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Quality and validity of diet quality indices for use in Australian contexts: a systematic review

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Abstract

Diet quality indices (DQIs) are tools used to evaluate the overall diet quality against dietary guidelines or known healthy dietary patterns. This review aimed to evaluate DQIs and their validation processes to facilitate decision making in the selection of appropriate DQI for use in Australian contexts. A search of CINAHL, PubMed and Scopus electronic databases was conducted for studies published between January 2010 and May 2020, which validated a DQI, measuring > 1 dimension of diet quality (adequacy, balance, moderation, variety) and was applicable to the Australian context. Data on constructs, scoring, weighting and validation methods (construct validity, criterion validity, reliability and reproducibility) were extracted and summarised. The quality of the validation process was evaluated using COnsensus-based Standards for the selection of health Measurement INstruments Risk of Bias and Joanna Briggs Appraisal checklists. The review identified twenty-seven indices measuring adherence to: national dietary guidelines (*n* 13), Mediterranean Diet (*n* 8) and specific population recommendations and chronic disease risk (*n* 6). Extensiveness of the validation process varied widely across and within categories. Construct validity was the most strongly assessed measurement property, while evaluation of measurement error was frequently inadequate. DQIs should capture multiple dimensions of diet quality, possess a reliable scoring system and demonstrate adequate evidence in their validation framework to support use in the intended context. Researchers need to understand the limitations of newly developed DQIs and interpret results in view of the validation evidence. Future research on DQIs is indicated to improve evaluation of measurement error, reproducibility and reliability.

Key words: Diet Quality Index: Dietary assessment: Diet quality: Dietary patterns

Diet quality is a concept first developed in nutritional epidemiology to evaluate dietary patterns of populations and their association with health outcomes or the effectiveness of dietary interventions[1]. While no universal definition for the concept exists presently, it is generally understood that diet quality comprises of four dimensions: adequacy, balance, moderation and variety[2]. Adequacy of a diet is defined by sufficiency of intake to meet specific dietary recommendations based on requirements[1]. The 'balance' dimension addresses the proportionality of energy-yielding macronutrients and fatty acid composition in the overall diet to maintain health[1]. Moderation refers to the restriction of food portions that pose an increased risk of adverse health outcomes[1]. Lastly, the variety dimension accounts for both across and within food groups consumed over a specific period[1]. The inclusion of these dimensions in diet quality assessments provides a holistic evaluation of the healthfulness of diets by accounting for the synergistic effect of diversity and quantity in diet compositions.

Diet quality indices (DQIs) are frameworks using scoring systems to measure, evaluate and categorise diet quality based on the extent of the healthfulness of dietary patterns, with data most often derived from FFQ or dietary recalls[3]. Using these indices, compliance to national dietary recommendations could be assessed, areas requiring public health interventions could be identified, changes and trends in population's food choices may be tracked and chronic disease risk factors and mortality may be predicted[1,3–5]. Depending on research objectives, the constructs of DQIs vary in the number of components, in cut-off values that define adherence to recommendations or optimal diet and in scoring criteria. Indices may be food based, nutrient based or a combination of both to best reflect their research purposes and may also be standardised to a 100-point scale to

Abbreviations: AHEI-2010, Alternative Healthy Eating Index; COSMIN, Consensus-based Standards for the selection of health Measurement Instruments; DASH-Q, Dietary Approaches To Stop Hypertension Quality; DQI, diet quality index; DQT, Diet Quality Tool; DRA, Dietary Risk Assessment; DST, Dietary Screening Tool; HEIFA-2013, Healthy Eating Index For Australian 2013; MEDAS, Mediterranean Diet Adherence Screener; MediCul, Mediterranean Diet and Culinary Index; MD, Mediterranean Diet; TDS, Total Diet Score.

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improve interpretability and for comparison with other indices[6–11].

Several systematic reviews have been conducted to identify, assess and summarise the quality of existing DQI[12–14]. Kant recommended food-based DQIs to account for the complexity of the whole diet[12]. Indices of diet quality based on foods and food groups should undergo a validation process, be assessed against established parameters of nutritional status and be administered repeatedly to demonstrate reliability[13]. In 2009, a systematic review on DQIs emphasised further the difficulties of direct comparison of the quality of indices, given their differences in design, and suggested that most indices required further validation to enable practical application to different contexts, such as the clinical field and in public health[14]. More recently in 2019, Trijsburg *et al.* conducted a systematic review on indices for low- and middle-income countries[15]. While the scope of the reviews differed, both concluded there was a need for more robust validation of the indices, especially in establishing an association with the intended health outcomes.

Given the numerous tools available, clinicians and researchers need to consider the constructs of the DQIs and their suitability in relation to research aims when selecting an appropriate index because no standard framework for the validation of DQI currently exists[14–16]. Despite being non-region specific in its study selection, the previous systematic review conducted in 2009 did not identify DQIs developed based on the Australian Dietary Guidelines[14]. This omission presented a gap in the literature for identification of DQI that can be used in Australian contexts, including those with constructs similar to food groups or principles mentioned in the Australian Dietary Guidelines, and dietary patterns that are relevant to Australia, for example, Western eating pattern and the Mediterranean Diet (MD)[14,17]. Thus, this review aims to provide clinicians and researchers with information on the new validated DQI by describing the indices and assessing their validation processes to facilitate decision making in the selection of the most appropriate tool for the defined purpose, within Australian settings[14].

Methods

The study methods and reporting comply with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses[18].

Search strategy and eligibility criteria

The literature search was conducted in CINAHL, PubMed and Scopus to identify publications on existing validated DQI. Search strategies were created using Boolean operators 'AND' and 'OR'. The basic search strategy was '(diet × OR 'diet × qualit×' OR food × OR meal×) AND (index OR indice × OR scor × OR tool × OR indicat × OR guideline × OR pattern × OR divers × OR variet×) OR 'Healthy Eating Index' OR 'HEI' OR 'Healthy Eating Index for Australian' OR 'Aust-HEI' OR 'HEIFA' OR 'Mediterranean Diet Score' OR 'Diet Quality Index' OR 'DQI' OR 'Alternative Healthy Eating Index' OR 'AHEI' OR 'Recommended Food Score'. Limits applied included human, English language and published in 2010–2020. The full search strategy for each electronic database is attached in online Supplementary Material 1.

Study eligibility was guided by PICO (Population, Intervention, Comparator, Outcome) criteria: Population – adults 18 years of age and over; Intervention – DQI that have undergone a validation process as stated or indicated in the study to assess its ability to measure dietary patterns or diet quality; Comparator – N/A; Outcome – validity of indices to measure dietary patterns or diet quality. Articles were included if (i) they described and/or evaluated a DQI for its validity – which may include separate articles on the same tool; (ii) they stated an evaluation process to validate the tool or claimed validity of the tool; (iii) the tool was food based and measured more than one dimension of diet quality; and (iv) the tool was applicable to the Australian context – with constructs similar to food groups or principles reflected in the Australian Dietary Guidelines; dietary patterns prevalent in Australia, for example, Western eating pattern (characterised by high intake of processed meat, red meat, high-fat dairy products and refined grains); and MD[19]. For tools that have been regularly updated in accordance with national dietary guidelines, only the latest versions of the tools were included as they reflect the latest nutrition science.

Articles were excluded if (i) the tool was a nutrient-based index, due to the growing body of research on benefits of using a whole food approach, as reflected in the adoption of dietary patterns approach in national dietary guidelines globally and (ii) constructs of the DQI did not encompass key food groups of the Australian Dietary Guidelines[20–22]. Articles were not excluded based on study design.

Screening and data synthesis

Title–abstract eligibility for full-text screening was first assessed independently by two reviewers (M. S. T. and H. C. C.) and disagreements were resolved by consensus and then checked by a third reviewer (H. L. M. or L. J. R.). Subsequently, M. S. T. and H. C. C. performed full-text screening individually and cited references were checked for potentially relevant articles. All outcomes of the screening were cross-checked for proposed articles inclusions by M. S. T. and H. C. C., and any discrepancy was discussed until an agreement was reached, or on occasions referred for consensus decision by H. L. M. and L. J. R. on the final inclusion list.

Data extraction

Data extraction was performed by M. S. T. and H. C. C. who each independently extracted half of the included articles and reviewed one another's extracted data. The information extracted from the studies included the index name, country where the study was held, basis of index and target population. Key features and limitations of the indices were extracted and summarised, including, constructs, scoring system and aspects of diet quality they measure. Indices were categorised according to their theoretical constructs (i.e. adherence to national dietary guidelines, MD pattern and for specific populations and chronic disease risk).

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Quality assessment and risk of bias assessment

Quality of evidence assessment of the DQIs' validation process consisted of two parts – quality assessment using Joanna Briggs Institute's critical appraisal tools and the risk of bias assessment using Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) Risk of Bias checklist[16,23]. Validation methods used by the DQIs were also summarised.

Joanna Briggs Institute's critical appraisal tools for cross-sectional and cohort studies were utilised to assess the methodological quality of the study design and the extent to which the study design addressed the possibility of bias. Each aspect was assessed with a 'yes', 'no', 'unclear' or 'not applicable' and a brief explanation was provided for those indicated with a 'no' or 'unclear'. The overall rating of the quality assessment was allocated at the level of the criteria with the lowest quality rating.

The COSMIN Risk of Bias checklist was developed to assess the methodological quality of Patient-Reported Outcome Measures (PROMs): content validity, structural validity, internal consistency, cross-cultural validity, measurement invariance, reliability, measurement error, criterion validity, construct validity and responsiveness[16]. Each measurement property, apart from content validity, was rated on a 4-point rating scale of 'very good', 'adequate', 'doubtful' or 'inadequate' and an overall methodological quality score was derived by taking the worst score count of the standards that fall under the measurement property[16]. The standards used to evaluate content validity were not applicable to DQIs and therefore excluded from the appraisal. COSMIN components of structural validity, internal consistency, cross-cultural validity and measurement invariance – which reflects the internal structure of the tool – were not evaluated[16].

M. S. T. and H. C. C. independently assessed the quality and risk of bias assessments, with each assessing 50 % of the included articles. Both reviewers then cross-checked half of each other's allocated articles. Upon disagreement, discussions were conducted among both reviewers until 100 % agreement was reached and consistency in ratings was achieved.

Results

A total of twenty-seven studies and twenty-seven DQIs were included in the analysis[6,8,24–48]. Details of the literature search and selection processes are summarised in Fig. 1.

The indices were categorised into three broad groups depending on the dietary pattern they measured and their theoretical basis: thirteen indices were based on national dietary guidelines in Australia, Canada, New Zealand, Spain or the USA; eight were based on the MD published in Australia, Greece, Italy, Spain and USA; and six indices relating to specific sub-populations and chronic disease risk[6,8,24–48]. These included indices targeted at older adults or individuals at risk of CVD or assessed dietary patterns for the prevention of chronic diseases[8,24,28–31,33,46].

Scoring systems of the indices generally followed a positive-scoring algorithm where higher scores reflect better diet quality or greater adherence, and two DQIs have standardised scores out of 100 for easier interpretation and comparison[6,38]. All DQIs utilise continuous scores to reflect the extent to which the assessed diet conforms to the dietary guidelines. In addition, MEDI-LITE, Mediterranean Diet Serving Score, Evident Diet Index, Elderly Dietary Index and Dietary Screening Tool (DST) further translated the continuous scores to dichotomised scores to classify individuals as adherent or non-adherent to the diet[6,24,29,32,42]. The descriptions of the included indices are summarised in Table 1.

Common constructs and dimensions of diet quality measures

Category 1: national dietary guidelines. Most indices used an approach that measured a combination of whole foods and nutrients, and seven were based on food only[25,26,36,37,40,44,47]. The number of components included in the constructs of the indices varied, even for those indices based on the same dietary guidelines[25,26,43]. Only one index included a consideration of lifestyle factors, which was the frequency of breakfast consumption[47]. To measure dietary intake, most of the included studies utilised a FFQ or a specific questionnaire designed for this purpose[25,26,36,37,39,40,43,44,47,48]. In some cases, different studies utilised different dietary measurement tools for the same DQI[36,37,39,44,48]. The number of individual responses required to ascertain dietary intake in the dietary assessment method ranged from six for screening tools to more than 100 for indices using FFQ to assess dietary intake, indicating variability in respondent burden. DQI in this category measure at least two dimensions of diet quality, with 'adequacy' measured in all indices[25–27,36,37,39,40,44,47]. Healthy Eating Index For Australian 2013 (HEIFA-2013), Total Diet Score (TDS), Dietary Guideline Index 2013, Aussie Diet Quality Index, Dietary Guidelines Adherence Index 2015, Healthy Eating Index-2015 and the US Healthy Food Diversity Index all assessed dimensions of diet quality[27,36,37,39,43,44,48].

Category 2: adherence to the Mediterranean Diet. All indices in this category were published in the Mediterranean region including Greece, Italy and Spain, with the exceptions of Mediterranean Diet and Culinary Index (MediCul) and Mediterranean-Style Dietary Pattern Score which were published in Australia and the USA, respectively[6,32,34,35,38,41,42,45]. All indices used a food-based approach only[6,32,34,35,38,41,42,45]. Only MediCul assessed for lifestyle factors, which included habits with meal preparation, eating meals, fasting and napping[35]. DQIs of this category consist of the characteristic components: fish, olive oil and alcohol, due to their contribution to the beneficial effects of the Mediterranean dietary pattern, with olive oil (primarily) and fish contributing to the high unsaturated fat intake in the diet and the consumption of wine contributing to antioxidants[49,50]. Some indices only assessed certain types of alcohol, such as wine only in MEDI-Quest, beer and wine only in Mediterranean Diet Serving Score, red wine only in Mediterranean Diet Adherence Screener (MEDAS) score[32,41,45]. Adequacy and moderation were assessed in all indices[6,32,34,35,38,41,42,45]. None of the indices measured 'balance'[6,32,34,35,38,41,42,45].

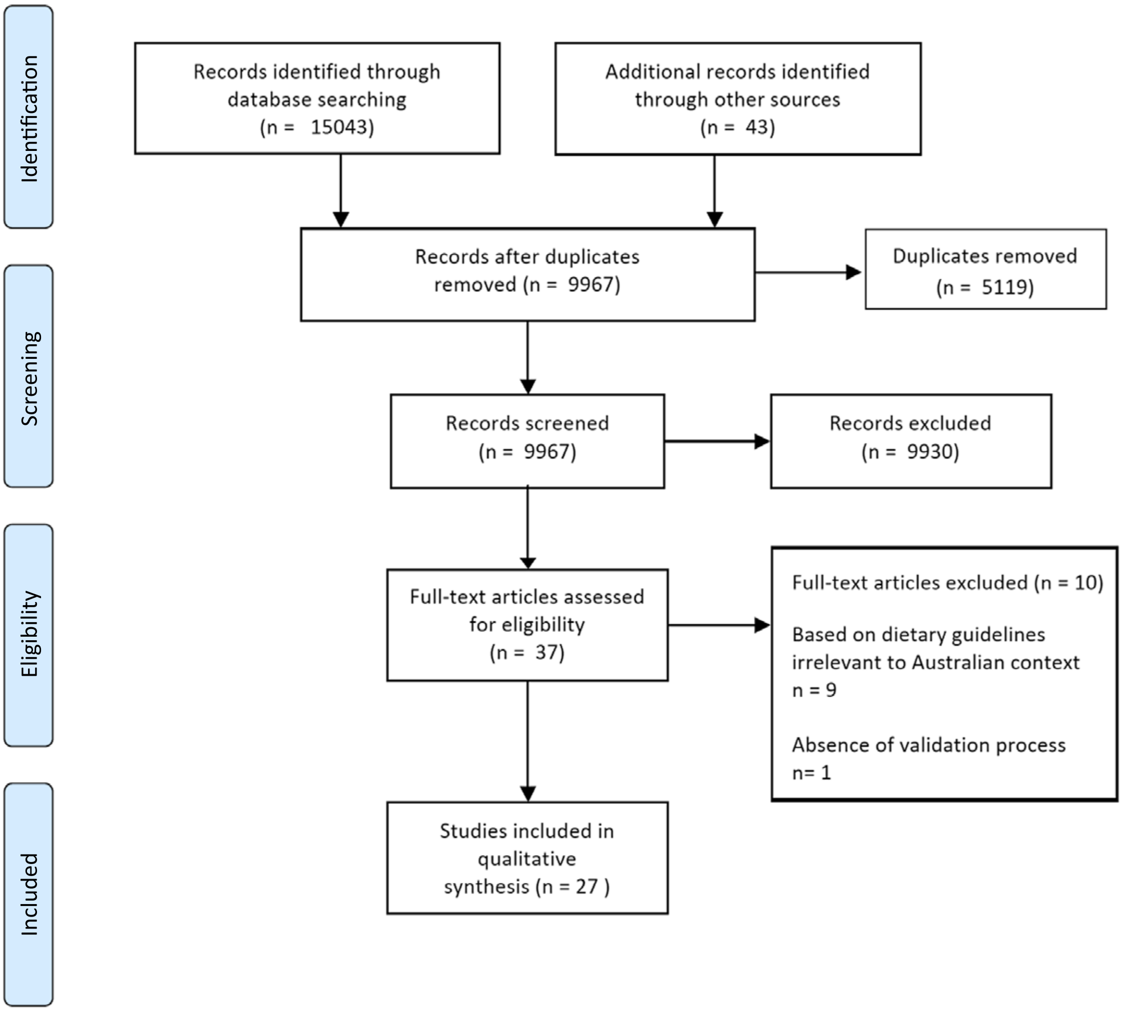

Fig. 1. Flow diagram of study selection for a systematic review of validated diet quality indices.

Category 3: specific sub-populations and chronic disease risk. Alternative Healthy Eating Index (AHEI-2010), Dietary Risk Assessment (DRA), Diet Quality Tool (DQT) and Dietary Approaches To Stop Hypertension Quality (DASH-Q) were based on literature-identified evidence, multiple modified national or disease-specific dietary guidelines, or a combination of these[8,28,33,46]. Indices in this category used a food-based approach, with the exceptions of AHEI-2010 and DRA that utilised both food and nutrient components[8,24,28–31,33,46]. Since AHEI-2010, DQT, DRA and DASH-Q are disease-related DQIs, their constructs include food and nutrients of concern[8,26,31,44]. For example, high-sodium foods were included in DASH-Q and constructs of DQT more specifically focused on dietary fats[33,46]. Elderly Dietary Index and DST were both developed for older adults and included similar basic food groups in their constructs (fruits, vegetables, meat, dairy and grains)[24,29–31]. However, Elderly Dietary Index consists of elements from MD (olive oil, fish and alcohol) as it was developed in the Mediterranean region, whereas DST aims to identify individuals at risk of malnutrition and, therefore, awarded more points for dietary supplement use[24,29–31]. Four indices measured three dimensions of diet quality and two indices measured two dimensions.

Scoring system

For most of the indices, score calculation involved the simple summation of individual construct scores, with the exceptions of EVIDENT Diet Score and Mediterranean-Style Dietary Pattern Score which involved standardising the total score into a 0–100 range[6,8,24–48]. Individual constructs are scored based on inclusion or exclusion in diet, meeting specific cut-off values for minimum or maximum intake, or scored in proportion to a defined range based on guidelines. Indices may attribute additional points for certain dietary behaviours such as choosing non-refined grains over refined grains or having fish or white meat over red or processed meat depending on the dietary pattern being assessed. However, six indices penalised individuals for having intakes exceeding the recommended serve of a food group[29,32,38,42,45,48]. For example, Aussie Diet Quality Index assigned a lower score to individuals having more than four serves of dairy per day than those only having two to four serves[48].

Table 1. Characteristics of identified validated diet quality indices

Author (country)	Diet quality index	Dietary guidelines/ patterns assessed	Adapted from an existing index?*	Dietary assessment method	Score range	Constructs of index: Food components	Constructs of index: Nutrient/other components	Dimensions of diet quality measured*: Adequacy	Variety	Balance	Moderation
Category 1: adherence to national dietary guidelines											
Bivoltsis *et al.*, 2018[25] (Australia)	RDGI	ADG-2013	NA	24 item FFQ	0–100	Vegetables, fruit, grains/cereals, lean meats, dairy or alternatives, water, alcohol	Nutrient components: saturated fat, added salt, added sugar	•			•
	S-RDGI1			Subset of 6 item from the 24 item FFQ	0–31·5	Vegetables, fruit, lean meat excluding fish, type of milk, chips/ French fries/ wedges/fried potatoes/crisps, meat products		•			•
	S-RDGI2			Subset of 9 item from the 24 item FFQ	0–46·5	Vegetables, fruit, lean meat, type of milk, chips/French fries/ wedges/fried potatoes/crisps, meat products, alcohol		•			•
Collins *et al.*, 2015[26] (Australia)	ARFS	ADG-2013	Recommended Food Score and The Australian Child and Adolescent Recommended Food Score	120 item FFQ with 15 supplementary questions about vitamin supplementation, food and sedentary behaviour	0–73	Vegetables, fruit, meat, meat alternatives, grain, dairy, water, spread/sauces		•	•		
Roy *et al.*, 2015[37] (Australia)	HEIFA-2013	DGAA – 2003 AGHE-2013	NA	Weighed food record, 74 item FFQ	0–100	Vegetables, fruit, grain/cereal foods, meat and protein food alternatives, milk and milk alternatives, discretionary food, alcohol, water	Nutrient components: Unsaturated fat, added salt, % Energy from added sugar, %Energy from saturated fat	•	•	•	•
Russell *et al.*, 2017[39] (Australia)	TDS	DGAA-2003 AGHE-1998 DGAI-2005	Aust-HEI	Weighed food record, 145 item FFQ	0–20	Vegetables, fruit, grains, meat and alternatives, dairy, alcohol, discretionary food	Nutrient component: sodium, %Energy from saturated fat, %Energy from sugar Other component: ratio of energy intake to expenditure	•	•	•	•

Table 1. (*Continued*)

Author (country)	Diet quality index	Dietary guidelines/ patterns assessed	Adapted from an existing index?*	Dietary assessment method	Score range	Constructs of index		Dimensions of diet quality measured*			
						Food components	Nutrient/other components	Adequacy	Variety	Balance	Moderation
Thorpe *et al.*, 2016[43] (Australia)	DGI-2013	ADG-2013	DGI	111 item FFQ	0–130	Vegetables, fruit, grain foods, lean meat, dairy and alternative, type of milk, water, discretionary foods, alcohol, variety (≥ 1 serve from each core food group a week), discretionary food	Nutrient components: added salt, added sugar Other component: trimming fat from meat	•	•	•	•
Zarrin *et al.*, 2013[48] (Australia)	Aussie-DQI	DGAA-2003	NA	24 h recall, 129 item FFQ	0–120	Vegetables, fruits, cereals, meat and alternatives, dairy products, processed meat, alcohol	Nutrient components: %Energy from saturated fats, % Energy from sugar, added salt and dietary variety (≥ 1 serve vegetable/ fruit/whole grain/ fish a day)	•	•	•	•
Jessri, *et al.*, 2016[27] (Canada)	DGAI-2015	DGA-2015	2005 Dietary Guidelines for Americans Adherence Index	24 h recall	0–19	Dark green vegetables, red/orange vegetables, legumes, starchy vegetables, other vegetables, fruits, variety of fruits and vegetables, grains, meat and beans, dairy, alcohol, % Whole grain from total grains, %Low fat dairy from total dairy, %Low fat meat products from total meat products	Nutrient components: cholesterol, sodium, dietary fibre density, % Energy from total fat, %Energy from saturated fat, % Energy from Sugar	•	•	•	•
Wong *et al.*, 2017[47] (New Zealand)	HDHI	New Zealand Food and Nutrition Guidelines for Healthy Adults 2003. DHQ	NA	25 item DHQ	0–60	Vegetables, fruit, bread, red meat, chicken, fish/shellfish, milk, spreads, low fat foods, fries, fast foods, soft drinks, low salt products	Nutrient components: added salt. Other components: breakfast consumption	•	•		•

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Table 1. (*Continued*)

Author (country)	Diet quality index	Dietary guidelines/ patterns assessed	Adapted from an existing index?*	Dietary assessment method	Score range	Constructs of index		Dimensions of diet quality measured*			
						Food components	Nutrient/other components	Adequacy	Variety	Balance	Moderation
Schroder, *et al.*, 2012[40] (Spain)	DQI	Dietary Guidelines for the Spanish Population 2011	NA	sDQS questionnaire	16–48	Vegetables, legumes, nuts, fruit, rice and pasta, bread, cereals, meat, fish, milk and yogurt, cheese, sausages, pastry, animal fat (butter/lard), vegetable oils (olive and sunflower, other vegetable oils (palm oil, etc.), fast food, alcohol		•	•		•
Reedy *et al.*, 2018[36] (USA)	HEI-2015	DGA-2015	HEI-2010	24 h food recall, 124 item FFQ	0–100	Total vegetables, greens and beans, total fruits, whole fruits, whole grains, total protein foods, seafood and plant proteins, dairy, refined grains	Nutrient components: %Energy from saturated fat, sodium, %Energy from added sugar, ratio of unsaturated fat to saturated fat	•	•	•	•
Vadiveloo *et al.*, 2014[44] (USA)	US HFD Index	DGA-2010	BI German HFD	24 h food recall, 124 item FFQ	0–1	Dark green vegetables, red and orange vegetables, legumes, starchy vegetables, other vegetables, fruits, whole grains, seafood, nuts, seeds and soya products, meat, poultry, eggs, refined grains, low fat milk, discretionary solid fats, cooking oil	Nutrient components: added sugar	•	•		•
Category 2: adherence to Mediterranean Diet											
Radd-Vagenas, *et al.*, 2018[35] (Australia)	MediCul	Traditional Mediterranean dietary pattern Previous literature	NA	MediCul questionnaire	0–100	Vegetable, fruit, whole grains, legumes, fish/shellfish, eggs, white meat, red/processed meat, dairy products, nuts, sweet and sugary drinks, takeaways, water, olive oil, alcohol, coffee	Other components: use of herbs/spices/lemon/vinegar/fermented food/feta cheese/sofrito, cooking methods, growing own's vegetables, main meal cooked at home, main meal eaten alone, snacking, fasting, napping	•	•		•

Table 1. (*Continued*)

Author (country)	Diet quality index	Dietary guidelines/ patterns assessed	Adapted from an existing index?*	Dietary assessment method	Score range	Constructs of index: Food components	Constructs of index: Nutrient/other components	Dimensions of diet quality measured*: Adequacy	Variety	Balance	Moderation
Panagiotakos, *et al.*, 2006[34] (Greece)	MDS	Mediterranean Diet Pyramid	NA	156 item FFQ	0–55	Vegetables, fruit, non-refined cereals, potatoes, legumes, fish, meat and meat products, poultry, full fat dairy products, olive oil and alcohol		•			•
Sofi *et al.*, 2017[42] (Italy)	MEDI-LITE	Mediterranean Diet based on literature	NA	MEDI-LITE questionnaire	0–18	Vegetables, fruit, cereal grains, legumes, fish and fish products, meat and meat products, dairy products, olive oil, alcohol		•			•
Vitale *et al.*, 2018[45] (Italy)	MEDI-Quest	Traditional Mediterranean Diet	NA	MEDI-Quest questionnaire	0–9	Vegetables, fruit, whole grain cereals, legumes and nuts, fish and fish products, meat and meat products, olive oil, animal fat, alcohol		•			•
Monteagudo, *et al.*, 2015[32] (Spain)	MDSS	Mediterranean Diet Pyramid	NA	129 item FFQ	0–24	Vegetables, fruit, cereals, potatoes, legumes, eggs, fish, white meat, red meat, nuts, dairy products, olive oil, sweets, fermented beverages		•	•		•
Rodríguez-Martin *et al.*, 2017[6] (Spain)	Evident Diet Index	Mediterranean Diet based on FFQ used	NA	137 item FFQ	0–100	Vegetables, fruit, dairy, fish, poultry, beans, lentils and chickpeas, whole grain, olive oil, tea, wine, beer, red meat, processed meat, desserts, confectionery, potatoes, sauce, beverages, soda, salty snack foods, added fats, butter		•	•		•
Schroder *et al.*, 2011[41] (Spain)	MEDAS score	Mediterranean Diet	NA	MEDAS questionnaire	0–14	Vegetables, fruit, pulses, fish/seafood, red meat/ processed meat, nuts, pastries, red wine, olive oil,	Other component: preference of white meat or red meat/ processed meat	•			•

Table 1. (*Continued*)

Author (country)	Diet quality index	Dietary guidelines/ patterns assessed	Adapted from an existing index?*	Dietary assessment method	Score range	Constructs of index: Food components	Constructs of index: Nutrient/other components	Dimensions of diet quality measured*: Adequacy	Variety	Balance	Moderation
						animal fat, sugar-sweetened beverages, dish with a traditional sauce of tomatoes, garlic, onion, or leeks sautéed in olive oil/ boiled vegetables					
Rumawas *et al.*, 2009[38] (USA)	MSDPS	Mediterranean Diet pyramid	NA	126 item FFQ	0–100	Vegetables, fruit, whole grain cereals, dairy, wine, fish, poultry, olives/ legumes/nuts, potatoes, eggs, sweets, meats, olive oil		•			•
Category 3: specific sub-populations and chronic disease risk											
Bailey, *et al.*, 2009[24] (USA) Liu, *et al.*, 2019[30] (USA) Marra, *et al.*, 2018[31] (USA)	DST	To characterise older adults into different categories of nutrition risk	Dietary Screening Questionnaire (DST)	DST questionnaire	0–105	Vegetables, whole fruit and juice, total and whole grains, lean proteins, dairy, added fats, sugars and sweets, processed meats	Other components: dietary supplement use	•	•		•
Chiuve, *et al.*, 2012[8] (USA)	AHEI-2010	Food and nutrients associated with lower risk of chronic disease as identified from literature, discussions with nutrition researchers, findings from AHEI 2005 that was originally modified from HEI-1995	AHEI-2005	131 item FFQ	0–110	Vegetables, fruit, whole grains, nuts and legumes, red/ processed meat, sugar-sweetened beverages or fruit juice, alcohol	Nutrient components: %Energy from trans fat, %Energy from long chain (n-3) fatty acids, % Energy from polyunsaturated fats, sodium	•		•	•
Jilcott, *et al.*, 2007[28] (USA)	Dietary Risk Assessment	Diets associated with CVD risk as identified from literature	(Original) Dietary Risk Assessment	Dietary Risk Assessment Questionnaire	0–108	Vegetables, fruits, cereal, meat, eggs, dairy, side dishes, desserts, snacks, spreads, salad dressings, oils	Nutrient components: added salt total fat, saturated fat	•	•		•
Kourlaba, *et al.*, 2009[29] (Cyprus and	EDI	Modified MyPyramid for Older Adults, Modified Food Guide Pyramid for 70+ Adults,	NA	FFQ (number of items assessed not mentioned)	10–40	Vegetables, fruits, cereals, bread, legumes, meat, fish and seafood, dairy, olive oil, alcohol			•		•

Table 1. (*Continued*)

Author (country)	Diet quality index	Dietary guidelines/ patterns assessed	Adapted from an existing index?*	Dietary assessment method	Score range	Constructs of index: Food components	Constructs of index: Nutrient/other components	Dimensions of diet quality measured*: Adequacy	Variety	Balance	Moderation
the Greek islands)		Previous studies published by DASH diet scientific group and the American Heart Association									
O'Reilly *et al.*, 2012[33] (Australia)	DQT	Heart Foundation's secondary prevention nutrition guidelines	NA	DQT	0–130	Vegetables, fruits, bread, pasta/rice/noodles, breakfast cereals, fish, fat on meats, milk, convenience high-fat sweet and savoury foods, spreads	Nutrient components: discretionary salt in meals and in cooking	•			•
Warren-Findlow *et al.*, 2016[46] (USA)	DASH-Q	DASH diet*	DASH diet subscale	DASH-Q questionnaire	0–77	Vegetables, pickled vegetables, fruit, whole grain breads/cereals/grits/oatmeal/brown rice, beans/peas/lentils, nuts/peanut butter, eggs, milk fried foods, packaged baked goods, frozen food		•	•		•

RDGI, RESIDE Dietary Guideline Index; S-RDGI1, Simple RESIDE Dietary Guideline Index 1; S-RDGI2, Simple RESIDE Dietary Guideline Index 2; ARFS, Australian Recommended Food Score; ADG, Australian Dietary Guidelines; NA, not applicable; HEIFA, Healthy Eating Index For Australian; DGAA, Dietary Guidelines For Australian Adults; AGHE, Australian Guide to Healthy Eating; TDS, Total Diet Score; DGAI, Dietary Guidelines Adherence Index; Aust-HEI, Australian Healthy Eating Index; DGI, Dietary Guideline Index; DQI, Diet Quality Index; DGA, Dietary Guidelines For Americans; HDHI, Healthy Dietary Habits Index; DHQ, Dietary Habits Questionnaire; sDQS, Short Diet Quality Screener; HEI, Healthy Eating Index; HFD, Healthy Food Diversity; BI, Berry Index; MediCul, Mediterranean Diet and Culinary Index; MDS, Mediterranean Diet Score; MDSS, Mediterranean Diet Serving Score; MEDAS, Mediterranean Diet Adherence Screener; MSDPS, Mediterranean-Style Dietary Pattern Score; DST, Dietary Screening Tool, AHEI, Alternative Healthy Eating Index; EDI, Elderly Dietary Index; DQT, Diet Quality Tool; DASH-Q, DASH Quality; DASH, Dietary Approaches To Stop Hypertension.

* These columns describe the dimensions of diet quality that are measured by the DQIs. These columns describe the dimensions of diet quality that are measured by the DQIs.

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Table 2. Quality of evidence of diet quality indices

Author country	Diet quality index	Study cohort	Age, % female	Risk of bias assessment* Reliability	Measurement error	Criterion validity	Construct validity	High quality†	Interpretation for use described by study authors	Limitations described and identified by study authors
Category 1: adherence to national dietary guidelines										
Bivoltsis, *et al.*, 2018[25] (Australia)	RDGI S-RDGI1 S-RDGI2	555	25–80, 62 %	A	I	V	V	Yes	• In settings where only incomplete dietary data are available across time points, method of regression based on available sub-set of questionnaire items may be used to generate a consistent measure of diet quality	• Limited generalisability due to modest response rate and participant characteristics incomparable to national statistics • Results may be confounded by design flaws of scores: Individual energy intake not adjusted, diet variety across food groups not measured, information about unsaturated fat and meat alternatives not collected, fruit juice not included as a serve of fruit • Actual agreement between scores may be lower than reported findings as use of same tool to create all three DQIs may have led to over-estimation of relative validity and contributed to correlated errors
Collins, *et al.*, 2015[26] (Australia)	ARFS	67	70 %	A	A	V	V	Yes	• Reproducible over a 5-month period and allows assessment of usual diet quality in adults	• Limited generalisability due to small sample size • Results more likely to represent younger female adults than males or older adults due to study cohort characteristics • May not be sensitive to detect change over time
Roy *et al.*, 2015[37] (Australia)	HEIFA-2013	100	18–34	A	A	NA	NA	No	• Assesses diet quality at group level • Relevant for use in public health monitoring and surveillance • Requires modification to suit dietary assessment method of choice	• Does not differentiate fat content of milk and beef cuts • Must be revised to reflect latest nutrition science and policies
Russell *et al.*, 2017[39] (Australia)	TDS	Validity assessment: 75 (63–83, 53 %) Biomarker analysis: 2486 (≥49, 54 %)		A	V	V	V	Yes	• May be used to rank diet quality of individuals using weighted food record • Useful for assessing diet quality in accordance with ADG at population level • Increased recommended serves of fruit and vegetable to achieve maximum score to account for overestimation of intake when FFQ is used	• Limited accuracy when using FFQ for dietary assessment

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Table 2. (*Continued*)

				Risk of bias assessment*						
Author country	Diet quality index	Study cohort	Age, % female	Reliability	Measurement error	Criterion validity	Construct validity	High quality†	Interpretation for use described by study authors	Limitations described and identified by study authors
Thorpe *et al.*, 2016[43] (Australia)	DGI-2013	4082	55–65, 59 %	I	I	NA	V	Yes	• Discriminates diet quality across socio-economic factors, health behaviours and health outcomes	• Limited indicators of unsaturated fat intake • Individuals on a vegetarian diet may be disadvantaged in score calculation
Zarrin *et al.*, 2013[48] (Australia)	Aussie-DQI	Validity assessment: 10 851 (≥19, 55 %) Association of Aussie-DQI all-cause mortality: 1355 (≥ 25, 58 %)		I	I	V	V	Yes	• Able to assess diet quality using cross-sectional and longitudinal data • Incorporated recommendations from UK and USA for processed meat, SFA and sugar	• Salt intake was not reflected in score when 24 h recall was used due to insufficient indicators. • Lack of association found between index and all-cause mortality which may be attributed to small sample size and lack of statistical power
Jessri, *et al.*, 2016[27] (Canada)	DGAI-2015	11 748	≥18, 50 %	A	I	V	V	Yes	• Utilises a proportional scoring scheme instead of dichotomous scoring system	• Causal inference of score to predict obesity or chronic disease risk was limited due to cross-sectional nature of study • Trans fat score component was not calculated due to lack of survey data
Wong *et al.*, 2017[47] (New Zealand)	HDHI	3993	19–98, 57 %	I	I	V	V	Yes	• Assesses diet quality at group level in the New Zealand population	• May only be useful in assessing diet quality at the population level due to lack of benchmark to define a 'healthy' diet
Schroder, *et al.*, 2012[40] (Spain)	DQI	102 (mean 58·6, 49 %)		A	A	NA	V	Yes	• None reported by authors	• Reduced external validity due to higher education level of participants
Reedy *et al.*, 2018[36] (USA)	HEI-2015	Validity assessment: 4797 (≥ 20, 50 %) All-cause mortality association: 422 928 (50–71, 43 %)		A	I	V	V	Yes	• Assesses diet quality at group level • Distinguishes diet quality across sex, age and smoking habits • Analysis of both component score and total score is encouraged as the same total score can be derived from different dietary patterns	• Does not capture excessive protein intake • Uncertain if DQI can detect differences between groups with significant variation in overall eating patterns
Vadiveloo *et al.*, 2014[44] (USA)	US HFD Index	7470	≥20, 49 %	A	I	NA	V	Yes	• Sensitive to small changes in diet • Distinguishes diet quality across groups with established differences in diet quality	• Higher than necessary weighting given to low-fat dairy foods as diet quality was assessed based on USDA Food Patterns

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Table 2. (*Continued*)

Author country	Diet quality index	Study cohort	Age, % female	Risk of bias assessment*				High quality†	Interpretation for use described by study authors	Limitations described and identified by study authors
				Reliability	Measurement error	Criterion validity	Construct validity			
Category 2: adherence to the Mediterranean Diet										
Radd-Vagenas, *et al.*, 2018[35] (Australia)	MediCul	68 (mean 75·9, 65 %)		V	V	NA	V	Yes	• Allows for rapid assessment of MD adherence • MEDAS score can be derived directly from the tool thus improving utility	• Cannot be generalised to younger or cognitively unimpaired groups
Panagiotakos, *et al.*, 2006[34] (Greece)	MDS	3042 adults (> 18, 50 %)		I	I	V	V	Yes	• None reported by authors	• None reported by authors
Sofi *et al.*, 2017[42] (Italy)	MEDI-LITE	4082	23–78, 59 %	A	I	NA	V	Yes	• Assesses adherence to MD at individual level • Reports precise consumption amounts in grams per day/week of each food group used for scoring	• Potential confounded results due to higher education level of participants and associated increased MD adherence • Validity limited by use of MDS as comparator as authors cited it was the only tool that can used at patient's level
Vitale *et al.*, 2018[45] (Italy)	MEDI-Quest	Validity assessment: 411 (18–85, 54 %) Cross-validation with MDS: 138 (18–85, 55 %)		A	I	NA	V	Yes	• Allows users to target key dietary behaviours of subgroups to be modified to improve diet quality	• Only accounts of frequency of consumption not quantity
Monteagudo, *et al.*, 2015[32] (Spain)	MDSS	1155	12–83, 100 %	I	I	NA	V	Yes	• Considers the upper and lower recommended limits for each food group so that individuals not meeting or exceeding recommended intakes are penalised	• Limited generalisability as cohort was all female
Rodríguez-Martin *et al.*, 2017[6] (Spain)	EVIDENT Diet Index	1553	20–80, 60 %	I	I	V	V	Yes	• Associated with CVD risk and arterial stiffness	• Lacks validity as index was adapted from Spanish dietary patterns proposed by other authors
Schroder *et al.*, 2011[41] (Spain)	MEDAS score	Validity assessment: 7146 (55–80, 57 %) CVD risk association: 4675 (55–80, 59 %)		V	V	V	V	Yes	• Ranks adherence to MD at individual level • Tool accounts for consumption of food non-traditional of MD	• Limited generalisability due to study cohort being at older age and higher risk of CVD risk • Likely overestimation of validity due to similarity of MEDAS to comparator
Rumawas *et al.*, 2009[38] (USA)	MSDPS	3021	≥ 20, 54 %	A	I	NA	V	Yes	• Assesses degree of MD adherence quantitatively using a continuous scale • Accounts for food not included in MD pattern • Different ways to achieve a higher score and may require analysis of individual construct scorings for interpretation of overall diet	• Limited by recommendations of MD that does not distinguish between sexes and age

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Table 2. (*Continued*)

Author country	Diet quality index	Study cohort	Age, % female	Risk of bias assessment*: Reliability	Measurement error	Criterion validity	Construct validity	High quality†	Interpretation for use described by study authors	Limitations described and identified by study authors
Category 3: specific sub-populations and chronic disease risk										
Bailey, *et al.*, 2009[24] (USA)	DST	204	73–94, 60 %	I	I	V	V	Yes	• Dietary screening could be completed in 10 min • Facilitates identification of dietary problems and targeted nutrition education by clinicians	• Limited generalisability due to cohort being almost exclusively white and older adults, and that scoring system was developed based on cohort-specific characteristics
Liu, *et al.*, 2019[30] (USA)		122	≥ 80, 54 %	A	I	NA	V	Yes	• None reported by authors	• Limited food items included in scoring system leading to inability to estimate energy intake • Scores based on limited set of food specific to cohort • Reduced generalisability due to entire cohort residing in rural USA with limited diversity
Marra, *et al.*, 2018[31] (USA)		87	45–64, 59 %	I	I	V	V	Yes	• Could distinguish intake of fruit and vegetables, and those at potential nutrition risk in a well-nourished population	• Reduced generalisability due to small sample size of mostly non-Hispanic white adults • Sample had a higher income and education level and may not represent the Appalachian population • Validity of index to assess certain markers of nutritional status, for example, vitamin D or essential fatty acids unknown
Chiuve, *et al.*, 2012[8] (USA)	AHEI 2010	112 524	30–75, 64 %	I	NA	V	V	Yes	• Associated with lower risks of chronic diseases, especially diabetes and CHD	• Reduced external validity due to cohort mostly being white, well-educated health professionals • Non-diet-related lifestyle factors that increase the risks of chronic disease may confound findings
Jilcott, *et al.*, 2007[28] (USA)	Dietary Risk Assessment	236	46–64, 100 %	A	I	V	V	Yes	• May help guide health professionals in dietary counselling in CVD prevention programmes	• Not all components were used in score calculation and may have contributed to errors • Limited external validity due to sample size consisting only mid-life Southern US women • Index is not a valid alternative to longer FFQ due to lack of quantitative assessment of nutrient intake
Kourlaba, *et al.*, 2009[29] (Cyprus and the Greek islands)	EDI	668	≥ 65, 46 %	I	I	V	V	Yes	• Potential to serve as tool for public health policymakers or health professionals in detecting elderlies at higher risk for CVD	• All components of index contributed equally to the calculation of total score despite being impossible that all food groups have the same health impacts on CVD outcomes

Table 2. (*Continued*)

Author country	Diet quality index	Study cohort	Age, % female	Risk of bias assessment* Reliability	Measurement error	Criterion validity	Construct validity	High quality†	Interpretation for use described by study authors	Limitations described and identified by study authors
O'Reilly *et al.*, 2012[33] (Australia)	DQT	37 (mean 61·2, 14 %)		A	I	NA	V	No	• Could be delivered by non-nutrition qualified individuals • Facilitates delivery of individualised nutrition information • Able to identify *n*-3 fatty acid intake • Assesses diet quality at group level • May identify participants who would benefit from individualised dietetic counselling over group education	• Small sample size • Validity of index limited to saturated fat, fibre and *n*-3 fatty acid intake • May not influence dietary change
Warren-Findlow *et al.*, 2016[46] (USA)	DASH-Q	812	≥ 21, 66 %	A	I	NA	A	No	• Assesses diet quality with item content consistent with DASH diet • Distinguishes diet quality across diet-related habits such as cooking for oneself and label reading • Could be adapted to other cultures and translated to other languages • Cut-off points may be lowered by 1 point for use in samples with more than 10 % missing responses	• Findings limited by use of some single-item measures to validate index

RDGI, RESIDE Dietary Guideline Index; S-RDGI1, Simple RESIDE Dietary Guideline Index 1; S-RDGI2, Simple RESIDE Dietary Guideline Index 2; ARFS, Australian Recommended Food Score; HEIFA, Healthy Eating Index For Australian; TDS, Total Diet Score; ADG, Australian Dietary Guidelines; DGI, Dietary Guideline Index; DQI, Diet Quality Index; DGAI, Dietary Guidelines Adherence Index; HDHI, Healthy Dietary Habits Index; HEI, Healthy Eating Index; HFD, Healthy Food Diversity; USDA, United States Department of Agriculture; MD, Mediterranean Diet; MediCul, Mediterranean Diet And Culinary Index; MDS, Mediterranean Diet Score; MEDAS, Mediterranean Diet Adherence Screener; MDSS, Mediterranean Diet Serving Score; MEDAS, Mediterranean Diet Adherence Screener; MSDPS, Mediterranean-Style Dietary Pattern Score; DST, Dietary Screening Tool, AHEI, Alternative Healthy Eating Index; EDI, Elderly Dietary Index; DQT, Diet Quality Tool; DASH-Q, DASH Quality; DASH, Dietary Approaches To Stop Hypertension

* V, very good; A, adequate; I, inadequate; NA, not applicable. Risk of bias was assessed using Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) Risk of Bias Checklist. Full assessment results are included in online Supplementary Material 2.

† Quality is assessed using Joanna Briggs Institute Critical Appraisal Checklist for Cross-sectional Study or Joanna Briggs Institute Critical Appraisal Checklist for Cohort Study according to study design. Articles were rated against eight (cross-sectional) or eleven (cohort) yes/no questions. Any rating of 'no' in the checklist would result in a classification of N in Table 2. Full assessment results are included in online Supplementary Material 3.

In many indices, meat and meat alternatives were scored separately as independent adequacy constructs[6,25,26,32,34,35,38–45,47,48]. The exceptions were HEIFA-2013, Dietary Guideline Index 2013, Dietary Guidelines Adherence Index 2015 and Healthy Eating Index-2015, which scored meat alternatives in the same component as meat[27,36,37,43]. DASH-Q included nuts or legumes as constructs, and only measured processed meat intake, with no meat constructs[46]. For AHEI-2010, no penalty was given for having no meat intake because meat was scored as a 'moderation component' where meat intake is to be limited[8]. See online Supplementary Material 2 for details on the scoring systems of DQI.

Quality of evidence and validation framework

Table 2 summarises the indices' overall quality of evidence, including the outcomes of risk of bias and quality assessments, limitations and implications for use[6,8,24–48].

The Joanna Briggs Institute's quality assessment determined all but HEIFA-2013, DASH-Q and DQT to have clearly defined criteria for participant inclusion, measurement and objective statistical analysis[6,8,24–48]. The risk of bias assessment deemed seven studies of category 1, six studies of category 2 and eight studies of category 3 to be at an increased risk of bias[6,8,24,25,27–34,36,38,42–48].

Table 3 summarises the validation methods used in the studies in demonstration of their validity and key findings of the indices[6,8,24–48]. The validation methods varied largely across indices or studies, and each index may have been evaluated using several means to establish validity[6,8,24–48]. Construct validity was most commonly assessed. Risk of bias in this area was well-accounted for in the validation process as all indices, except HEIFA-2013 and DASH-Q, were rated 'very good' according to COSMIN[6,8,24–36,38–45,47,48]. Most of the indices were evaluated for their association or correlation between index scores and a healthful food or nutrient profile in participants' diets[24,25,27–29,31,33–38,40,41,44,46–48]. This was to determine if an index was able to attribute a more favourable score to individuals with better diet quality (i.e. increased adherence to the dietary pattern being assessed). Most indices were also evaluated for their ability to measure diet quality independent of energy intake through inclusion in scoring system or adjustments in statistical analysis[6,8,26–28,30,31,34,36,38,39,41,44,47,48]. In addition, five indices were evaluated against existing validated DQI by determining the extent of agreement between overall scores or between the scores of similar constructs present in both[6,30,32,42,45].

To establish criterion validity, many indices were evaluated for their association with clinical outcomes which resulted in 'very good' ratings on the risk of bias assessment[6,8,27,29–31,34,36,39,41,47,48]. In addition, derivatives of RESIDE Dietary Guideline Index, S-RESIDE Dietary Guideline Index 1 and 2, and Australian Recommended Food Score have been compared with their original longer version RESIDE Dietary Guideline Index and the FFQ, respectively, and thus awarded 'very good' ratings based on COSMIN guidelines as well[25,26].

Risk of bias in establishing reliability and measurement error was least assessed by indices[6,8,24–48]. Only MediCul and MEDAS score achieved 'very good' rating for reliability and only TDS, MediCul and MEDAS score were rated 'very good' for measurement error[35,39,41]. Indices that were rated 'adequate' determined reliability using Pearson or Spearman correlation coefficients instead of using the standard of intraclass correlation coefficient recommended by COSMIN[26,27,35–38,46]. For measurement error, COSMIN requires evaluation by administering the DQI at least twice using the same instrument. Most indices were only administered once and therefore measurement error could not be assessed. In studies where the DQI was administered twice, the dietary measurement tool used to measure intake was different. For example, limits of agreement were calculated for the HEIFA scores, TDS scores, MediCul scores derived from weighed food record and FFQ, and MEDAS scores derived from the FFQ and the screener[37,39,41,51]. In the context of DQIs, measurement error presents as a systematic error stemming from its design. Deviation from the 'true diet quality value' occurs during translation of dietary intake into usable data for score calculation. DQIs need to capture the underlying construct of diet quality and some studies have calculated Cronbach's α to capture systematic variance underlying the components[27,36,37,46,47]. Others have used an existing DQI to quantify the effect of measurement error, as described above[6,30,32,42,45].

A common limitation for all the indices was their limited generalisability to the entire population as tested in specific sub-populations[6,8,24–48]. For example, the study samples for Australian Recommended Food Score and HEIFA-2013 were predominantly young adults and did not represent national population characteristics, and the items included in the DRA were specific to the Southern US region[26,28,37]. Studies were prone to inherent errors from portion size estimation, seasonal variations and recall bias due to score calculations being based on self-reported dietary intake[6,8,24–48]. Memory-based tools such as FFQ and 24-h recalls have been cited for misreporting dietary intake as they report on participants' perceived intake rather than the actual intake[52]. This was somewhat accounted for by studies via adjustments in their statistical models, such as excluding participants with an unreasonably high or low energy intake though they have been criticised for alteration of data[53].

Discussion

The current systematic review provides an update to the previous review conducted by Wirt and Collins and identified twenty-seven new or updated validated DQI[6,8,14,24–48]. This study is the first to provide a summary and evaluation of the extent of validity of DQIs. The DQIs exhibit similarities and differences in their constructs and the dimensions of diet quality they measure inter- and intra-category. Among the DQIs, Australian Recommended Food Score, HEIFA-2013, TDS, DQI, MediCul, MEDAS met COSMIN's criteria on the risk of bias assessment for the validation method used and received 'adequate' or 'very good' rating(s) for the validation evidence they provided[8,35,37,39–41]. None provided all four types of validation evidence (construct validity, criterion validity, reliability and reproducibility). Although few produced satisfactory evidence in

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Table 3. Key validation framework and findings

Diet quality index	Key validation methods: Construct validity – Association/correlation between index score and healthful dietary profile	Construct validity – Agreement of scoring outcomes with reference method(s)	Construct validity – Ability to distinguish between population subgroups with known differences in diet quality	Construct validity – Ability to differentiate diet quality independent of energy intake	Criterion validity – Association of scoring results and clinical outcomes	Reliability – Internal consistency/contribution of each constructs to final score/agreement of scoring outcomes across multiple time points	Reproducibility – Agreement of scoring results across dietary assessment methods	Key validation findings
Category 1: adherence to national dietary guidelines								
RDGI[25]	Yes		Yes					• Higher score significantly correlated with intakes of healthful ADG components • S-RDGI2 performed slightly better than S-RDGI1 across all measures of agreement • Able to distinguish between population subgroups with known differences in diet quality
S-RDGI1[25]	Yes	Yes	Yes					
S-RDGI2[25]	Yes	Yes	Yes					
ARFS[26]		Yes		Yes		Yes		• Significant, strong correlations between corresponding ARFS and FFQ food groups and mineral intakes • High agreement of scoring outcomes over a 5 month period
HEIFA-2013[37]	Yes					Yes	Yes	• Higher HEIFA-2013 score indicated closer adherence to the dietary guidelines • Differences in results of HEIFA-2013 from FFQ and WFR, indicating HEIFA scores may be affected by methods of dietary data collection
TDS[39]				Yes	Yes		Yes	• Good correlation and agreement between TDS scores resulted from both FFQ and WFR, however reduced accuracy when with FFQ • Individuals with highest diet quality measured by TDS had significantly higher levels of serum vitamin B_{12}, folate, homocysteine and total cholesterol than those with lower diet quality
DGI-2013[43]			Yes					• Lower DGI-2013 score was associated with population subgroups known to have reduced diet quality, which is consistent with previous literature
Aussie-DQI[48]	Yes		Yes	Yes	Yes			• Higher Aussie-DQI score is associated with a higher quality diet • Aussie-DQI score was able to reflect trends of intake in population subgroups, as consistent with previous literature • Higher Aussie-DQI score was associated with reduced risk of cancer mortality in men after adjusting for confounders

Table 3. (*Continued*)

Diet quality index	Key validation methods: Construct validity: Association/correlation between index score and healthful dietary profile	Construct validity: Agreement of scoring outcomes with reference method(s)	Construct validity: Ability to distinguish between population subgroups with known differences in diet quality	Construct validity: Ability to differentiate diet quality independent of energy intake	Criterion validity: Association of scoring results and clinical outcomes	Reliability: Internal consistency/contribution of each constructs to final score/agreement of scoring outcomes across multiple time points	Reproducibility: Agreement of scoring results across dietary assessment methods	Key validation findings
DGAI-2015[27]	Yes		Yes	Yes	Yes	Yes		• There was a significant positive trend between 2015 DGAI score and health-promoting nutrients • Robust association between DGAI with various socio-economic, lifestyle and dietary characteristics in the expected direction • DGAI demonstrated accuracy in distinguishing participants that are obese *v.* not obese
HDHI[47]	Yes		Yes	Yes	Yes	Yes		• Higher HDHI scores were significantly associated with higher intake of health-promoting nutrients • HDHI was able to distinguish differences of diet quality among participants with different socio-demographic and lifestyle factors known to have diverging effects on diet quality • Higher HDHI scores were associated with better nutritional biomarker levels
DQI[40]	Yes	Yes					Yes	• Higher ratings of DQI were associated with increased intake of health-promoting nutrients and reduced intake of moderation nutrients • Reasonable absolute agreement between scores derived from three assessment methods with 24 h recall as reference, but lower for brief Mediterranean Diet screener
HEI-2015[36]	Yes		Yes	Yes	Yes	Yes		• High HEI score obtained from known high-quality menus such as the sample menus from the US Department of Agriculture and the DASH eating plan • Demonstrated ability to distinguish between groups of population with known differences in diet quality • High HEI score was associated with reduced risk of mortality

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Table 3. (*Continued*)

Diet quality index	Key validation methods: Construct validity: Association/correlation between index score and healthful dietary profile	Construct validity: Agreement of scoring outcomes with reference method(s)	Construct validity: Ability to distinguish between population subgroups with known differences in diet quality	Construct validity: Ability to differentiate diet quality independent of energy intake	Criterion validity: Association of scoring results and clinical outcomes	Reliability: Internal consistency/contribution of each constructs to final score/agreement of scoring outcomes across multiple time points	Reproducibility: Agreement of scoring results across dietary assessment methods	Key validation findings
US HFD Index[44]	Yes	Yes	Yes	Yes				• US HFD index sores were positively correlated with intake of key health-promoting nutrients and negatively correlated with moderation nutrients • Positively correlated with overall diet quality as measured in accordance with dietary recommendations of DASH • Differentiated between populations with established differences in diet quality
Category 2: adherence to the Mediterranean Diet								
MediCul[35]	Yes	Yes				Yes		• Increased diet quality is associated with increased MediCul score • No systematic bias between MediCul and 3 d food record • Scores obtained across two time points were equally variable • Lifestyle-related questions not validated due to inability to include in scoring and statistical analysis
MDS[34]	Yes			Yes	Yes			• Higher score was associated with increased consumption of healthful food groups aligning with the MD • Significant association between the score and health outcomes assessed • Inverse relationship between diet score and odds of CHD
MEDI-LITE[42]		Yes	Yes					• MEDI-LITE is significantly correlated with MDS • Able to discriminate against adherents and non-adherents of the MD
MEDI-QUEST[45]		Yes	Yes					• MEDI-QUEST had good concordance with the MDS
MDSS[32]		Yes	Yes					• No significant differences between MDS and MDSS values for the total population/age group assessed • Able to differentiate adherents and non-adherents of the MD pattern

Table 3. (*Continued*)

Diet quality index	Key validation methods: Construct validity: Association/correlation between index score and healthful dietary profile	Construct validity: Agreement of scoring outcomes with reference method(s)	Construct validity: Ability to distinguish between population subgroups with known differences in diet quality	Construct validity: Ability to differentiate diet quality independent of energy intake	Criterion validity: Association of scoring results and clinical outcomes	Reliability: Internal consistency/contribution of each constructs to final score/agreement of scoring outcomes across multiple time points	Reproducibility: Agreement of scoring results across dietary assessment methods	Key validation findings
EVIDENT Diet Score[6]		Yes	Yes	Yes	Yes			• Good predictor of adherence to the MD pattern • EVIDENT Diet Score was associated with cardiovascular risk and its components, as well as pulse wave velocity which is an index of arterial stiffness
MEDAS [41]	Yes	Yes		Yes	Yes			• Increased intake of healthful nutrient/food found in quintiles with increased MEDAS score • Significant agreement between MEDAS and FFQ • Inverse relationship between MEDAS score and cardiometabolic risk variables and estimated congenital heart disease risk
MSDPS [38]	Yes			Yes		Yes		• Higher MSDPS score reflects greater compliance to a MD pattern
Category 3: specific sub-populations and chronic disease risk								
DST (older adults) [24]	Yes	Yes			Yes			• Lower DST scores associated with unfavourable dietary patterns • Significantly different HEI-2005 and MAR across the at risk, possible at risk and not at risk group, with the at-risk group having the lowest MAR and HEI-2005 scores • Lower DST individuals had unfavourable trends of biomarkers of nutritional status
DST (Oldest adults) [30]		Yes		Yes				• Significant correlation between DST and HEI-2015
DST (middle-aged adults) [31]	Yes			Yes	Yes			• Lower DST score is associated with poorer diet quality as assessed by HEI scores and is at higher odds of also getting a low HEI score • Lower DST score is associated with reduced intake of healthful nutrients • Lower DST group had significant lower serum levels of biomarkers of nutritional status regarding carotenoid status
AHEI-2010[8]		Yes		Yes	Yes			• High correlations between HEI-2005 and AHEI-2010 • AHEI score was inversely associated with risk of major chronic disease • AHEI score was more strongly associated with the risk of major chronic disease than HEI-2005

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Table 3. (*Continued*)

Diet quality index	Key validation methods: Construct validity: Association/correlation between index score and healthful dietary profile	Construct validity: Agreement of scoring outcomes with reference method(s)	Construct validity: Ability to distinguish between population subgroups with known differences in diet quality	Construct validity: Ability to differentiate diet quality independent of energy intake	Criterion validity: Association of scoring results and clinical outcomes	Reliability: Internal consistency/contribution of each constructs to final score/agreement of scoring outcomes across multiple time points	Reproducibility: Agreement of scoring results across dietary assessment methods	Key validation findings
Dietary Risk Assessment[28]	Yes			Yes	Yes			• A more favourable score is correlated with higher intake of healthful nutrients and less intake of moderation nutrients • Significant correlation between scores and the reference diet quality indices
EDI[29]	Yes				Yes			• Higher EDI score is significantly related to higher intake of healthful food components • Strong inverse relationship between EDI score and being obese, hypertensive and having at least one CVD risk factor • Ability to discriminate participants: obese *v.* non-obese, hypertensive *v.* non-hypertensive, having one CVD risk factor *v.* having none
DQT[33]	Yes							• DQT score is positively correlated with increased intake of key healthful nutrients
DASH-Q[46]	Yes	Yes				Yes		• DASH-Q score is correlated with better dietary habits (e.g. reading food labels) and health • DASH-Q correlates with self-rated diet quality and DST score

RDGI, RESIDE Dietary Guideline Index; S-RDGI1, Simple RESIDE Dietary Guideline Index 1; S-RDGI2, Simple RESIDE Dietary Guideline Index 2; ARFS, Australian Recommended Food Score; WFR, Weighted Food Record; HEIFA, Healthy Eating Index For Australian; TDS, Total Diet Score; DGI, Dietary Guideline Index; DQI, Diet Quality Index; DGAI, Dietary Guidelines Adherence Index; HDHI, Healthy Dietary Habits Index; HEI, Healthy Eating Index; HFD, Healthy Food Diversity; MediCul, Mediterranean Diet And Culinary; MDS, Mediterranean Diet Score; MD, Mediterranean Diet; MEDAS, Mediterranean Diet Adherence Screener; MDSS, Mediterranean Diet Serving Score; MEDAS, Mediterranean Diet Adherence Screener; MSDPS, Mediterranean-Style Dietary Pattern Score; DST, Dietary Screening Tool; MAR, Mean Adequacy Ratio; AHEI, Alternate Healthy Eating Index; EDI, Elderly Dietary Index; DQT, Diet Quality Tool; DASH, Dietary Approaches To Stop Hypertension; DASH-Q, DASH Quality.

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demonstration of validity, the DQIs remain relevant as nutrition tools so long as their purposes and shortcomings are recognised.

The current review observed diversity in the dimensions that DQI measure and their constructs across categories due to differing research aims. Indices in Categories 1 and 3 may include 'balance' and 'variety' dimensions to reflect the principles of national dietary guidelines and nutrition recommendations specific to disease. However, few indices in category 2 (measure adherence to MD) include those dimensions. Compared with DQI for national dietary guidelines, the Mediterranean dietary pattern emphasises consumption of cardiac-protective foods included in the MD pyramid (adequacy) and reducing foods non-adherent to the diet (moderation). Therefore, it may not be necessary to measure the other dimensions, especially 'balance' as adherence to the MD should result in high unsaturated fatty acid intake.

Within categories of indices, differences in the constructs could also be observed. This is likely due to subjectivity introduced by the researchers in their interpretation of guidelines during the development of indices. Weightage of each dietary component was at the discretion of the researchers as only food and nutrients were mentioned in the guidelines. These differences in weightage affect the scoring system and consequently their association with health outcomes. Strength of association with health outcomes may be flawed if the constructs were not appropriately weighed in representation of their significance to the diet the DQI aims to evaluate. For example, if vegetable intake was assigned a disproportionally low weighting in the scoring system of a DQI designed to evaluate cardiovascular risk, individuals with the same saturated fat intake but lower vegetable intake may be given similar diet quality scores. This would weaken the strength of association between the DQI and CVD because the DQI is unable to differentiate individuals with varying vegetable intake in relation to their cardiovascular risk. The insufficient variation in scores reflects poor construct validity of the DQI and affects its predictability of health outcomes. Thus, when selecting DQI for identifying associations between dietary patterns and health outcomes, it is essential to recognise the inter-relationships between dietary components and health outcomes especially for DQI used in predicting chronic disease risk.

Besides using continuous scores, some indices also used dichotomous scores to classify the participants according to adherence or non-adherence to the defined guidelines. Cut-off points for categorisation were determined by comparison with a reference to calculate the degree of agreement (Bland–Altman plot) or Cohen's kappa and subsequently, sensitivity and specificity. However, the quantitative definition of a high-quality diet is population specific because the DQI were validated based on the data set of the sample. For instance, cut-off points defined by validating DQI in the Australian population cannot be used for categorising individuals as adherent or non-adherent in the US population, although the index itself may still be used to assess individuals within the US population. This limits the usefulness of comparing dichotomous scores of the same DQI across populations as well as correlations with health outcomes[54].

General dietary habits within a population also need to be considered to ensure a lower score is attributable to poor diet quality only, and not individuals' lifestyle or cultural choices[45]. Few indices accommodated vegan or vegetarian diets, placing individuals on these diets at disadvantage when some indices are used[27,29,32,36–38,42,43,45,48]. In view of a global push for more plant-based diets, there is a need for indices to be more inclusive when assessing dietary protein, fat and iron intake, especially those aiming to assess populations with diverse cultural dietary patterns.

This review illustrated wide variations in validation processes between indices. As there is no gold standard for diet quality, assessment of validity is varied and subjective[55]. It is notable that most of the indices did not meet the standard by COSMIN to receive 'very good' rating due to the use of a different validation method[6,8,24–34,36–40,42–48]. Therefore, exercising caution is necessary when interpreting validation evidence as the quality of the validation is only as robust as the standard it was held against.

Researchers need to determine if the validation evidence of each index was adequate to support their use, and whether the validation framework used was low in risk of bias for the results to be reliable[14]. For example, despite providing evidence of validity in different population groups, DST has only been tested for its reliability by Liu *et al.* in the oldest-old population group[30]. None of the three studies on DST evaluated the measurement error component[25,30,31]. The validation process is subjected to measurement error due to the nature of dietary collection tools. In particular, establishing associations between diet quality and clinical outcomes needs to be scrutinised in recognition that diet quality was determined based on perceived intake. However, the validity of DQI should not be entirely equated to that of dietary collection tools as they are separate entities.

When using a reference DQI to calibrate measurement error, the reference tool should ideally be free of systematic error[56]. New DQIs are often compared with existing ones which are considered to be more validated. However, the index has limited generalisability as there is no gold standard DQI reference and the relative validity has been determined using an imperfect reference[56]. Furthermore, few research administered the DQI twice using the same tool to allow for its evaluation of measurement error and majority were not assessed for validity of use across different dietary collection tools[6,8,24–48]. Reliability across different time points was only measured by Australian Recommended Food Score and MediCul[26,35]. Given that DQIs have been used in longitudinal studies and interventions, it signifies the need for researchers to undertake more extensive validation studies to establish confidence in measuring dietary change[57–59], and specifically, to evaluate test–retest reliability and use varied dietary data collection methods when developing DQI.

Considerations for selecting a suitable diet quality assessment tool

Three key factors should be taken into consideration when selecting a suitable DQI: research aims, scoring system and validation evidence. When assessing diet quality based on adherence to national dietary guidelines, DQIs need to be revised to be inclusive and reflect the latest evidence. For specific diets, the suitability of a 'relative' *v.* 'absolute' approach in scoring

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needs to be considered. Caution is to be exercised when using predefined cut-off points to categorise individuals' adherence to dietary patterns as they are population specific and may not be applicable for cross-population use. At the individual level, DQI that are easy and rapid to administer are more appropriate for assessing diet quality in a time-limited clinical setting to identify at-risk individuals due to lower respondent burden. These indices are usually used with a designated questionnaire or a screener that allows assessment to be completed quickly compared with more comprehensive dietary assessment methods like FFQ. Screeners and short tools include RESIDE Dietary Guideline Index and its derivatives, DQI, MEDI-LITE, MEDAS score, DST, DQT and DASH-Q[24,25,33,40–42,46]. Indices such as DQT may also be designed to identify specific areas of the diet that require attention to support nutrition counselling[33]. At the group level, indices suitable for assessment can distinguish diet quality within population subgroups and can be used for public health monitoring and surveillance, though validity for monitoring changes is uncertain due to the insufficient evidence to account for measurement bias.

The index should have a reliable scoring system where correlations between constructs should be evaluated to ensure that weightage of each construct reflects their significance to the overall diet assessed. The scoring range also affects the suitability of DQI for assessment at group and individual level. For individual assessment, a small scale may be sufficient to assess the diet quality and determine if nutritional intervention is needed. However, in group settings where a greater variation is expected or ranking of individuals required, DQI with small range and dispersion of scales may not be informative for research purposes as they are unlikely to capture the extreme inherent characteristics of the dietary pattern[60].

Evidence of indices' validation should be adequate to support their use in the intended context and their validation framework should ideally be free of potential bias[14]. TDS, Dietary Guidelines Adherence Index 2015 and Healthy Eating Index-2015 of category 1, Mediterranean-Style Dietary Pattern Score of category 2, AHEI-2010 and DRA of category 3 are suitable for use at the population level[8,27,28,36,38,39]. MEDAS score is suitable for use at the individual level[41]. Despite these indices being assessed to be more robust than the others based on this review, researchers need to acknowledge their limitations and interpret the results with caution.

Strengths of this review are that it provided a detailed summary of the most recently published and updated DQI and provided an assessment of risk of bias and quality of the tools using the COSMIN framework. While the tools have been curated for use in Australian contexts, the DQI could potentially be used in other contexts, especially those in category 2 and 3 that were not based on country-specific dietary guidelines. In addition, findings from evaluating the validation processes provide generalisable factors to be considered in selection of DQI for different contexts beyond those included in this study. The study was limited by the fact that COSMIN tool for risk of bias assessment of PROMs was not a perfect fit to assess DQI. DQI are unlike classic PROMs where each subscale or component can be evaluated individually as required by COSMIN. Subsequently, the strength of the validation results (e.g. high or low intraclass correlation coefficient, extent of correlations) could not be assessed as the criteria were unsuitable for multidimensional instruments like DQI. However, the COSMIN tool was the most fitting tool that could be identified in the absence of better frameworks. The current study's search only included indices with demonstrated validation processes published from 2010 to 2020. Therefore, some DQI published after the previous 2009 review may not have been identified. Despite this, we manually identified and included DQI published before 2009 if their validation process was published after 2009.

To conclude, existing DQI need further validation for measurement error, reliability and reproducibility. When selecting a DQI, researchers should consider the validation evidence and suitability of the tool for their research aims to increase the robustness of research findings in nutritional epidemiology and dietary intervention studies.

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Supplementary material

For supplementary material referred to in this article, please visit https://doi.org/10.1017/S0007114521004943

References

1. Alkerwi A (2014) Diet quality concept. *Nutrition* **30**, 613–618.
2. Burggraf C, Teuber R, Brosig S, *et al.* (2018) Review of a priori dietary quality indices in relation to their construction criteria. *Nutr Rev* **76**, 747–764.
3. Gil Á, Martinez de Victoria E & Olza J (2015) Indicators for the evaluation of diet quality. *Nutr Hosp* **31**, 128–144.
4. Patterson RE, Haines PS & Popkin BM (1994) Diet quality index: capturing a multidimensional behavior. *J Acad Nutr Diet* **94**, 57–64.
5. Haines PS, Siega-Riz AM & Popkin BM (1999) The diet quality index revised: a measurement instrument for populations. *J Am Diet Assoc* **99**, 697–704.
6. Rodríguez-Martin C, Alonso-Domínguez R, Patino-Alonso M, *et al.* (2017) The evident diet quality index is associated with cardiovascular risk and arterial stiffness in adults. *BMC Public Health* **17**, 1.
7. Mellen PB, Gao SK, Vitolins MZ, *et al.* (2008) Deteriorating dietary habits among adults with hypertension: dash dietary

accordance, NHANES 1988–1994 and 1999–2004. *Arch Intern Med* **168**, 308–314.
8. Chiuve S, Fung T, Rimm E, *et al.* (2012) Alternative dietary indices both strongly predict risk of chronic disease. *J Nutr* **142**, 1009–1018.
9. Guenther PM, Kirkpatrick SI, Reedy J, *et al.* (2014) The healthy eating index-2010 is a valid and reliable measure of diet quality according to the 2010 dietary guidelines for Americans. *J Nutr* **144**, 399.
10. Dubois L, Girard M & Bergeron N (2000) The choice of a diet quality indicator to evaluate the nutritional health of populations. *Public Health Nutr* **3**, 357–365.
11. Krebs-Smith SM, Pannucci TE, Subar AF, *et al.* (2018) Update of the healthy eating index: HEI-2015. *J Acad Nutr Diet* **118**, 1591.
12. Kant AK (1996) Indexes of overall diet quality: a review. *J Acad Nutr Diet* **96**, 785–791.
13. Kant AK (2004) Dietary patterns and health outcomes. *J Acad Nutr Diet* **104**, 615–635.
14. Wirt A & Collins CE (2009) Diet quality – what is it and does it matter? *Public Health Nutr* **12**, 2473–2492.
15. Trijsburg L, Talsma EF, de Vries JHM, *et al.* (2019) Diet quality indices for research in low- and middle-income countries: a systematic review. *Nutr Rev* **77**, 515–540.
16. Prinsen CAC, Mokkink LB, Bouter LM, *et al.* (2018) COSMIN guideline for systematic reviews of patient-reported outcome measures. *Qual Life Res* **27**, 1147–1157.
17. National Health and Medical Research Council (2013) *Australian Dietary Guidelines*. Canberra: National Health and Medical Research Council.
18. Moher D, Liberati A, Tetzlaff J, *et al.* (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* **339**, e78–e336.
19. Strate LL, Keeley BR, Cao Y, *et al.* (2017) Western dietary pattern increases, and prudent dietary pattern decreases, risk of incident diverticulitis in a prospective cohort study. *Gastroenterology* **152**, 1023–1030.e1022.
20. U.S. Department of Health and Human Services & U.S. Department of Agriculture (2015) *2015–2020 Dietary Guidelines for Americans,* 8th ed. https://health.gov/our-work/food-nutrition/previous-dietary-guidelines/2015 (accessed June 2020).
21. National Health and Medical Research Council (2013) *Eat for Health: Australian Dietary Guidelines; Providing the Scientific Evidence for Healthier Australian Diets, Australian Dietary Guidelines: Providing the Scientific Evidence for Healthier Australian Diets*. Canberra: National Health and Medical Research Council.
22. Freeland-Graves J & Nitzke S (2013) Position of the academy of nutrition and dietetics: total diet approach to healthy eating. *J Acad Nutr Diet* **113**, 307–317.
23. Aromataris E & Munn Z (2020) *JBI Manual for Evidence Synthesis*. https://synthesismanual.jbi.global (accessed June 2020).
24. Bailey RL, Miller PE, Mitchell DC, *et al.* (2009) Dietary screening tool identifies nutritional risk in older adults. *Am J Clin Nutr* **90**, 177.
25. Bivoltsis A, Trapp GSA, Knuiman M, *et al.* (2018) Can a simple dietary index derived from a sub-set of questionnaire items assess diet quality in a sample of Australian adults? *Nutrients* **10**, 486.
26. Collins CE, Burrows TL, Rollo ME, *et al.* (2015) The comparative validity and reproducibility of a diet quality index for adults: the Australian recommended food score. *Nutrients* **7**, 785.
27. Jessri M, Lou WY & L'Abbé MR (2016) The 2015 dietary guidelines for Americans is associated with a more nutrient-dense diet and a lower risk of obesity. *Am J Clin Nutr* **104**, 1378–1392.
28. Jilcott SB, Keyserling TC, Samuel-Hodge CD, *et al.* (2007) Validation of a brief dietary assessment to guide counseling for cardiovascular disease risk reduction in an underserved population. *J Am Diet Assoc* **107**, 246–255.
29. Kourlaba G, Polychronopoulos E, Zampelas A, *et al.* (2009) Development of a diet index for older adults and its relation to cardiovascular disease risk factors: the elderly dietary index. *J Am Diet Assoc* **109**, 1022–1030.
30. Liu Y-H, Gao X, Mitchell DC, *et al.* (2019) Validation of a diet quality screening tool for use in the oldest old. *J Nutr Gerontol Geriatr* **38**, 196–204.
31. Marra M, Thuppal SV, Johnson E, *et al.* (2018) Validation of a dietary screening tool in a middle-aged Appalachian population. *Nutrients* **10**, 345.
32. Monteagudo C, Mariscal-Arcas M, Rivas A, *et al.* (2015) Proposal of a Mediterranean diet serving score. *PLOS ONE* **10**, e0128594.
33. O'Reilly S & Mccann L (2012) Development and validation of the diet quality tool for use in cardiovascular disease prevention settings. *Aust J Prim Health* **18**, 138–147.
34. Panagiotakos DB, Pitsavos C & Stefanadis C (2006) Dietary patterns: a Mediterranean diet score and its relation to clinical and biological markers of cardiovascular disease risk. *Nutr Metab Cardiovasc Dis* **16**, 559–568.
35. Radd-Vagenas S, Fiatarone Singh MA, Inskip M, *et al.* (2018) Reliability and validity of a Mediterranean diet and culinary index (MediCul) tool in an older population with mild cognitive impairment. *Br J Nutr* **120**, 1189–1200.
36. Reedy J, Lerman JL, Krebs-Smith SM, *et al.* (2018) Evaluation of the healthy eating index-2015. *J Acad Nutr Diet* **118**, 1622–1633.
37. Roy R, Hebden L, Rangan A, *et al.* (2015) The development, application, and validation of a healthy eating index for Australian adults (HEIFA – 2013). *Nutrition* **32**, 432–440.
38. Rumawas M, Dwyer J, McKeown N, *et al.* (2009) The development of the Mediterranean-style dietary pattern score and its application to the American diet in the Framingham offspring cohort. *J Nutr* **139**, 1150–1156.
39. Russell J, Flood V, Sadeghpour A, *et al.* (2017) Total diet score as a valid method of measuring diet quality among older adults. *Asia Pac J Clin Nutr* **26**, 212–219.
40. Schröder H, Benitez Arciniega A, Soler C, *et al.* (2012) Validity of two short screeners for diet quality in time-limited settings. *Public Health Nutr* **15**, 618–626.
41. Schröder H, Fitó M, Estruch R, *et al.* (2011) A short screener is valid for assessing Mediterranean diet adherence among older Spanish men and women. *J Nutr* **141**, 1140–1145.
42. Sofi F, Dinu M, Pagliai G, *et al.* (2017) Validation of a literature-based adherence score to Mediterranean diet: the Medi-Lite score. *Int J Food Sci Nutr* **68**, 757–762.
43. Thorpe MG, Milte CM, Crawford D, *et al.* (2016) A revised Australian dietary guideline index and its association with key sociodemographic factors, health behaviors and body mass index in peri-retirement aged adults. *Nutrients* **8**, 160.
44. Vadiveloo M, Dixon LB, Mijanovich T, *et al.* (2014) Development and evaluation of the US healthy food diversity index. *Br J Nutr* **112**, 1562–1574.
45. Vitale M, Racca E, Izzo A, *et al.* (2019) Adherence to the traditional Mediterranean diet in a population of south of Italy: factors involved and proposal of an educational field-based survey tool. *Int J Food Sci Nutr* **70**, 195–201.
46. Warren-Findlow J, Reeve CL & Racine EF (2016) Psychometric validation of a brief self-report measure of diet quality: the Dash-Q. *J Nutr Educ Behav* **49**, 92–99.e91.

47. Wong J, Haszard J, Howe A, *et al.* (2017) Development of a healthy dietary habits index for New Zealand adults. *Nutrients* **9**, 454.
48. Zarrin R, Ibiebele T & Marks G (2013) Development and validity assessment of a diet quality index for Australians. *Asia Pac J Clin Nutr* **22**, 177–187.
49. Gerber MJ, Scali JD, Michaud A, *et al.* (2000) Profiles of a healthful diet and its relationship to biomarkers in a population sample from Mediterranean Southern France. *J Am Diet Assoc* **100**, 1164–1171.
50. Giacosa A, Barale R, Bavaresco L, *et al.* (2016) Mediterranean way of drinking and longevity. *Crit Rev Food Sci Nutr* **56**, 635–640.
51. Radd-Vagenas S, Singh MAF, Daniel K, *et al.* (2018) Validity of the Mediterranean Diet and Culinary Index (Medicul) for online assessment of adherence to the 'Traditional' Diet and aspects of cuisine in older adults. *Nutrients* **10**, 1913.
52. Archer E, Marlow ML & Lavie CJ (2018) Controversy and debate: memory-based methods paper 1: the fatal flaws of food frequency questionnaires and other memory-based dietary assessment methods. *J Clin Epidemiol* **104**, 113–124.
53. Archer E, Pavela G, Lavie CJ, *et al.* (2015) A discussion of the refutation of Memory-Based Dietary Assessment Methods (M-BMS): the rhetorical defense of pseudoscientific and inadmissible evidence/in reply-a discussion of the refutation of Memory-Based Dietary Assessment Methods (M-BMS): the rhetorical defense of pseudoscientific and inadmissible evidence. *Mayo Clin Proc* **90**, 1736.
54. Ocké MC (2013) Evaluation of methodologies for assessing the overall diet: dietary quality scores and dietary pattern analysis. *Proc Nutr Soc* **72**, 191–199.
55. Newby PK, Hu FB, Rimm EB, *et al.* (2003) Reproducibility and validity of the diet quality index revised as assessed by use of a food-frequency questionnaire. *Am J Clin Nutr* **78**, 941–949.
56. Bennett DA, Landry D, Little J, *et al.* (2017) Systematic review of statistical approaches to quantify, or correct for, measurement error in a continuous exposure in nutritional epidemiology. *BMC Med Res Methodol* **17**, 146–146.
57. Carbonneau E, Bégin C, Lemieux S, *et al.* (2017) A health at every size intervention improves intuitive eating and diet quality in Canadian women. *Clin Nutr* **36**, 747.
58. Pelucchi C, Galeone C, Negri E, *et al.* (2010) Trends in adherence to the Mediterranean diet in an Italian population between 1991 and 2006. *Eur J Clin Nutr* **64**, 1052.
59. Perkins S, Daley A, Yerxa K, *et al.* (2019) The effectiveness of the Expanded Food and Nutrition Education Program (EFNEP) on diet quality as measured by the healthy eating index. *Am J Lifestyle Med* **14**, 316–325.
60. Arvaniti F & Panagiotakos DB (2008) Healthy indexes in public health practice and research: a review. *Crit Rev Food Sci Nutr* **48**, 317–327.

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