

BMJ Open Evaluation of Mediterranean diet adherence scores: a systematic review

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ABSTRACT

Objective The aim of this review was to evaluate the conceptual suitability, applicability and psychometric properties of scores used internationally to measure adherence to the Mediterranean diet (MD).

Design This was a systematic review to identify original articles that examined some aspects of the conceptual suitability, applicability or psychometric properties of the MD adherence score. Electronic searches were carried out on the international databases MEDLINE, Scopus, Web of Science and EMBASE (from January 1980 to 31 December 2015).

Eligibility criteria for selecting studies The study included original articles that examined some aspects of the conceptual suitability, applicability or psychometric properties of the MD adherence score. The studies where MD adherence scores were administered but did not bring forward any evidence about their performance related to conceptual suitability, applicability or psychometric properties were excluded.

Data extraction Information relating to the scales was extracted in accordance with the quality criteria defined by the Scientific Advisory Committee of the Medical Outcomes Trust for measurement of health results and the quality criteria recommended by Terwee: (1) conceptual, (2) applicability and (3) psychometric properties. Three authors independently extracted information from eligible studies.

Results Twenty-seven studies were identified as meeting the inclusion criteria, yielding 28 MD adherence scores. The results showed that evidence is scarce and that very few scores fulfilled the applicability parameters and psychometric quality. The scores developed by Panagiotakos *et al*, Buckland *et al* and Sotos-Prieto *et al* showed the highest levels of evidence.

Conclusions Scores measuring adherence to MD are useful tools for identifying the dietary patterns of a given population. However, further information is required regarding existing scores. In addition, new instruments with greater conceptual and methodological rigour should be developed and evaluated for their psychometric properties.

INTRODUCTION

Several epidemiological studies have evaluated the relationship between health and food intake.^{1–6} Specifically, various population surveys and clinical trials provide evidence that diets that are high in fruits,

Strengths and limitations of this study

- This systematic review represent, to our knowledge, the most comprehensive examination of the evidence on the conceptual suitability, applicability and psychometric properties of scores used internationally to measure adherence to the Mediterranean diet (MD).
- Twenty-seven studies were identified as meeting the inclusion criteria, yielding 28 MD adherence scores. The results showed that evidence is scarce and that very few scores fulfilled the applicability parameters and psychometric quality.
- This review only took account of studies wherein the main objective was to develop or examine data about the applicability or psychometric properties of an MD adherence score. It could produce an underestimation of the predictive and/or concurrent validity, which are the most frequently analysed in longitudinal studies on MD adherence scores.
- Future research should focus on improving the psychometric properties of the MD adherence scores, and analysing the concordance between these instruments in compliance with the normative quality criteria.

vegetables, legumes, whole grains and fish, and moderate in dairy intake, are associated with lower incidence of chronic diseases.^{4–7–10}

The Mediterranean diet (MD) is characterised by a high intake of plant-based foods (vegetables, legumes, fruits, nuts, cereals (mainly whole grain)), olive oil as the main source of fat, moderate amounts of dairy (yoghurt and cheese), low or moderate consumption of fish and meat, moderate consumption of wine consumed with meals, and an active lifestyle.^{11–14} Although the various geographical regions of the Mediterranean have different diets, influenced by sociocultural, religious or economic factors, among others, it can be assumed that these diets are variations of the same MD diet.^{15–16}

Various longitudinal studies have analysed the benefits of MD in comparison with other types of diet.^{17–23} These studies have shown that people with good adherence to MD have



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a better quality of life and greater life expectancy, along with a decreased prevalence of chronic diseases such as certain types of cancer, type 2 diabetes, and cardiovascular or neurodegenerative diseases.^{15 10 24–27} Specifically, the protective role of MD has been attributed to the high intake of plant-based foods, along with a moderate consumption of wine, fish and dairy, and a high intake of monounsaturated fatty acids in lieu of saturated and trans fatty acids, which are linked with an elevated antioxidant capacity.^{8 10} Therefore, it is important to ascertain the degree of adherence to MD through accurate measurement tools such as dietary scores based on the frequency of pattern-consistent and pattern-inconsistent food consumption, as well as compliance with recommended intake.²⁸

Evidence shows that dietary scores are useful tools to evaluate the degree of adherence to MD and its benefits in regard to health. Scores are composite constructs based on dietary components, combining foods and nutrients to obtain valid operational variables that analyse the association between the quality of diet and its health effects.²⁹ Several scores are used to measure the degree of agreement with MD. The first and most widely used score was created by Trichopoulou *et al* in 1995.³⁰ This score evaluates concordance with the dietary pattern, by assigning one point when the intake of protective foods is higher than the median, in the study/sample population, or when the consumption of non-protective foods is lower than the median, and zero in the opposite situations. Other scores based on MD have been created for use in different geographical populations, for populations with different underlying physiological states, so that alternate foods can be incorporated into and/or accounted for within the canonical pattern.^{11 31–34}

The characteristics of MD scores have been reviewed in different studies.^{15 35} However, the quality of these instruments, which is fundamental to ensuring their valid and reliable application, has not been analysed. The heterogeneity of MD adherence scores raises the potential for disparity in analyses, as well as confusion as to which specific score to choose. Therefore, to be able to

select a good instrument, one must first know the quality criteria it offers. Knowledge of such criteria is imperative for the accurate use of the instrument.^{36–39} According to the Scientific Advisory Committee (SAC) of the Medical Outcomes Trust, eight quality criteria must be established, corresponding to three groups of information: conceptual suitability (conceptual and measurement model, cultural and linguistic adaptation); applicability (demands of the administrator and respondent, alternative forms, interpretability); and psychometric properties (reliability, validity and responsiveness).³⁹

For this reason, the aim of this review was to evaluate the conceptual suitability, applicability and psychometric properties of MD adherence scores used internationally.

METHODOLOGY

Search strategy

To obtain original documents, electronic searches were carried out using the following international databases: MEDLINE, Scopus, Web of Science and EMBASE. The search strategy was designed to obtain original studies about the development or validation of scores measuring adherence to MD, published until 31 December 2015 (January 1980 to 31 December 2015). This strategy focused on combining the following keywords: Mediterranean diet, score and adherence, and terms associated with the psychometric properties of instruments (validity, quality and reproducibility). In order to increase the sensibility of the search strategy, searches were conducted using the thesaurus of each of the databases selected and keywords—in the title and abstract—associated with the search terms (figure 1). The electronic searches were complemented by manual searches⁴⁰ in international journals with regard to their relevance and frequency in the publication, by new searches on PubMed under the names of the identified MD score and under the names of the authors who had created or adapted them, and by the references of the articles that complied with the inclusion criteria. Abstracts from congresses and grey literature were excluded.

1. (mediterranean diet[Title/Abstract]) OR mediterranean diet[MeSH Terms]
2. (adherence [Title/Abstract])
3. (score [Title/Abstract]) OR (index [Title/Abstract])
4. ((quality) [Title/Abstract]) OR (validity[Title/Abstract]) OR reproducibility of results [MeSH Terms] OR reproducibility of results [Title/Abstract] OR psychometrics [MeSH Terms] OR psychometrics Title/Abstract]
5. 1 AND 2 AND 3 AND 4

Figure 1 Search strategy using MEDLINE for studies on the evaluation of Mediterranean diet adherence scores. Search was conducted on MEDLINE with the appropriate search terms used for the other databases.

Inclusion criteria

All original articles that examined some aspects of the conceptual suitability (conceptual and measurement model, cultural and linguistic adaptation), applicability (demands of the administrator/respondent, alternative forms and interpretability) or psychometric properties (reliability, validity and responsiveness) of the MD adherence score in English or Spanish published until 31 December 2015 (from January 1980 to 31 December 2015) were included.

Exclusion criteria

The studies where MD adherence scores were administered but did not bring forward any evidence about their performance related to conceptual suitability, applicability or psychometric properties were excluded.

Selection of studies

Two reviewers (RF-C and AZ-M) assessed the titles and abstracts to determine their inclusion or exclusion from the review. The reviewers worked independently, and if they were in disagreement a third reviewer (MJC-M) would resolve the disagreement or recommend reading the whole article.

Data extraction

Information was extracted by the same researchers (MJC-M, RF-C and AZ-M), who had independently carried out the selection of original articles, resolving disagreements through consensus with a third person. The information extracted was divided into two sections: information about the characteristics of the study and the sample, and information about the measurement scales. The first section included the characteristics of the study and the sample (inclusion criteria, sample size and origin of the population).

Information relating to the scales was extracted in accordance with the quality criteria defined by the SAC of the Medical Outcomes Trust for measurement of health results and the quality criteria recommended by Terwee.^{36–39} In order to facilitate understanding, the eight attributes of the SAC were included in three groups of information⁴¹: (1) conceptual suitability (conceptual and measurement model, cultural and linguistic adaptation); (2) applicability (demands of the administrator/respondent, alternative forms and interpretability); and (3) psychometric properties (reliability, validity and responsiveness). Online supplementary table 1 sets out the quality criteria used and their measurement values. Finally, a summary table was created providing evidence from all the scales, with a view to synthesising information on the basis of the criteria developed by McDowell.⁴² The following assessment criteria were established: (1) process of cross-transcultural adaptation (? : not reported; + : translation only; ++ : translation-back translation; +++ : translation-back translation and pilot test); (2) applicability (? : not reported; + : data about the process of administration and interviewing; ++ : visual material about foods

and training of interviewers; +++ : normative data); (3) reliability (? : not reported or weak associations of some aspects of internal consistency reported; + : alpha coefficient of internal consistency, or intrarater or inter-rater reliability reported; ++ : alpha coefficient or interclass correlation coefficients (ICC) or correlated coefficient >0.70; and (4) validity (? : not reported; + : evidence from criterion or construct validity; ++ : evidence from criterion and construct validity).

RESULTS

Search results

A total of 56 articles met the inclusion criteria, which were reduced to 52 once the duplicates had been removed (figure 2). In addition, 19 of these articles were excluded after reviewing the title and the abstract because they did not meet the inclusion criteria. Finally a further six articles were excluded because they did not use specific MD adherence scores in their methodology. Therefore, 27 articles were included in the review, from which 28 MD adherence scores were used.

Characteristics of included studies

The designs of the studies included were principally observational (12 cohort studies,^{14 16 26 28–31 43–47} 1 case and control study,³⁴ 14 descriptive studies^{6 11 12 29 32 33 48–55} and 1 intervention study⁵⁶). A total of 17 studies focused on the general population,^{6 14 26 29 32–34 46–50 52–56} 3 on the elderly,^{30 43 45} 2 on children,^{11 12} 1 on university students¹⁶ and 1 on pregnant women.³¹ Finally, three of them did not indicate the target population of the scores.^{16 28 44} With respect to sample size, the scores created by Trichopoulou *et al*^{14 43} were developed using large samples: 22 043 and 74 607 people, respectively. There were three studies with a sample size of <150 people.^{29 51 56}

Conceptual suitability

Online supplementary table 2,3 summarise key data regarding the conceptual suitability of the different scores: the context in which they were applied, content validity and cross-cultural adaptation process. The scores were listed according to their conceptual model and measurement. The majority of the scores (n=18)^{6 11 14 16 26 29–34 43–45 48 49 51} were based on positive and negative components of MD. Five of them were based on the structure of the MD food pyramid,^{28 52–54 56} three on the general characteristics of MD^{46 47 55} and one on the Diet Quality Index.¹² As a fundamental model, the scores created by Trichopoulou *et al*^{14 30 43} have been the most widely used, with six scores being created on the basis of their components.^{16 26 29 31 45 50}

Although there is no consensus on the meaning of the ratings, as a general rule, interpretation of these scales is positive for healthy items and negative for unhealthy items, with high scores indicating good adherence to the MD and low scores, poor adherence. Only the scores created by Scali *et al*⁴⁸ and Gerber⁴⁹ provide inverted

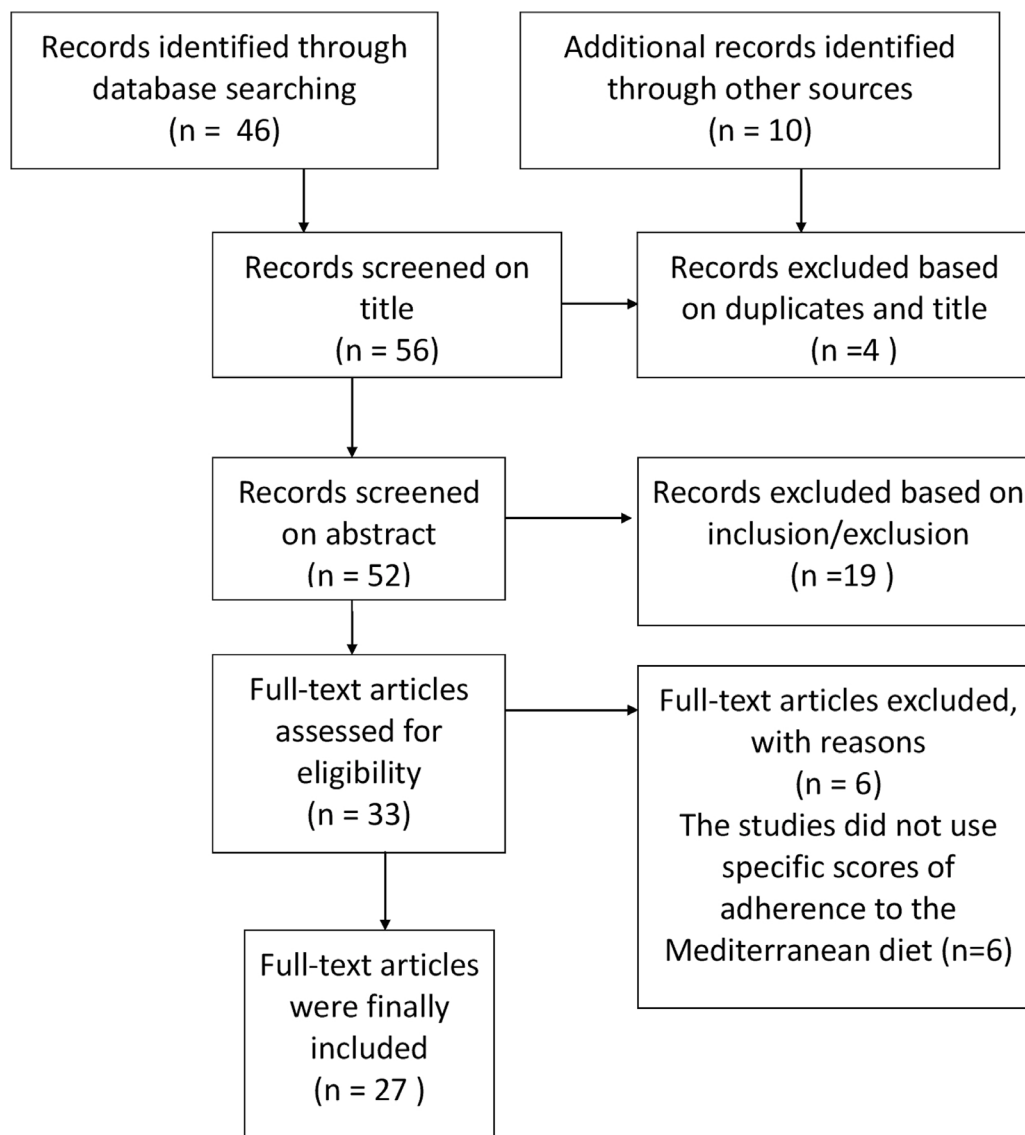


Figure 2 Search and inclusion process flow chart of studies to include in systematic review of the evaluation of Mediterranean diet adherence scores: identification, screening, eligibility and inclusion.

scores, where high scores indicate low adherence and low scores indicate good adherence (online supplementary table 2).

The majority of the scores were developed in Mediterranean countries: Spain (n=14),^{11 12 16 26 29 31–34 47 50 53 54} Greece (n=3),^{6 14 30} Italy (n=2),^{46 47} and France (n=2).^{48 49} The remainder were developed in Canada (n=1),⁵⁶ other European countries (n=3),^{43–45} Japan^{52 55} and the USA (n=2).^{28 55} (see online supplementary table 2).

Regarding the context of application (online supplementary table 3), 12 of the 28 scores analysed were applied to the general population,^{16 26 45–47 49–54 56} 6 in primary care,^{6 29 32 43 48 55} 3 in hospital care,^{31 33 34} 6 in the community^{6 11 14 28 30 55} and 1 in sports clubs.¹² The scores developed by Panagiotakos *et al*⁶ and Woo *et al*⁵⁵ are used in the context of primary care and also in the community.

None of the MD adherence scores detail the process of cross-transcultural adaptation. The majority of the scores come from the one Food Frequency Questionnaire

(FFQ) previously validated for the population studied; however, in the original studies of this instrument (FFQ), the process of cross-cultural adaptation has not been detailed.

With regard to content validity, the majority of scores based on negative and positive components^{6 14 26 29 31 43 45 50} are created in function of the scores developed by Trichopoulou and colleagues.³⁰ Scores of the MD pyramid are based on the pyramid elaborated by Bach-Faig and colleagues.⁵⁷ The rest of the scores are founded in general references of the MD pattern.

Applicability

Relating to the applicability of the MD adherence scores, with the exception of the score created by Woo *et al*,⁵⁵ who did not specify the method of administration, all diet questionnaires were administered by trained interviewers. Regarding the source of information, all of the scores were answered by the patients/participants (not by a

proxy), except for the scores created by Serra-Majem *et al*¹¹ and Woo *et al*.⁵⁵ The participants completed the diet questionnaires, and the researchers calculated the MD score. The time taken to administer and complete the items was not reported for any of the scales analysed. The only information provided was the existence of trained staff to administer the questionnaires. Regarding the completion of questionnaires about food intake, only five of the scores^{6 14 26 48 55} indicate having used a portion size booklets in order to help participants estimate their food intake more accurately. None of the studies provided normative data about the scores.

Psychometric properties

With regard to internal consistency (online supplementary table 4), only the score created by Sotos-Prieto *et al*⁵⁴ provided a Cronbach alpha coefficient of 0.75. Given that the authors do not report item-test correlation coefficients, the degree of association between the items and the overall score was taken into account. The association between high global scores and the consumption of fruits, vegetables, nuts and olive oil^{6 14 28 31 48–50 53} was reported in eight of the scores. With respect to equivalence, only the two scores created by Benítez-Arciniega *et al*²⁹ provided data on equivalence (*inter-rater*) (ICC modified Mediterranean Diet Score=0.48 and ICC Mediterranean-Like Diet Score=0.62). None of the scores reported on test–retest reliability (*intra-rater*).

Relating to criterion validity, predictive and concurrent validity were evaluated (online supplementary tables 5a and 5b). Predictive validity was reported in 5 of the 28 scores, using mortality rate or cardiovascular events as the predictive criterion. High MD adherence scores were associated with a significant reduction in the risk of mortality OR (0.64–0.83).^{14 26 30 43 45} In only one study was the MD adherence score associated with cardiovascular events (increase adherence=40% lower cardiovascular risk; $P<0.001$).²⁶ Concurrent validity was reported in 10 of the 28 scores; adherence to MD was associated inversely with clinical and biological markers of cardiovascular disease risk,^{6 33 34 52 56} body mass index, waist-hip and weight.^{28 31 32 50 53 56} Finally, for the analysis of construct validity, the authors linked scores with other variables and scales (online supplementary table 6). All measurement scores, with the exception of those developed by Trichopoulou *et al*^{14 30 43} and Alberti-Fidanza *et al*,⁴⁶ displayed a relationship with other health and dietary behaviour variables (sociodemographic variables, level education, physical activity, habit of smoking, alcohol consumption, age, antioxidants, energy and food intake). As for the relationship with other scales, only the scores created by Buckland *et al*,²⁶ Mariscal-Arcas *et al*,³¹ Knoops *et al*⁴⁵ and Monteagudo *et al*⁵³ indicate comparison with the MD adherence score created by Trichopoulou *et al*,³⁰ obtaining high levels of agreement (70%).

With regard to the measure of responsiveness, none of the scores provided an estimation of a statistic capable of measuring effect size. Only the score developed by Goulet

*et al*⁵⁶ examined the effect of a nutritional intervention, in which MD adherence scores increased significantly from 21.1±3.6 in week 0 to 28.6±4.4 ($P<0.001$) after 6 weeks of intervention.

Online supplementary table 7 presents the MD summary scores. Only four scores did not provide any information about the cross-transcultural process.^{14 31 32 47} The scores developed by Panagiotakos *et al*,⁶ Trichopoulou *et al*,¹⁴ Scali *et al*,⁴⁸ Gerber⁴⁹ and Woo *et al*⁵⁵ obtained the best evaluations in terms of applicability. The score created by Sotos-Prieto *et al*⁵⁴ was the instrument with the most and best evidence on reliability. Information about validity was provided for most of the scores, but concurrent and predictive validity were only reported for the scores created by Panagiotakos *et al*,⁶ Schröder *et al*,³² Martínez-González *et al*^{33 34} and Knoops *et al*.⁴⁵ The results indicate that the scores with the best overall evaluation were those created by Panagiotakos *et al*,⁶ Buckland *et al*²⁶ and Sotos-Prieto *et al*.⁵⁴ However, only the study by Sotos-Prieto *et al*⁵⁴ provided information about reliability.

DISCUSSION

The review conducted here included 27 references and identified 28 MD adherence scores used internationally. The evidence obtained from these studies has been evaluated based on conceptual suitability, applicability and psychometric properties. The results reveal that evidence is scarce, and that very few scores fulfil psychometric properties and applicability parameters typically associated with scales/indices. The scores developed by Panagiotakos *et al*,⁶ Buckland *et al*²⁶ and Sotos-Prieto *et al*⁵⁴ provide the most information. However, as with the other scores analysed, none of them provide complete information about the process of transcultural adaptation used. The scores reviewed here only specify that a previously validated FFQ for the original population has been used, but do not provide the transcultural adaptation of these dietary questionnaires (translation, back translation and pilot study). The Scientific Committee of the Medical Outcomes Trust³⁹ considers cultural and linguistic adaptation to be an especially important criterion in achieving linguistic and cultural equivalence with an original instrument.

Applicability is one of the sections that present the most information gaps. None of the scores report on normative data, and only five of them^{6 14 25 48 55} provide detailed information about the administration process using photographic and visual material to obtain information as close to reality as possible.

The data about reliability are the most deficient. To ascertain the degree to which all the items on a scale measure the same construct, internal consistency must be measured. In this case, the score created by Sotos-Prieto *et al*⁵⁴ is the only one that provides information about this topic, through the Cronbach alpha value. The degree of association between the scores obtained and the items included on the instrument has been taken into account,

but this information cannot be considered a quality item-test measure of reliability. Regarding reliability data, only the two scores created by Benítez-Arciniega *et al.*²⁹ display test–retest reliability and equivalence reliability.

Validity was the most widely reported property. Only the scores created by Benítez-Arciniega *et al.*²⁹ did not include any information about validity. In the scientific literature, there are different gold standards to evaluate criterion validity, such as clinical and biological markers for concurrent validity, and adverse events for predictive validity. However, the best gold standard, ‘observation of food intake’, has not been used in any of the studies. In some of the studies analysed,^{26,31} the gold standard used is the score created by Trichopoulou *et al.*,³⁰ obtaining agreement levels of close to 70% with the original, considered here to provide construct validity. This one was the first score used to measure levels of adherence to MD, but it cannot be considered a gold standard, since there is new evidence indicating changes in food and diet patterns. It should also be pointed out that no confirmatory analysis was conducted in relation to the structure of the instruments.

It has been consistently demonstrated that MD helps to protect against cardiovascular disease, inflammatory and metabolic diseases, as well as numerous chronic degenerative diseases^{12,35,58–63}; nevertheless, the protective effect of MD is very different across the studies.^{35,64} Consequently, a large number of MD adherence scores are being created to ascertain the relationship between diet and health. However, recent publications indicate that some of these scores do not offer strong predictive capacity regarding mortality or disease, thus questioning the quality.^{13,64,65} This observation is borne out by the findings of this study, which has shown that the majority of the scores analysed are lacking in information about the quality attributes of the scales.

For all of the above reasons, greater attention must be paid to the way in which these scores have been created. First, a common criterion should be established to identify the components that make up MD. Second, different elements need to be unified: the number of components (nutrients, foods or food groups), classification categories for each population, measurement scale, statistical parameters (mean, median, tertiles and so on) and the contribution of each component (positive or negative) to the score total.^{15,35,66,67} Finally, given the great heterogeneity of MD in different countries, further confirmatory analyses are required using biomarkers with a view to validating said dietary pattern.

Strengths and limitations

Although the data are conclusive regarding the lack of quality of MD adherence scores and the need to improve the measurement of MD adherence, it is important to take into consideration the limitations of this review, which are related to the process of bibliographic searches, derived from the electronic search and retrieval of documents. In order to control this limitation, multiple synonyms

of the search terms were used, and complementary searches of prestigious journals and bibliographic references were also conducted. Furthermore, this review only took account of studies wherein the main objective was to develop or examine data about the applicability or psychometric properties of an MD adherence score. It could produce an underestimation of the predictive and/or concurrent validity, which are the most frequently analysed in longitudinal studies on MD adherence scores.

In conclusion, the use of scores to measure adherence to MD is a very useful tool for identifying the dietary patterns of the population. However, our results point out that fewer of the analysed scores suit the quality criteria. The scores developed by Panagiotakos *et al.*,⁶ Buckland *et al.*²⁶ and Sotos-Prieto *et al.*⁵⁴ have obtained better evidence, although they have not been considered as gold standard because they do not fit all of the quality criteria. As a consequence, it could be possible that the employed scores to evaluate the relationship between MD and health do not present a good predictive ability, originating significant bias in the obtained results. For all these reasons, further information is required about the scores that currently exist, and/or new instruments with better concept grounded must be developed. Future research should focus on improving the psychometric properties of the MD adherence scores and analysing the concordance between these instruments in compliance with the normative quality criteria.

Contributors Conceived and designed the experiments: AZ-M, MJC-M, RF-C. Analysed the data: AZ-M, MJC-M, RF-C, JAH-S, AL-P. Wrote the paper: AZ-M, MJC-M, RF-C, JAH-S, AL-P. Data interpretation and critical revision of manuscript: AZ-M, MJC-M, RF-C, JAH-S, AL-P. All authors reviewed and approved the manuscript.

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