weight gain
	FA – highest *v.* lowest quintile of healthy and fibre-rich pattern	1 study associated with lower annual change in BMI ($\beta = -0{\cdot}51$, 95 % CI: –0·82, –0·20) in females and no significant association in males
	FA – highest *v.* lowest quintile of healthy and fibre-rich pattern	1 study associated with lower annual change in WC ($\beta = -1{\cdot}06$ cm, 95 % CI –1·88, –0·24)
	FA – higher healthy pattern score	1 study reported decrease in BMI in normal-weight and overweight females at baseline (–0·05 kg/m^2 and –0·11 kg/m^2, respectively).
	FA – (1) green factor very similar to MD with a high intake of fruit, vegetables, whole grains, fish and cheese; (2) sweet factor (cake, biscuits, baked goods, candy, chocolate, soft drink ice cream, jam and honey; and (3) **traditional factor (meat, pate, lunch meats, potatoes, white bread, sausage, butter, lard, margarine and eggs) contain more meat, foods with higher energy density and less vegetables**	1 study associated with increase in weight ($\beta = -0{\cdot}40$, 95 % CI: 0·054, –0·13) in males and no significant association in females
	FA – (1) green factor very similar to MD with a high intake of fruit, vegetables, whole grains, fish and cheese; (2) **Sweet factor (cake, biscuits, baked goods, candy, chocolate, soft drink ice cream, jam and honey**; and (3) traditional factor (meat, pate, lunch meats, potatoes, white bread, sausage, butter, lard, margarine and eggs) contain more meat, foods with higher energy density and less vegetables	1 study associated with 'decreased' change in BMI in females and no significant association in males
	FA – high *v.* low Western pattern score (rich in red and processed meats, refined grains, sweets and desserts, and potatoes)	1 study associated with increased weight gain 5·62 kg *v.* 4·90 kg in females
	FA – food factor scores	1 study reported no significant association with 'obesity'
	FA – food factor scores	1 study reported no significant association with change in WC
	CA – (1) healthy pattern: higher in fruit, reduced-fat dairy and high-fibre cereal. Higher in EI from CHO and fibre and subject in these patterns were more likely to use vitamin supplements (reference group); (2) white bread pattern: white bread or refined grains, high-fat dairy, meat, and high-fat baked goods; (3) alcohol pattern: higher in alcohol, meat, high-fat dairy and white bread or refined grains; (4) sweets pattern: higher in high-fat baked goods, high-fat dairy, white bread or refined grains and meat; and (5) **meat and potatoes pattern: higher in meat, high-fat dairy and fruit**	1 study associated with greater annual increase in BMI ($\beta = 0{\cdot}26$)
	CA – (1) healthy pattern: higher in fruit, reduced-fat dairy and high-fibre cereal. Higher in EI from CHO and fibre and subject in these patterns were more likely to use vitamin supplements (reference group); (2) **white bread pattern: white bread or refined grains, high-fat dairy, meat, high-fat baked goods;** (3) alcohol pattern: higher in alcohol, meat, high-fat dairy and white bread or refined grains; (4) sweets pattern: higher in high-fat baked goods, high-fat dairy, white bread or refined grains and meat; (5) meat and potatoes pattern: higher in meat, high-fat dairy and fruit	1 study associated with greater WC among subjects in the white bread pattern group ($\beta = 0{\cdot}90$ cm)

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Table 3 *Continued*

Author, year	Types of DP	Summary of findings by study designs
	CA – (1) heart healthy: a lower-fat, nutritionally varied diet higher in vegetables, fruits, low-fat milk and other low-fat, fibre-rich foods. Most closely matched the Food Guide Pyramid's DP (reference group); (2) light eating: consumed more diet beverages and firm vegetables fats, vegetables and other low-fat foods; (3) wine and moderate eating: higher consumption of wine and cholesterol-rich foods, diet beverages and firm vegetables fats; (4) high fat: higher amounts of animal and vegetable fats, sweets and desserts, and meats and mixed dishes; and (5) **empty calorie: diet that was rich in sweets and fats with fewer servings of nutrient-dense fruits, vegetables, and lean food choices, and also drink more sweetened beverages**	1 study associated with increased incidence of 'overweight' (RR = 1·4, 95 % CI 0·9, 2·2)
	CA – (1) healthy pattern: higher in fruit, reduced-fat dairy and high-fibre cereal. Higher in EI from CHO and fibre and subject in these patterns were more likely to use vitamin supplements (reference group); (2) white bread pattern: white bread or refined grains, high-fat dairy, meat and high-fat baked goods; (3) alcohol pattern: higher in alcohol, meat, high-fat dairy and white bread or refined grains; (4) sweets pattern: higher in high-fat baked goods, high-fat dairy, white bread or refined grains and meat; and (5) **meat and potatoes pattern: higher in meat, high-fat dairy and fruit**	1 study reported no significant association with WC
Asghari, 2017		Cohort studies (*n* 1)
	HEI	1 study inversely associated with WC '(approximately 3 to 4 cm)'
	HEI	1 study inversely associated with lower BMI '(approximately 1 unit)'
		Cross-sectional studies (*n* 14)
	HEI	4 studies associated with 'lower' BMI
	HEI	2 studies associated with lower BMI '(β ranging from –0·095 to –1·3)'
	HEI	2 studies associated with decreased OR for prevalence of abdominal obesity (OR ranging from 0·65 to 0·99)
	HEI	1 study associated with 'lower' prevalence of overweight/obesity in males and no significant association in females
	HEI	1 study associated with 'approximately lower' OR for prevalence of overweight/obesity (OR = 0·65)
	HEI	1 study associated with decreased OR for prevalence of obesity (OR = 0·6)
	Lower HEI	1 study associated with increased OR for prevalence of obesity (OR = 1·9) in males and (OR = 1·7) in females
	Lower HEI	1 study associated with increased OR for prevalence of overweight (OR = 1·5) in males and no significant association in females
	HEI	1 study reported no significant association with WHR
	HEI	1 study reported no significant association with % BF
	HEI	2 studies reported no significant association with WC
	HEI	3 studies reported no significant association with BMI
		Cohort studies (*n* 5)
	A 10-point increase DQI	1 study associated with decreased risk of 10-kg weight gain (OR = 0·9) in Whites (for normal-weight group)
	Higher DQI adherence	1 study associated with decreased risk of weight gain (3·3 lb *v.* 8 lb) in females and (2·7 lb *v.* 5·1 lb) in males
	Higher DQI	1 study associated with decreased risk of 'weight change' (OR ranging from 0·6 to 0·7) in males and no significant association in females
	Higher DQI adherence	1 study associated with increased risk of obesity (OR = 1·32) in males and no significant association in females
	Higher DQI	1 study associated with lower WC '(3·2 cm reduction)'
	DQI	2 studies reported no significant association with BMI
	DQI	1 study reported no significant association with WC
		Cross-sectional studies (*n* 5)
	DQI	1 study associated with 'lower' BMI

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Table 3 *Continued*

Author, year	Types of DP	Summary of findings by study designs
	Higher DQI	1 study associated with 'lower' BMI in females and no significant association in males
	Higher DQI	1 study associated with lower BMI ($\beta = -0.053$)
	Higher DQI	1 study associated with 'higher' BMI
	Higher DQI	1 study associated with 'higher' WC
	Higher DQI	1 study associated with 'lower prevalence of overweight' in females and no significant association in males
	DQI	1 study reported no significant association with BMI
	DQI	1 study reported no significant association with WC
		Cross-sectional studies (*n* 4)
	Variety scores – highest *v.* lowest quartile DDS	1 study associated with decreased OR for prevalence of obesity (OR = 0·2)
	Variety scores – highest *v.* lowest quartile DDS	1 study associated with decreased OR for prevalence of abdominal obesity (OR = 0·2)
	Variety scores – higher FVS	1 study associated with 'increased' prevalence of overweight
	Variety scores – higher FVS	1 study associated with 'increased' prevalence of obesity
	Variety scores – DDS	1 study associated with increased OR for prevalence of obesity (OR = 1·39)
	Variety scores – higher FVS	1 study associated with 'increased' prevalence of abdominal obesity
	Variety scores – DDS	1 study reported no significant association with WHR
	Variety scores – DDS	1 study reported no significant association with WC
	Variety scores – FVS	1 study reported no significant association with WC
	Variety scores – FVS	1 study reported no significant association with BMI
		Cohort studies (*n* 1)
	Higher DGAI	1 study associated with decreased risk of 'weight change' (OR = 0·6) in males and no significant association in females
		Cross-sectional studies (*n* 4)
	Higher DGAI	2 studies associated with lower 'in approximately 2 units' of BMI
	Higher DGAI	2 studies associated with 6 cm lower WC
	Higher DGAI	1 study associated with decreased OR for prevalence of 'enlarged WC' (OR = 0·5)
	DGAI	1 study reported no significant association with WC
	DGAI	1 study reported no significant association with BMI
		Cohort studies (*n* 1)
	Highest *v.* lowest quartile of DGI	1 study associated with less likely to gain BMI (0·05 *v.* 0·11 kg/m^2/year) in males and no significant association in females
	Third quartile *v.* lowest quartile of DGI	1 study associated with less likely to gain WC (0·04 *v.* 0·26 cm/year) in males and no significant association in females
		Cross-sectional studies (*n* 1)
	DGI	1 study associated with decreased OR for prevalence of abdominal obesity (OR = 0·7) in males and no significant association in females
		Cohort studies (*n* 2)
	Other dietary indices – PNNS-GS	1 study associated with 'weight change' (OR ranging from 0·6 to 0·7) in males and no significant association with females
	Other dietary indices – ARFS	1 study reported no significant association with incidence of overweight
	Other dietary indices – ARFS	1 study reported no significant association with incidence of obesity
		Cross-sectional studies (*n* 6)
	Other dietary indices – Higher RFS	1 study associated with a 'lower' BMI
	Other dietary indices – RFS	1 study associated with 0·3 unit increase in BMI in females and 0·2 unit decrease in BMI in males
	Other dietary indices – Higher EDI	1 study associated with decreased OR for prevalence of obesity (OR = 0·4)
	Other dietary indices – DQS	1 study reported no significant association with WC
	Other dietary indices – NRFS	1 study reported no significant association with BMI
	Other dietary indices – DQS	1 study reported no significant association with BMI
	Other dietary indices – NRFS	1 study reported no significant association with WC
	Other dietary indices – RFS	1 study reported no significant association with BMI

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Table 3 *Continued*

Author, year	Types of DP	Summary of findings by study designs
Buckland, 2008	MD	Cohort studies (*n* 3)
	High adherence	1 study associated with decreased incidence of 'obesity' (OR = 0·73, 95 % CI 0·57, 0·93) in females and (OR = 0·71, 95 % CI 0·55, 0·93) in males
	MDS	2 studies reported no significant association with 'overweight'
	MDP	1 study reported no significant association with 'overweight/obesity'
	MDP	1 study reported no significant association with BMI
		Cross-sectional studies (*n* 7)
	High adherence	2 studies associated with decreased OR for prevalence of 'obesity' (OR ranging from 0·61 to 0·88)
	High adherence	1 study associated with decreased OR for prevalence of 'overweight/obesity' (OR = 0·49, CI 0·42, 0·56)
	High adherence	2 studies associated with lower BMI (β ranging from –4 to –0·186 kg/m^2)
	High adherence	1 study associated with lower BMI (β = –0·21, CI –0·10, –0·32) in males and no significant association in females
	High adherence	1 study associated with lower BMI (β = –0·43 kg/m^2) in males and (β = –0·68 kg/m^2) in females
	MDS	1 study reported no significant association with BMI
	MDS	1 study reported no significant association with BMI in females
Choi, 2019		Cross-sectional studies (*n* 7)
	Highest *v.* lowest tertile of KDP	1 study associated with increased OR for prevalence of obesity (OR = 1·19, 95 % CI 1·06, 1·33)
	Highest *v.* lowest tertile of KDP	2 studies associated with increased OR for prevalence of abdominal obesity (OR ranging from 1·07 to 1·27) in females
	Highest *v.* lowest tertile of KDP	1 study associated with decreased OR for prevalence of abdominal obesity (OR = 0·76, 95 % CI 0·59, 0·98)
	KDP	1 study reported no significant association with abdominal obesity
	KDP	1 study reported no significant association with abdominal obesity in males
	KDP	2 studies reported no significant association with obesity in females
		Cohort studies (*n* 5)
	High *v.* low score of MDP	1 study associated with decreased incidence of obesity (OR = 0·68, 95 % CI 0·53, 0·89) in males and (OR = 0·69, 95 % CI 0·54, 0·89) in females
	High *v.* low score of MDP	1 study associated with decreased incidence of obesity (OR = 0·53, 95 % CI 0·32, 0·89)
	MDP	2 studies reported no significant association with overweight/obesity
	MDP	2 studies reported no significant association with overweight
		Cross-sectional studies (*n* 8)
	High MD adherence	1 study associated with decreased OR for prevalence of abdominal obesity (OR = 0·72, 95 % CI 0·56, 0·92)
	High *v.* low score of MDP	2 studies associated with decreased OR for prevalence of obesity (OR ranging from 0·35 to 0·81)
	High MD adherence	1 study associated with decreased OR for prevalence of obesity (OR = 0·61, 95 % CI 0·40, 0·92) in males and (OR = 0·61, 95 % CI 0·40, 0·93) in females
	Low MD adherence	1 study associated with increased OR for prevalence of obesity (OR = 1·56, 95 % CI 1·16, 2·11)
	High MD adherence	2 studies associated with decreased OR for prevalence of obesity (OR ranging from 0·49 to 0·88)
	High MD adherence	1 study associated with decreased OR for prevalence of overweight (OR = 0·33, 95 % CI 0·13, 0·83)
Green, 2016		Cross-sectional studies (*n* 3)
	Higher model 2 (DP-1 fruit, dairy products, snacks)	1 study associated with higher BMI, abdominal adiposity or WC
	Higher model 3 (DP-2 sweets, snacks)	1 study associated with higher BMI, abdominal adiposity or WC
	Higher model 4 (DP-3 snacks, meat)	1 study associated with higher BMI, abdominal adiposity or WC
	Higher model 5 (DP-2 butter, oil, ghee)	1 study associated with higher BMI, abdominal adiposity or WC
	Higher model 8 (DP-3 red meat, poultry, fish, eggs)	1 study associated with higher BMI, abdominal adiposity or WC

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Table 3 *Continued*

Author, year	Types of DP	Summary of findings by study designs
Garcia, 2014		Cohort studies (*n* 3)
	High MDS	1 study associated with a decreased risk of weight gain (β = –20·16 kg, 95 % CI 20·24, 20·07)
	High MDS	1 study associated with a decreased incidence of 'overweight/obesity' (OR = 0·9, 95 % CI 0·4, 0·18)
	High MDS	1 study associated with a decreased incidence of 'obesity' (OR = 0·73, 95 % CI 0·57, 0·93) in females and (OR = 0·71, 95 % CI 0·55, 0·93) in males in overweight subjects
	High MDS	1 study associated with a decreased risk of weight gain (OR = 0·76, 95 % CI 0·64, 0·90)
		Cross-sectional studies (*n* 6)
	High MDS	1 study associated with decreased OR for prevalence of 'obesity' (OR = 0·61)
	A 5-point increase in MDS	1 study associated with lower BMI (β = –0·43 kg/m^2) in males and (β = –0·68 kg/m^2) in females
	MD adherence	1 study reported no significant association with 'obesity'
	Higher MDS	1 study associated with lower BMI (β = –0·186)
	A 5-point increase in MDS	1 study associated with decreased OR for prevalence of 'obesity and overweight' (OR = 0·49, 95 % CI 0·42, 0·56)
	Higher MDS	1 study associated with lower BMI (β = –4 kg/m^2)
	A 10-point increase in MDS	1 study associated with decreased OR for prevalence of 'obesity' (OR = 0·88)
	Higher MDS	1 study associated with lower WC (β = –20·09, 95 % CI –20·14, –20·04) in males and (β = –20·06, 95 % CI –20·10, –20·01) in females
Grosso, 2014	MD	Cohort studies (*n* 7)
	High score or adherence	2 studies associated with 'lower' WC
	High adherence	1 study associated with change in weight (–0·16 kg, 95 % CI –0·24, –0·07)
	High adherence	1 study associated with decreased incidence of 'overweight or obesity' (OR = 0·9, 95 % CI 0·82, 0·96)
	High adherence	1 study associated with decreased incidence of 'obesity' (OR = 0·69, 95 % CI 0·54, 0·89) in females and (OR = 0·68, 95 % CI 0·53, 0·89) in males
	High adherence	1 study reported no significant association with 'weight loss' adjusting for confounding
	Adherence	2 studies reported no significant association with incidence of 'obesity'
	High adherence	2 studies reported no significant association with incidence of 'overweight'
		Cross-sectional studies (*n* 9)
	MD	1 study associated with 'lower' WC
	One unit increase in MDS	1 study associated with lower WC (β = –0·06, 95 % CI –0·10, –0·01) in females and (β = –0·09, 95 % CI –0·14, –0·04) in males
	High adherence	3 studies associated with decreased OR for prevalence of 'obesity' (OR ranging from 0·12 to 0·61)
	'Poor' MD	1 study associated with 'increased prevalence of obesity' in females and no significant association in males
	Highest *v.* lowest tertile MD	1 study associated with decreased OR for prevalence of 'central obesity' (OR = 0·41, 95 % CI 0·35, 0·47)
	MDS	1 study associated with lower WHR (*r* = –0·31)
	MDS	1 study associated with lower BMI (*r* = –0·4)
	MDS	1 study associated with 'lower' BMI
	Five-unit increase in MDS	1 study associated with 'change in the BMI' of (0·43) in males and (0·68) in females
	MD	3 studies reported no significant association with BMI
	MD	1 study reported no significant association with WHR
	MD adherence	1 study reported 'weak association with WHR' in females and no significant association in males
Hsiao, 2011		Cross-sectional studies (*n* 10)
	Lowest quality by HDI group	1 study associated with 'higher' WC
	Lowest quality by FS-MDS group	1 study associated with 'higher' WC
	High quality by HDI	1 study associated with 'lower' BMI
	FS-MDS	1 study reported no significant association with BMI
	CA – (1) sugar: sugar and sugar products, legumes, nuts, seeds; (2) fish and grain; (3) **meat, eggs and fat**; (4) milk and fruit: high intakes of vitamins and Ca; and (5) alcohol: lowest intakes of vitamins and Ca	1 study associated with 'higher' BMI

Table 3 *Continued*

Author, year	Types of DP	Summary of findings by study designs
	MDS / HDS	1 study reported no significant association with BMI 1 study associated with 'lower' BMI
	A 10-unit increase in MDS	1 study associated with decreased OR for prevalence of 'obesity' (OR = 0·88)
	Modified DQI-R	1 study associated with 'lower' BMI
	A 10-unit increase in the MDS	1 study associated with lower BMI ($\beta = -1{\cdot}2$ kg/m^2)
	MDS	1 study reported no significant association with obesity
	CA – (1) fruit, breakfast cereal: lowest energy contributions from added fats, meats and soft drinks; (2) starchy vegetables; (3) **rice: rice, added fats (cooking oil), beans, and poultry**; (4) milk:>20 % total energy from whole milk; and (5) sweets: baked sweets, bread, pasta, meat, potatoes, candy and sugars, dairy desserts, processed meat, eggs, and alcohol	1 study associated with 'higher' BMI
	CA – (1) fruit, breakfast cereal: lowest energy contributions from added fats, meats and soft drinks; (2) starchy vegetables; (3) **rice: rice, added fats (cooking oil), beans and poultry;** (4) milk:>20 % total energy from whole milk; and (5) sweets: baked sweets, bread, pasta, meat, potatoes, candy and sugars, dairy desserts, processed meat, eggs, and alcohol	1 study associated with 'higher' WC
	CA – (1) fruit, breakfast cereal: lowest energy contributions from added fats, meats and soft drinks; (2) starchy vegetables; (3) rice: rice, added fats (cooking oil), beans and poultry; (4) **milk:>20 % total energy from whole milk;** and (5) sweets: baked sweets, bread, pasta, meat, potatoes, candy and sugars, dairy desserts, processed meat, eggs, and alcohol	1 study associated with 'higher' BMI
	CA – (1) **low-nutrient-dense: higher intakes from the bread, cereal, rice, and pasta and the fats, oils, and sweets groups;** and (2) high-nutrient-dense: higher intakes from the vegetable; fruit; and milk, yogurt and cheese groups	1 study associated with 'higher' BMI
	CA – (1) low-nutrient-dense: higher intakes from the bread, cereal, rice, and pasta and the fats, oils, and sweets groups; and (2) **high-nutrient-dense: higher intakes from the vegetable; fruit; and milk, yogurt and cheese groups**	1 study associated with 'lower' WC
	CA – (1) **low-nutrient-dense: higher intakes from the bread, cereal, rice, and pasta and the fats, oils, and sweets groups**; and (2) high-nutrient-dense: higher intakes from the vegetable; fruit; and milk, yogurt and cheese groups	1 study reported no significant association with obesity
	CA – (1) **low-nutrient-dense: higher intakes from the bread, cereal, rice, and pasta and the fats, oils, and sweets groups**; and (2) high-nutrient-dense: higher intakes from the vegetable; fruit; and milk, yogurt and cheese groups	1 study associated with increased OR for prevalence of central obesity (OR = 2·33, 95 % CI 1·16, 4·69)
	PCA – (1) **vegetable-based**: vegetables, vegetable oils, fruits, pasta, rice and other grains, legumes PCA; and (2) sweet- and fat-dominated: cereals, cakes, condiments, sauces, margarine, sugar and confectionary, dairy products	1 study associated with 'higher' BMI
	PCA – (1) vegetable-based: vegetables, vegetable oils, fruits, pasta, rice and other grains, legumes PCA; and (2) **sweet- and fat-dominated: cereals, cakes, condiments, sauces, margarine, sugar and confectionary, dairy products**	1 study associated with 'lower' BMI
	PCA – (1) vegetable-based: vegetables, vegetable oils, fruits, pasta, rice and other grains, legumes PCA; and (2) **sweet- and fat-dominated: cereals, cakes, condiments, sauces, margarine, sugar and confectionary, dairy products**	1 study associated with 'lower' WHR
	PCA – (1) prudent: high intakes of fruit, vegetables, oily fish, wholemeal cereals; low intakes of processed foods and high-fat dairy (2) Traditional: high intakes of green, root, salad and other vegetables; red, processed and organ meat, fish and	1 study reported no significant association with BMI

Table 3 *Continued*

Author, year	Types of DP	Summary of findings by study designs
	puddings; low intakes of milky drinks, reduced fat spread and breakfast cereal	
	CA – (1) meat, snacks, fats and alcohol; (2) sweets and desserts; (3) refined grains; (4) breakfast cereal; (5) healthy foods: higher intakes of low-fat dairy products, fruit, whole grains, poultry, fish and vegetables; lower intake of red meat, sweets, added fats and high-energy drinks; and (6) high-fat dairy products	1 study reported no significant association with BMI
Hutfless, 2013		Cohort studies (*n* 2)
	Quintiles of high-fibre/low-fat food pattern score	1 study reported no significant association with weight gain
	Quintiles of fruits, vegetables, nuts, whole-fat dairy foods, low-fat dairy foods, potato chips, potatoes, whole grains, refined grains, 100 % fruit juice, sugar-sweetened beverages, diet soda, sweets and desserts, processed meats, unprocessed red meats, trans fat, and fried foods	1 study reported no significant association with weight gain
		Cross-sectional studies (*n* 2)
	More than 698 g/d *v.* less than 362 g/d of fruits and vegetables	1 study associated with decreased weight gain (OR = 0·26, 95 % CI 0·07, 0·97)
	FV consumption (5 servings/d threshold)	1 study reported no significant association with weight gain
Kastorini, 2011		Cohort studies (*n* 1)
	High *v.* low MD score category	1 study reported no significant mean difference in WC
		Cross-sectional studies (*n* 3)
	High *v.* low MD scale category	1 study reported significant mean difference in WC –5·30 (–8·15 to –2·45)
	High *v.* low MD scale category	1 study reported no significant mean difference in WC
	High *v.* low MD scale category	1 study reported significant mean difference in WC –0·80 (–0·93 to –0·67) in males and –1·60 (–1·70 to –1·50) in females
Kastorini, 2010		Cohort studies (*n* 2)
	MD scale	1 study reported no significant association with obesity
	High adherence to the MD	1 study associated with decreased incidence of 'obesity' in overweight subjects (OR = 0·68, 95 % CI 0·53, 0·89) in males and (OR = 0·69, 95 % CI 0·54, 0·89) in females
		Cross-sectional studies (*n* 10)
	Highest *v.* lowest tertile of MDS	1 study associated with decreased OR for prevalence of 'obesity' (OR = 0·49, 95 % CI 0·42, 0·56)
	Highest *v.* lowest tertile of MDS	1 study associated with decreased OR for prevalence of 'central obesity' (OR = 0·41, 95 % CI 0·35, 0·47)
	Highest *v.* lowest tertile of MDS	1 study associated with 'decreased prevalence of obesity' in overweight subjects
	High adherence to the MD	1 study associated with decreased OR for prevalence of 'obesity' (OR = 0·84, 95 % CI 0·73, 0·97)
	High adherence to the MD	1 study associated with decreased OR for prevalence of 'obesity' (OR = 0·61, 95 % CI 0·40, 0·92) in males and (OR = 0·61, 95 % CI 0·40, 0·93) in females
	Mediterranean score	1 study associated with 'lower' BMI
	Highest *v.* lowest category of modified MDS	1 study associated with 'lower' BMI
	Highest *v.* lowest category of modified MDS	1 study associated with lower WC (–0·09 cm, 95 % CI –0·14, –0·04) in males and (–0·06 cm, 95 % CI –0·10, –0·01) in females
	MD	4 studies reported no significant association with BMI
	MD	2 studies reported no significant association with obesity
	MD	2 studies reported no significant association with WHR
Ledoux, 2011		Cohort studies (*n* 1)
	Highest *v.* lowest quintile of median change in FV intake	1 study associated with decreased incidence of 'obesity' (OR = 0·76, 95 % CI 0·69, 0·86)
	Highest *v.* lowest quintile of median change in FV intake	1 study associated with decreased risk of weight gain >25 kg (OR = 0·72, 95 % CI 0·55, 0·93)
	Increased *v.* decreased FV intake	1 study associated with decreased weight gain (0·76 kg less in overweight subjects and 0·52 kg less in normal-weight subjects at baseline)
		Meta-analysis

Table 3 *Continued*

Author, year	Types of DP	Summary of findings by study designs
Rezagholizadeh, 2017		
	Healthy DP	High *v.* low healthy DP was associated with a decreased pooled OR (0·81, 95 % CI 0·66, 0·96) for central obesity
	Unhealthy DP	High *v.* low unhealthy DP was not associated with central obesity
Salehi, 2016		Cross-sectional studies (*n* 14)
	Higher DDS	3 studies associated with 'lower' BMI
	Higher DDS	4 studies associated with 'higher' BMI
	Higher DDS	1 study associated with 'lower' BMI in females and no significant association in males
	Higher DDS	1 study associated with 'increased' prevalence of overweight/obesity
	Higher DDS	1 study associated with 'decreased' prevalence of overweight/obesity
	Higher DDS	4 studies reported no significant association overweight/obesity
	Higher DDS	4 studies reported no significant association with BMI
Togo, 2001		Cross-sectional studies (*n* 7)
	DI – **Type A** (pasta/cereals/rice, starchy vegetables, bread, desserts, snack chips/crackers, soft drinks/lemonade, jams/jelly, table fats/salad dressings and gravy/sauces *v.* Type B (milk, meat/eggs/cheese, legumes, non-starchy vegetables, fruits and juices)	1 study associated with increased OR for prevalence of obesity (OR = 1·61) in males and (OR = 1·53) in females
	DI – higher DDS	2 studies associated with 'lower' BMI
	DI – higher HEI	2 studies associated with 'lower' BMI
	DI – RFS	1 study reported no significant association with BMI
	DI – DMGFV food combinations	1 study reported no significant association with BMI
		Case–control studies (*n* 1)
	DI – diet diversity	1 study reported no significant association with BMI
		Cross-sectional studies (*n* 5)
	FA – **healthful**; low culinary complexity (confectionery, butter, cookies); satiating (macaroni, sausage and white bread)	1 study associated with 'lower' BMI in males and no significant association in females
	FA – **prudent**; Western	1 study associated with 'lower' BMI in males
	FA – **healthful**; low culinary complexity (confectionery, butter, cookies); satiating (macaroni, sausage and white bread)	1 study associated with 'lower' BMI in males and no significant association in females
	FA – traditional; cosmopolitan; **convenience**; 'meat & two vegetables'	1 study associated with 'lower' BMI in females and no significant association in males
	FA – vegetables; junk foods; breakfast foods; hot meal foods; tea foods; 'bread & butter' and **bush foods**	1 study associated with 'increased' prevalence of obesity
	FA – prudent; **Western**	1 study associated with 'higher' BMI in males and no significant association in females
	FA – prudent; Western	1 study reported no significant association with BMI
		Case–control studies (*n* 1)
	FA – 'substituter'; Prudent; 'coffee & roll'; **high fat/sugar-dairy**; drinker; fruit juice; and Western	1 study associated with 'lower' BMI in males and no significant association in females
	FA – 'substituter'; Prudent; 'coffee & roll'; high fat/sugar-dairy; **drinker**; fruit juice; and Western	1 study associated with 'lower' BMI in females and no significant association in males
	FA – 'substituter'; Prudent; 'coffee & roll'; high fat/sugar-dairy; **drinker**; fruit juice; and Western	1 study associated with 'higher' BMI in males and no significant association in females
	FA – 'substituter'; Prudent; 'coffee & roll'; high fat/sugar-dairy; drinker; **fruit juice**; and Western	1 study associated with 'higher' BMI in males and no significant association in females
	FA – 'substituter'; Prudent; 'coffee & roll'; High fat/sugar-dairy; drinker; fruit juice; and **Western**	1 study associated with 'higher' BMI
		Cross-sectional studies (*n* 8)
	CA – **high alcohol/low nutrients**; meat/fish/cheese/olive oil; vegetables/starchy foods; seed oil/fruit/cake	1 study associated with 'lower' BMI in males
	CA – **high fat/high alcohol**; medium fat/low alcohol; high fat/low alcohol	1 study associated with 'higher' BMI
	CA – alcohol; milk/cereal; **Meat/potatoes**; bread/potatoes	1 study associated with 'higher' BMI
	CA – alcohol; milk/cereal; meat/potatoes; **bread/potatoes**	1 study associated with 'higher' BMI
	CA – **meat and cheese**; skim milk; pastry; meat; white bread; soft drinks	1 study associated with 'lower' BMI in males and no significant association in females
	CA – vegetarian/low meat/cereal/legume/fruit; red meat/potatoes/sweet foods/cakes/tea; **alcohol/nuts/low**	1 study associated with 'higher' BMI in males and no significant association in females

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Table 3 *Continued*

Author, year	Types of DP	Summary of findings by study designs
	cereal/meat/; fruit/vegetables/poultry/fish/MUFA/PUFA; low energy	
	CA – vegetarian/low meat/cereal/legume/fruit; red meat/ potatoes/sweet foods/cakes/tea; alcohol/nuts/low cereal/meat/; **fruit/vegetables/poultry/fish/MUFA/ PUFA**; low energy	1 study associated with 'higher' BMI
	CA – **low diversity vegetarian**; high diversity vegetarian; health conscious; monotonous low-quantity omnivores; conservative omnivores; traditional meat/chips/pudding; higher diversity traditional omnivores	1 study associated with 'lower' BMI in females
	CA – low diversity vegetarian; **high diversity vegetarian**; health conscious; monotonous low-quantity omnivores; conservative omnivores; traditional meat/ chips/ pudding; higher diversity traditional omnivores	1 study associated with 'lower' BMI in females
	CA – healthy; refined sugars; meat; alcohol and small eaters; lean green; gourmands; modest eaters (w); milk drinker	2 studies reported no significant association with BMI
Vadivello, 2013	Overall diet variety	Cross-sectional studies (*n* 12)
	High DDS	1 study associated with decreased OR for prevalence of abdominal obesity (OR = 0·21, 95 % CI 0·06, 0·98)
	High DDS	1 study associated with decreased OR for prevalence of overweight (OR = 0·22, 95 % CI 0·07, 0·80)
	High DDS	1 study associated with decreased OR for prevalence of obesity (OR = 0·21, 95 % CI 0·06, 0·96)
	DDS	1 study reported low DDS was associated with increased OR for prevalence of obesity (OR = 1·39, 95 % CI 1·01, 1·51)
	HEI score	1 study associated with decreased OR for prevalence of obesity (OR = 0·97, 95 % CI 0·944, 1·011) in females and no significant association in males
	Food variety	1 study associated with lower BMI (β = –0·18)
	High DDS	2 studies associated with 'higher' BMI
	High DDS	1 study associated with 'higher percentage' of obesity (23 %)
	DDS	1 study reported DDS was higher in obese (2·6 (SD 1·1)) than normal weight (1·9 SD (0·90)) in males only
	Food variety	1 study reported no significant association with overweight
	DDS	1 study reported no significant association with overweight
	DDS	1 study reported no significant association with BMI
	FVS	2 studies reported no significant association with BMI
	Food variety	1 study reported no significant difference in BMI
	DDS	2 studies reported no significant association with WC
	FVS	1 study reported no significant association with WC
	DDS	2 studies reported no significant association with WHR
	DDS	1 study reported no significant association with obesity
	Recommended diet variety	Cross-sectional studies (*n* 7)
	Mean vegetable and grain variety	1 study associated with 'higher'among normal weight *v.* obese
	DDS-R	1 study reported FV was 'higher' among normal weight *v.* obese
	RFS	1 study reported FV was 'higher' among normal weight *v.* obese
	Higher RFBS	1 study reported higher RFBS group had lower proportion of individuals with BMI > 25 kg/m^2
	DDS-R	1 study associated with lower BMI (β = –0·38)
	RFS	1 study associated with lower BMI (β = –0·18)
	Energy-weak variety	1 study associated with a 'lower' BMI
	Higher DDS	1 study 'borderline' associated with obesity
	Higher DDS	1 study associated with greater 'excess weight' (β = 0·98)
	RFS	1 study reported no significant association with BMI
	Food variety	2 studies reported no significant association with BMI
	RFS	1 study reported no significant association with WC
	DDS	1 study reported no significant association with overweight
	Food variety	1 study reported no significant difference with abdominal obesity

Table 3 *Continued*

Author, year	Types of DP	Summary of findings by study designs
	Recommended diet variety	Cohort studies (*n* 1)
	Highest *v.* lowest quartile RFS	1 study associated with lower BMI (25·4 *v.* 25·6) in males and higher BMI (25·0 *v.* 24·7) in females
	Non-recommended variety	Cross-sectional studies (*n* 4)
	NRFS – meat variety score	1 study reported 'Meat variety' score was 'higher' in obese *v.* normal weight
	FVR – energy-dense variety	1 study associated with higher BMI ($\beta = 0{\cdot}118$)
	FVR – micronutrient weak variety	1 study reported no significant association between BMI and 'Micronutrient weak' variety
	NRFS	1 study reported no significant association with BMI
	NRFS	1 study reported no significant association with WC
	Non-recommended variety	Cohort studies (*n* 1)
	FVR	1 study associated with increased incidence of overweight (OR = 1·36, 95 % CI 1·01, 1·82)
	Snack variety	1 study reported 'Snack variety' was associated with increased incidence of overweight (OR = 1·45, 95 % CI 1·06, 1·98)

DI, Diet Index; DQI, Diet Quality Index; MDS, Mediterranean diet score; MD, Mediterranean diet; FA, factor analysis; WC, waist circumference; CA, cluster analysis; CHO, carbohydrate; EI, energy intake; HEI, Healthy Eating Index; DDS, Dietary Diversity Score; FVS, food variety score; DGAI, Dietary Guidelines for Americans Index; DGI, Dietary Guideline Index; PNNS-GS, Program National Nutrition Sante´-Guideline Score; ARFS, Australian Recommended Food Score; RFS, Recommended Food Score; EDI, Elderly Dietary Index; DQS, dietary quality score; NRFS, Not Recommended Food Score; MDP, Mediterranean diet pattern; KDP, Korean dietary pattern; RR, relative risk; DP, dietary pattern; HDI, Healthy Diet Indicator; FS-MDS, Framingham-SENECA Mediterranean Diet Score; HDS, Healthy Diet Score; DQI-R, Diet Quality Index, Revised; PCA, principal component analysis; FV, fruit and vegetable; DMGFV, combination of dairy, meat, grain, fruit and vegetables; DDS-R, Dietary Diversity Score-Revised; FVR, Food Variety Ratio.

Note. Studies may be counted more than once where they have reported more than one outcome. DP in bold show their corresponding results in the right.

OR = 0·76)[30]. No significant association between MD and overweight/obesity-related outcomes was reported in seven out of eleven studies included in three reviews[15,29,32].

Cross-sectional studies

Out of the nineteen cross-sectional studies, six reported a decreased prevalence of obesity (OR ranging from 0·12 to 0·88) associated with adherence to the MD or higher MDS. Three out of the six systematic reviews reported a decreased prevalence of central obesity in two cross-sectional studies with adherence to the MD or highest tertile of MDS (OR ranging from 0·41 to 0·72)[29,32,36]. Two out of the six reviews reported lower BMI in three cross-sectional studies with adherence to the MD or higher MDS (β ranging from –4 to –0·186)[15,30]. One out of the six reviews reported a decreased prevalence of overweight in one cross-sectional study with adherence to the MD (OR = 0·33)[29]. No significant association between MD and overweight/obesity-related outcomes was reported in four out of nineteen studies included in three reviews[15,32,43].

Diet quality

Five out of sixteen systematic reviews included fifteen cohort, forty-five cross-sectional or one case–control studies reported associations between diet quality measures such as Diet Quality Index (DQI), Diet Diversity Score (DDS), Food Variety Ratio (FVR), Elderly Dietary Index, Diet Guideline Index, Healthy Eating Index (HEI), and Recommended Food Score and overweight/obesity-related outcomes or weight gain[28,38,39,41,42]. The reviewers generally concluded that there is a mixed association between various diet quality measures and overweight/obesity outcomes.

Cohort studies

Two of three reviews reported an inverse association between weight gain and DQI (mean = –0·059 kg/year, 95 % CI –0·111, –0·008); (mean ± SD = 3·3 ± 17·4 lb *v.* 8·0 ± 13·0 lb in females and 2·7 ± 10·1 lb *v.* 5·1 ± 13·3 lb in males); (OR = 0·9); and (mean = –0·061 (–0·116, –0·006)) in four studies[28,42]. One of the three reviews reported decreased incidence of obesity (OR = 0·69, 95 % CI 0·54, 0·89 in females and OR = 0·68, 95 % CI 0·53, 0·89 in males) in one study[28]. In contrast, two of the three reviews reported increased incidence of obesity (with DQI) (OR = 1·32) or overweight (with FVR) (OR = 1·36, 95 % CI 1·01, 1·82) in two studies[39,42]. No significant association between diet quality measures and overweight/obesity-related outcomes or weight gain was reported in seven out of fifteen studies included in three reviews[28,39,42].

Cross-sectional studies

Three systematic reviews reported lower BMI (with DDS, DQI, energy-weak variety, Recommended Food Score, food variety and HEI) (β ranging from –1·3 to –0·05) in ten cross-sectional studies, but effect estimates were not reported in seven[39,41,42]. Two of the three reviews reported decreased abdominal obesity (with DDS, FVS and HEI) (OR ranging from 0·21 to 0·7) in five studies[39,42]. Similarly, the same reviews reported a decreased obesity (OR ranging from 0·2 to 0·97) (with DDS, Elderly Dietary

Index and HEI) in five studies. In contrast, all three reviews reported a higher BMI ($\beta = 0{\cdot}118$) (with DQI, DDS and FVR) in four studies, but effect estimates were unclear in three studies. No significant association between diet quality measures and overweight/obesity-related outcomes was reported in twenty-one out of forty-five studies included in all three reviews[39,41,42].

Case–control study

One systematic review with one case–control study reported no significant associations between a diet quality measure (diet index) and overweight/obesity-related outcomes[38].

Combined fruit and vegetable intake

Two out of sixteen systematic reviews included three cohort or two cross-sectional studies that reported associations between combined FV consumption and obesity or weight gain[34,40]. The reviewers generally concluded that eating more FV may prevent weight gain.

Cohort studies

Both reviews in one of the three cohort studies reported decreased incidence of obesity (OR = 0·76, 95 % CI 0·69, 0·86), decreased risk of weight gain >25 kg (OR = 0·72, 95 % CI 0·55, 0·93) and decreased weight gain (0·76 kg less in overweight subjects and 0·52 kg less in normal-weight subjects at baseline). No significant association between combined FV consumption and weight gain was reported in two out of three studies included in both reviews[34,40].

Cross-sectional studies

One review included two cross-sectional studies that reported an association between combined FV consumption and weight gain[34]. Of these two studies, one reported more than 698 g/d of fruits and vegetables was associated with decreased weight gain (OR = 0·26, 95 % CI 0·07, 0·97). No significant association between combined FV consumption and weight gain was reported in one out of two studies in this review[34].

Other DP

Five systematic reviews and one meta-analysis included forty cross-sectional, six cohort and one case–control studies that reported associations between a range of other different DP such as Korean DP, Indian DP, '*a priori*' DP, '*a posteriori*' DP and, healthy/unhealthy DP and overweight/obesity outcomes[28,29,31,33,37,38].

Cross-sectional studies

Korean diet pattern. One review reported an association between Korean diet pattern and obesity-related outcomes[29]. Of the forty studies, one study reported a decreased prevalence of abdominal obesity (OR = 0·76, 95 % CI 0·59, 0·98). In contrast, one reported a higher prevalence of obesity (OR = 1·19, 95 % CI 1·06, 1·33) and two studies reported a higher prevalence of abdominal obesity (OR ranging from 1·07 to 1·27) in females with the highest tertile of Korean diet pattern.

Indian DP. One review, in three out of forty studies, reported an association between DP in India and overweight/obesity outcomes. Five DP enriched with fruit, dairy products, snacks; sweets, snacks; snacks, meat; butter, oil, ghee; and red meat, poultry, fish, eggs were associated with high BMI, abdominal adiposity or WC in three studies; however, effect estimates were not reported[31].

'A priori' DP

Two reviews used '*a priori*' approaches for determining DP associated with obesity outcomes[33,38]. Of forty studies, two reported associations between lowest quality by Healthy Diet Indicator and Framingham-SENECA MDS and higher (effect estimates not reported) WC in one review[33]. Moreover, in the same review, two studies reported that higher Mediterranean score was associated with lower WC ($\beta = -1{\cdot}2$ kg/m^2 in one study, effect estimate was unclear the other study) and decreased prevalence of obesity (OR = 0·88) in another[33]. One review, in one study, reported a DP consisting type A diet (Table 3) was associated with increased OR for prevalence of obesity (OR = 1·61) in males and (OR = 1·53) in females[38].

'A posteriori' DP

Three reviews assessed the association between '*a posteriori*' DP (derived from cluster analysis, factor analysis or principal component analysis) and obesity outcomes[33,37,38]. Three of the forty studies in one review[38] reported DP such as 'low culinary complexity', 'prudent' and 'satiating' (Table 3) were associated with lower BMI in males, while 'convenience' was associated with lower BMI in females, but effect estimates were not reported. One study in the same review reported 'Western' DP was associated with higher BMI, whereas another reported 'bush foods' were associated with a higher prevalence of obesity. Three of the fifty-two studies in one review reported DP such as 'meat, eggs and fat', 'rice, added fats (cooking oil), beans and poultry', 'low-nutrient-dense' and 'vegetable-based' were associated with high BMI[33]. No significant association between other DP and overweight/obesity-related outcomes was reported in fifteen out of forty studies included in three reviews[29,33,38].

Cohort studies

'A posteriori' DP. One systematic review included six cohort studies that reported association between '*a posteriori*' DP (derived from cluster analysis or factor analysis) and obesity outcomes[28]. One of the six studies reported highest quintile of 'healthy and fibre-rich diet pattern' was associated with lower annual change in WC ($\beta = -1{\cdot}06$ cm, 95 % CI −1·88, −0·24). Another study showed 'meat and potatoes diet pattern' was associated with greater annual increase in BMI ($\beta = 0{\cdot}26$). No significant association between other DP and overweight/obesity-related

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outcomes was reported in three out of six studies in this review[28].

Case–control studies

'A posteriori' DP

One systematic review included one case–control study that reported associations between other DP and obesity outcomes. This study reported 'high fat/sugar-dairy' (Table 3) was associated with lower BMI in males, while 'Drinker' was associated with lower BMI in females, but effect estimate not reported[38]. 'Drinker' and 'Fruit juice' were associated with higher BMI in males, while 'Western' was associated with higher BMI in the same study.

Findings from meta-analysis

Healthy and unhealthy DP. One review with twelve cross-sectional and one case–control studies reported a decreased pooled OR (0·81, 95 % CI 0·66, 0·96) for central obesity with higher healthy DP (Table 3). However, no significant association between unhealthy DP and central obesity was reported[37].

Discussion

Summary of evidence

We believe that this is the first umbrella review of observational studies on specific DP associated with overweight/obesity outcomes. Our evidence summary suggests that the most widely researched Mediterranean-type DP was consistently associated with lower overweight or obesity prevalence and incidence over 2 to 9 years of follow-up[15,29,30,32,36,43]. Similarly, a smaller body of evidence suggests that combined FV consumption was inversely associated with weight gain[34,40]. Other DP, which also overlap with components of the MD, were also inversely associated with overweight/obesity outcomes[33,37,38]. By contrast, overweight/obesity outcomes were inconsistently associated with other diet quality predictors, namely DQI, DDS and FVR[28,39,41,42]. Thus, the body of evidence provides some support for the usefulness of Mediterranean-type DP in reducing the risk of obesity between 12 % and 65 %, a range that is broadly consistent with current guidelines for overall health[16,44].

The Mediterranean-type DP is characterised by high intake of plant foods such fruit, vegetables, legumes, nuts and whole grains; olive oil as the main source of dietary fat; a frequent but moderate intake of red wine with meals; moderate intake of fresh fish, dairy products, poultry and eggs; and a low intake of red meat and processed meat in amount and frequency[45,46]. The most important factor explaining how the Mediterranean-type DP is potentially protective against obesity is its low energy density composition[47]. A recent systematic review of cohort studies found consistent evidence of an increased risk of obesity outcomes associated with energy density[48]. By contrast, evidence from randomised controlled trials of the MD have consistently shown a reduction in body weight and BMI[49], as well as improvements in metabolic and inflammatory risk parameters[50]. The above-described overall health benefits of the Mediterranean DP may also be partly attributable to its high micronutrient and flavonoid content[51–53].

In this umbrella review, we found that variably measured diet quality was inconsistently associated with overweight/obesity outcomes. For instance, HEI was inversely consistently associated[42], while DQI, DDS and FVR were both directly and inversely associated with obesity outcomes[39]. It has been previously shown that higher diet diversity intervention may not be an effective strategy to promote healthy weight[54]. Moreover, the findings from other studies of diet quality are inconsistent for BMI outcomes across specific population groups[55,56]. Although diet quality is likely to be associated with obesity in some populations[57], the heterogeneity in diet quality measures may have confounded true associations among other populations.

In this study, the evidence on the positive relationship between FV consumption and decreased weight gain was limited but consistent with previous research[34]. For instance, a recent systematic review reported 'moderate quality evidence' for an inverse association between vegetable intake and weight-related outcomes in adults[58]. Another study published since showed that FV intake was inversely associated with BMI and WC[59]. FV consumption is often recommended by expert bodies as an effective strategy for obesity prevention[60] or weight management[61]. In this review, healthy DP, including higher fruits and vegetables, based on '*a posteriori*' approach (derived from principal component analysis) were also associated with decreased central obesity[37]. Thus, public health policy-makers should consider strategies to increase population-wide consumption of fruits and vegetables to reduce the risk of obesity in their countries.

Limitations

The present umbrella review has several limitations that should be considered. First, since the individual studies in included reviews were observational studies, the association between MD and overweight/obesity outcomes should be interpreted with caution. For instance, none of the reviews considered or handled the possibility of unadjusted confounding (in their included studies) from other well-established risk factors such as genetic or environmental factors[62,63,64]. Second, diet quality was assessed by different methods which may have contributed to the mixed findings between diet quality and overweight/obesity outcomes. For instance, of all the diet quality measures, only the HEI was consistently and inversely associated with overweight/obesity outcomes[38,39,42], whereas there was a mixed association between DQI and overweight/obesity outcomes[42]. Moreover, dietary assessment was heterogeneous, and the use of FFQ without evidence of their validity[28,29] in individual studies may have partially biased in findings of the included systematic reviews. Third, despite using a rigorous search strategy, we may have missed potentially relevant systematic reviews (e.g. selection bias, unpublished reports and records archived in other electronic databases).

Implications

This umbrella review indicates that there is a growing body of evidence supporting the potential benefit of Mediterranean-type DP in reducing the risk of obesity in adults. Public health policy-makers should consider developing dietary guidelines that are aligned with the Mediterranean-type DP for overall health benefits, including the prevention of overweight/obesity at the population level. Strategies focusing on DP that are low in energy density such as the MD could help reverse the high rates of obesity worldwide. Population-specific evidence of effective interventions and implementation strategies are still needed.

Conclusion

Our review confirms the hypothesis that Mediterranean-type DP reduce the risk of obesity in adults. Health policy-makers, healthcare professionals and consumers should consider the importance of Mediterranean-type DP and low energy density diets more broadly in applying obesity prevention recommendations, with caution.

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Supplementary material

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