Technology-based Nutrition Interventions employing the Mediterranean Diet: A Systematic Review

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Abstract

Context: Over the past two decades, overweight and obesity rates have increased exponentially, along with related comorbidities including Type II Diabetes, hypertension, cardiovascular disease, and some cancers. The Mediterranean Diet (MDiet) has been suggested as a potential way to mitigate the health burdens related to overweight and obesity. **Objective:** The current review examined the literature on digital interventions that were MDiet focused to determine efficacy, best practices, and potential limitations. **Data Sources:** The search was conducted across fifteen databases for relevant publications published through April 2020 in English, French, Spanish, Arabic, or Italian. **Data Extraction:** This review adopted PRISMA guidelines using a combination of the keywords and phrases and evaluated independently for relevance, merit, and inclusion/exclusion criteria. **Data Analysis:** The systematic literature review resulted in 15 articles that met search criteria. Ten interventions were delivered online, and 5 were delivered via smartphone using an app. The majority of online delivered, MDiet focused interventions were found to be effective, particularly when modeled after evidence based, and best-practice online nutrition education interventions. Such interventions have also been found to be effective in promoting positive health behaviors and health outcomes, such as increased physical activity, increased HDL, and a lower total HDL cholesterol ratio. **Conclusion:** Technology-based interventions to educate and promote adherence to MDiet are successful at achieving the stated outcomes. Further research is needed to determine the efficacy of MDiet interventions delivered via smartphone apps.

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Keywords: Mediterranean diet; Intervention; Technology; internet; apps

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Introduction

Over the past two decades, obesity rates have reached near pandemic levels. [1] Previous research has evaluated physical activity, nutrition, and diet as mitigators to chronic illnesses related to obesity. [2] The Mediterranean diet (MDiet) is among one of the diets with greatest empirical evidence in peer-reviewed literature that has positive effects on chronic illnesses. [3] The MDiet consists of fish, olive oil, fruits, vegetables, whole grains, legumes, nuts, and small amounts of low-fat and fermented dairy. [3] Empirical support for the MDiet suggests it reduces the incidence, and prevents progression of, cardiovascular disease, [4,5] breast cancer, [6,7] depression, [8,9] colorectal cancer, [10,11] Type II diabetes, [12-14] obesity, [13,15-17] asthma, [18,19] and cognitive decline. [20,21] Based on previous literature demonstrating MDiet's utility, the MDiet continues to be a central focus of many interventions aimed at reducing obesity. [15-17] Prior research on the MDiet assists with guidelines for researchers to develop interventions using the MDiet. [17] However, new modalities have been developed, such as online and mobile platforms supporting the MDiet as a potential way to manage overweight and obesity. [22] Literature demonstrating the effectiveness of adherence to the MDiet on mobile platforms is sparse, leaving a significant gap in knowledge about how best to deliver these interventions. Data collected during the last few decades suggest that tailored computer and online interventions can promote healthy eating habits. It remains to be examined on whether interventions promoting MDiet on mobile platforms are also effective. Online intervention and platforms allow incorporating a range and variety of programs and multimedia tools such as audio, video, etc. with low cost and convenience. The vast tools available lend towards applicability with various learning styles across multiple research and educational settings. We anticipate that technology-based interventions, especially those based on a theoretical framework or model, are effective at increasing adherence to a MDiet and can be

106 successfully implemented across diverse settings and populations, making the internet an ideal
107 resource to deliver health promotion interventions [22-24].

108 Recent reviews by Martinez-Gonzalez et al., [25] and Franquesa et al., [14] provide guidance
109 on methodological nuances, and clinical relevance; however, many questions remain about the
110 effectiveness of diet interventions delivered across all digital platforms. The aim of this
111 systematic review is to examine the current literature on technology-based interventions, with a
112 primary focus on adherence to the MDiet. For the purpose of this manuscript, we define online
113 interventions as those accessible via any Internet accessible device and interventions that are
114 both static (provide only information) and dyadic (web 2.0 human interface). Secondary
115 outcomes are related to the intervention and MDiet, and include weight loss, increase in HDL-c,
116 increased physical activity, increased fruit and vegetable intake, and decreased body fat
117 percentage. Our findings will guide our discussion on methods with most evidence, populations
118 for which digital interventions are most effective, and cost/benefit, if any. Among published
119 peer-reviewed literature, the current review sought consensus on best practices and limitations
120 among evidence-based interventions utilizing the MDiet. Our findings fill gaps that exist in the
121 literature specific to technology-based interventions and their impact on adherence to MDiet, as
122 well as related health outcomes. We also examine the role of theory in each study assessed. This
123 evaluation of the current literature highlights opportunities and areas for improvement in future
124 digitally implemented MDiet interventions.
125

126 **Methods**

127 ***Selection Criteria***

Table 1 details inclusion and exclusion criteria for selected articles. Briefly, inclusion articles considered the following items: 1.) Population - age groups with or without morbidities; 2.) Intervention type - all digitally delivered interventions examining adherence to the MDiet, the impact of MDiet on nutrition behaviors and nutrition-related health outcomes including changes in anthropometric measurements and body composition, blood pressure (BP), glycaemia level, blood lipid profile, dietary fiber intake, physical activity, well-being; and, 3.) Effectiveness of the intervention in achieving the stated aims related to MDiet, including increased scores for MDiet adherence. It is evaluated based on tools such as MDiet Score (for adults) and KIDMED score (for children and adolescents) , as well as changes in anthropometric and biochemical outcomes. The score for MDiet is measured using the validated questionnaire composed of 14 questions. Each question is scored as 0 or 1. Thus, the total score ranges from 0 to 14. Adequate adherence to the Mediterranean diet is considered when the total score is ≥9 points. [26] While, the KIDMED score is calculated using a 16-item questionnaire. It is constituted of 12 positive questions and 4 negative questions. After summing up the responses, the total score obtained is ranging from 0 to 12. [27] The adherence and compliance to the KIDMED is categorized as follows: ≤ 3 (low), 4-7 (medium), and ≥8 (high) .

Peer-reviewed articles published in English, French, Spanish, Arabic, or Italian languages were included. Nutrition interventions reported outside of traditional peer-reviewed articles were excluded (i.e. commentaries, narratives, communications, conference papers, non-interventional studies, white papers, and similar article types) (see Table 1). The search was conducted in Spring 2020 and the results communicate literature published through April 2020. Further, Figure 1 details the elimination process leading towards selected articles. Additionally, we incorporated the Population, Intervention, Comparison, Outcomes and Study (PICOS) [28,29]

151 design guidelines to develop our inclusion and exclusion criteria. Specifically, we are interested
152 in assessing digital interventions aimed at promoting MDiet adherence to address obesity and
153 overweight. The population of focus was generalized, interventions focused on digital platforms,
154 comparisons were guided by prior literature, outcomes sought were guided by prior literature
155 among face-to-face interventions. Logically, we assumed that findings relevant to digital
156 platforms would expand upon prior face-to-face interventions.

157 ***Search Procedures***

158 This systematic review used Preferred Reporting Items for Systematic Reviews and
159 Meta-Analyses (PRISMA) guidelines, [30] and began with a comprehensive search within
160 professional academic databases using a combination strategies of the following MeSH
161 keywords, terms, phrases and Boolean operators: "Computer [All Fields]; OR app [All Fields];
162 OR online [All Fields]; OR digital [All Fields]; OR technology[All Fields]; OR internet-based
163 [All Fields]; OR web-based [All Fields]; AND intervention [All Fields]; OR program [All
164 Fields]; OR education [All Fields]; AND Mediterranean diet [All Fields]; OR Mediterranean-
165 style diet [All Fields]." The search strategy was adapted according to the indexing systems of
166 each respective database. Two of the authors (B.A-E and C.J.S) conducted the searches for
167 relevant articles and one author (B.A-E) utilized Rayyan QCRI software [31] to assist in the
168 screening process. The following fifteen databases were utilized in this search: ArticleFirst;
169 Biomed Central; BioOne; BIOSIS; CINAHL; EBSCOHost; JSTOR; ProQuest; PubMed; SAGE
170 Reference Online; ScienceDirect; Scopus; SpringerLink; Taylor & Francis; and Wiley Online
171 (see Figure 1). Titles and abstracts were screened for relevancy, and subsequently, potentially
172 relevant journal abstracts were reviewed by 3 of the authors (N.B., E.D., and M.B.K.). Potential
173 studies for inclusion in this review were evaluated independently for relevance, merit, and

inclusion/exclusion criteria (see Table 1). Reference lists of included studies were screened for additional relevant studies. Articles accepted for inclusion were individually reviewed by each author; data relevant to review was extracted, tabulated, and assessed for quality based on the AND EAL process (see Table 2). [32] The AND EAL process was conducted by 1 of the authors (E.D.). Any potential disagreements were discussed within the team and consensus reached. Briefly, the AND EAL process expands on a mere narrative search by following a prescribed 5 step systematic literature search process that is established by the Academy of Nutrition and Dietetics. The prescribed steps include formulating an analysis question, gathering and classifying evidence, appraising merit of articles, summarizing evidence, and synthesizing results. [33] If an article did not contain sufficient information for inclusion eligibility, the article was reviewed in its entirety.

Study quality assessment and risk of bias

The authors were instructed on quality assessment before the search and review analysis was performed. Each study was assessed by 2 independent reviewers. After the initial assessment, the reviewing authors exchanged articles. The reviewing authors did not share assessment results. A subsequent discussion was held between the reviewing authors to verify their respective assessment results. All the articles were then discussed by the primary author before final decision for final article eligibility (see Figure 1). The quality of the studies was determined according to the AND EAL process mentioned above and respective quality score was assigned (see Table 2). [32,33]

Results

Study design and countries

The search identified 15 articles that met the established search criteria. The studies were classified according to study design, resulting in 2 single-arm pre-post, 2 quasi-experimental, 5 randomized controlled trial, 2 randomized, double-blind, multicenter, parallel group clinical trials, 2 intervention studies, 1 single blinded, two-arm RCT with individual allocation, and 1 randomized pilot trial. We also categorized whether theory was applied in the research, and if so, which theory was applied. Information regarding the methodology results for these studies is summarized in Table 2.

All studies were conducted between 2005 and 2020 in the following countries; USA, Scotland, Ireland, Netherlands, Spain, Greece, United Kingdom, Poland, Italy, Germany, and Australia. Most of the studies were from the Mediterranean region and Spain (56.2%). Post-intervention follow-up duration varied between studies, lasting from 2 to 12 months, with the exception of one study which included one-week calendar intervals to record pyramid adherence [34]. Six months of follow up was observed for 5 of the 15 studies. Two studies did not note duration.

Age and health status of the target population

Among the fifteen studies included in the systematic review, the majority (87.5%) targeted adults between 18 to 70 years of age. One study investigated 52 children with overweight/obese parents, and one examined adolescent soccer players [mean age=14.19]. Of the 15 studies, 12 included healthy individuals ages 25-75 years, while 3 studies included patients affected with T2DM, obesity and CVD (Table 2).

Technology approach used and measured outcomes

The interventions examined included a variety of digital approaches, such as the use of online courses or games, tailored and/or personalized nutrition education provided via internet or

web-based education, smartphone applications, physical activity monitoring, and tracking adherence to the MDiet. Adherence to MDiet and MDiet score were the most frequently measured outcomes. Other commonly measured outcomes included intake of specific foods (vegetables and fruits), level of physical activity, biomarkers (mostly lipids), BMI and BP.

Primary outcome

Ten studies utilized internet-based technology in their intervention (Table 2). The Food4Me PoP study, conducted across 7 European countries, evaluated a personalized nutrition (PN) and physical activity (PA) intervention using a web-based platform. [35] The study by Livingstone et al. [35] found that post intervention, MDiet scores were significantly greater across the 3 PN intervention levels compared with the control condition (p=.002). [35] Similarly, four other studies offering interventions via online platforms found an increase in MDiet score and adherence post intervention. These include a three-country research collaboration (N=454) conducted between Italy, Spain and Greece, [22] a intervention (N=53) examining MDiet adherence in Scottish females, [36] a pilot intervention based on the Health Action Process Approach (N=70) in Northeast England, [37] and a single arm pre-post study (N=81) using a website and AI coach to improve health outcomes. [38]

Secondary outcomes

At 3-months follow-up, researchers found that the intervention group from the Mediterranean Eating Experience intervention had increased adherence to MDiet, resulting in significantly higher HDL (p<.001) and significantly lower total: HDL cholesterol ratios (p<.001) compared to the control group. [39] A 3 intervention level RCT examining the use of print-based versus web-based educational materials to increase physical activity and adherence to MDiet in children with overweight and obesity (N=52) found significant decreases (p<.05) in body fat

243 across all intervention groups with no between group differences, suggesting that initial
244 counseling followed by the use educational materials whether print-based, web-based, or web-
245 based with motivational emails were equally effective in helping participants adhere to a
246 Mediterranean diet and physical activity regimen. [40]

247 Investigating the impact of a online MDiet module included in an undergraduate nutrition
248 course, researchers found that participants (N=65) increased their MDiet adherence, based on
249 pre-post KIDMED score, with significant increases noted in males ($p<.005$), Whites ($p<.001$),
250 and participants with a family history of heart disease ($p<.002$). [41] A randomized pilot trial
251 investigating knowledge of healthy diets in Spanish youth soccer players (mean= 14.9 years)
252 used the Mediterranean Diet Quality Index (KIDMED) questionnaire to measure MDiet
253 adherence pre-post a 6 month web-based nutrition education intervention and found that while
254 the intervention group significantly increased MDiet knowledge ($p<.001$) post-intervention, this
255 was positively, but weakly, correlated with MDiet adherence ($p=.013$). [42] In an approach
256 utilizing an online game, participants (N=16546) logged weekly food intake and activity relative
257 to the Italian food pyramid guidance system to receive personalized nutrition, and PA
258 recommendations; although MDiet adherence, assessed via a well-being index (W-I), was low, [34]
259 the literature in the current review supports further expanding such interventions to include the
260 use of tailored online education to improve MDiet adherence (Table 2).

261 As indicated in Table 2, Five studies examined adherence to MDiet and PA based on
262 interventions using smartphone apps. [43-47] A pilot RCT conducted with cardiac patients (N=100)
263 in the US compared adherence to MDiet in patients randomized to a standard-of-care (SOC)
264 counseling group vs. those receiving a smartphone-based counseling app; both groups
265 significantly increased adherence to MDiet at 6 months ($p<.001$), with no significant difference

between groups. [44] Another randomized controlled clinical trial (N= 833) examined the impact of a physical activity and MDiet intervention offered via a smartphone app compared to standard counseling on cardiovascular risk factors (CVRFs) and found no significant differences between groups; although cardiovascular risk (CVR) decreased in both groups at 3 months, at 12 months, this decrease was only maintained in the counseling group. [47] Garcia-Ortiz et al., [45] also found that participants in both groups increased MDiet score, however, there was not a significant difference (p=.46) between groups. [45] A study conducted by Recio-Rodriguez et al., [46] found that moderate-to-vigorous activity increased significantly (p<.02) in the intervention group compared to the counseling only group, but this difference was not significant between groups. [46] Utilizing the same app (EVIDENT II) as the previous studies, researchers conducted an RCT to investigate the impact of a multifactorial intervention including a food workshop, PA, and use of the app on adherence to MDiet in adults (N=204) with Type II Diabetes Mellitus (T2DM); it was found that participants in the intervention group reported significantly increased adherence to the MDiet compared to the control group at 3 (p<.001) and 12 months post-intervention (p<.001). [43] To reduce risk of bias we independently assessed quality of study for each selected article following methods described by Liberati et al. [30] and Ouzzani et al. [31] (see Table 2).

Discussion

The primary findings from this literature review indicate that technology-based interventions, particularly those that are based on a theoretical framework or model, are effective at increasing adherence to a MDiet. The applied theories spanned multiple disciplined and included behavioral theories and frameworks such as the Health Belief Model, and Stages of Change. The reviewed interventions effective at increasing MDiet adherence and in some cases physical activity, interestingly several also found a positive impact on critical indicators of

289 health, including decreased body fat, increased HDL cholesterol, and lower total:HDL
290 cholesterol ratios. MDiet has previously been demonstrated to increase HDL and lower the
291 total:HDL cholesterol ratio, which has the potential to reduce cardiovascular risk. [48]

292 These findings were persistent across diverse populations, including participants from the
293 US, Scotland, Ireland, Netherlands, Spain, Greece, UK, Poland, Germany, Italy and Australia,
294 [22,35,36,38,41,47] as well as across a diverse range of ages (14-75 years, [22,34-36,38,39,42-47] indicating that
295 the impact of technology-based interventions to increase adherence to a MDiet could be
296 successfully applied across multiple research and educational settings. A majority of the
297 countries included in the reviewed interventions are Mediterranean countries, and therefore it is
298 reasonable to assume that participants had a familiarity with the MDiet pattern. Further, the
299 diversity of countries included in this review demonstrate the feasibility of promoting healthful
300 eating and behavior change is high across far reaches of the globe. The reviewed research also
301 suggests that a MDiet is an acceptable modification to dietary patterns, regardless of the country
302 the intervention is being implemented in; the acceptability of and adherence to a MDiet in
303 diverse and non-Mediterranean countries has been described in the literature. [49-51]

304 Appropriate design is critical for successful online nutrition education intervention
305 outcomes, and online interventions are often comparably successful compared to face-to-face
306 interventions. [52] However, online interventions are widely accessible to a broader audience, and
307 can save time and resources required for face-to-face interventions.[53] Factors that increase the
308 efficacy of online interventions include tailoring of the intervention, researcher and participant
309 interaction, use of theory to inform the design, emphasis on targeting specific behaviors, and
310 intervention duration of 3 or more months are important factors that increase success. [54-56] Also
311 in alignment with previous findings, some of the reviewed studies found similar but significant

312 increases in MDiet adherence in both online vs face-to-face groups, but mainly no statistically
313 significant between group differences, indicating that effective online intervention design can
314 result in comparable behavior change outcomes relative to in-person interventions. While the
315 findings on the effect of smartphone or app-based interventions to increase MDiet adherence
316 were mixed, four of the included studies found comparable efficacy in the intervention group,
317 with no between-group differences in outcomes.

318 Based on the reviewed literature, online and app-based interventions, particularly
319 interventions that are developed to include a tailored component and are based on a theoretical
320 framework or model, such as the Health Belief Model,[34,35,38,41,47,57] Health Action Process
321 Approach, [22,58] Theory of Planned Behavior, [38,40,59] and the Behavior change wheel model [42,60]
322 are an effective way to educate consumers and promote dietary and health behavior change, to
323 include increasing MDiet adherence, and physical activity. The effect of online intervention
324 delivery is consistent across diverse populations, as well as a wide range of ages, and has broad
325 implications for delivery opportunities for nutrition education. Future research should focus on
326 the potential benefits of reduced programmatic and research costs and increased access related to
327 the ability to offer online interventions. Further research to determine best-practices in relation to
328 the delivery of MDiet related education via apps and smartphones is needed to inform
329 development of app-based interventions and to ascertain whether this modality is as efficacious
330 as online delivery.

331 **Study and outcome limitations**

332 These efforts are not without limitations. We acknowledge that although systematic and
333 thorough some studies not documented in the sought databases might have inadvertently led to
334 its omittance. To counter this limitation we sought among a robust number of 11 databases. Also,

in terms of limitations related to outcomes the vast spread of population, ages, and measures reported lead to limitations of generalizability to any specific subpopulation.

Implications

The current efforts offer critical tools for nutritionists, dieticians, and research interventionists alike that aim to improve weight and health of individuals facing overweight and obesity. The current efforts highlight the need for theoretically-driven intervention studies. Further, findings set the groundwork to enhance future digital interventions utilizing MDiet by synthesizing preliminary evidence of effectiveness of MDiet interventions delivered via digital platforms. The scientific premise is set for future work by highlighting aspects to consider (e.g. population, theory, age group, and measures) in future works.

Conclusion

Technology-based interventions to educate consumers about the benefits of MDiet, as well as increase adherence to MDiet, are successful at achieving these outcomes. In some instances, these technology-based interventions produced significant results when compared to in-person interventions, and in others, the results were comparable with no significant between group differences. Such interventions have also been found to be effective in promoting related health behaviors and health outcomes such as increased physical activity, increased HDL, and lower total: HDL cholesterol ratio secondary to promoting MDiet. Best practices in the design and implementation of online nutrition education can be successfully applied to online interventions specific to MDiet. Further investigation on the best practices related to the development and delivery of app-based interventions to increase adherence to MDiet are needed. Based on the current review, online delivery of MDiet interventions can be successfully

implemented across diverse settings and populations, making the internet an ideal resource to deliver health promotion interventions.

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Conflict of interest

The authors declare no conflict of interest.

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Figure 1. Flow Diagram of Literature Search Process

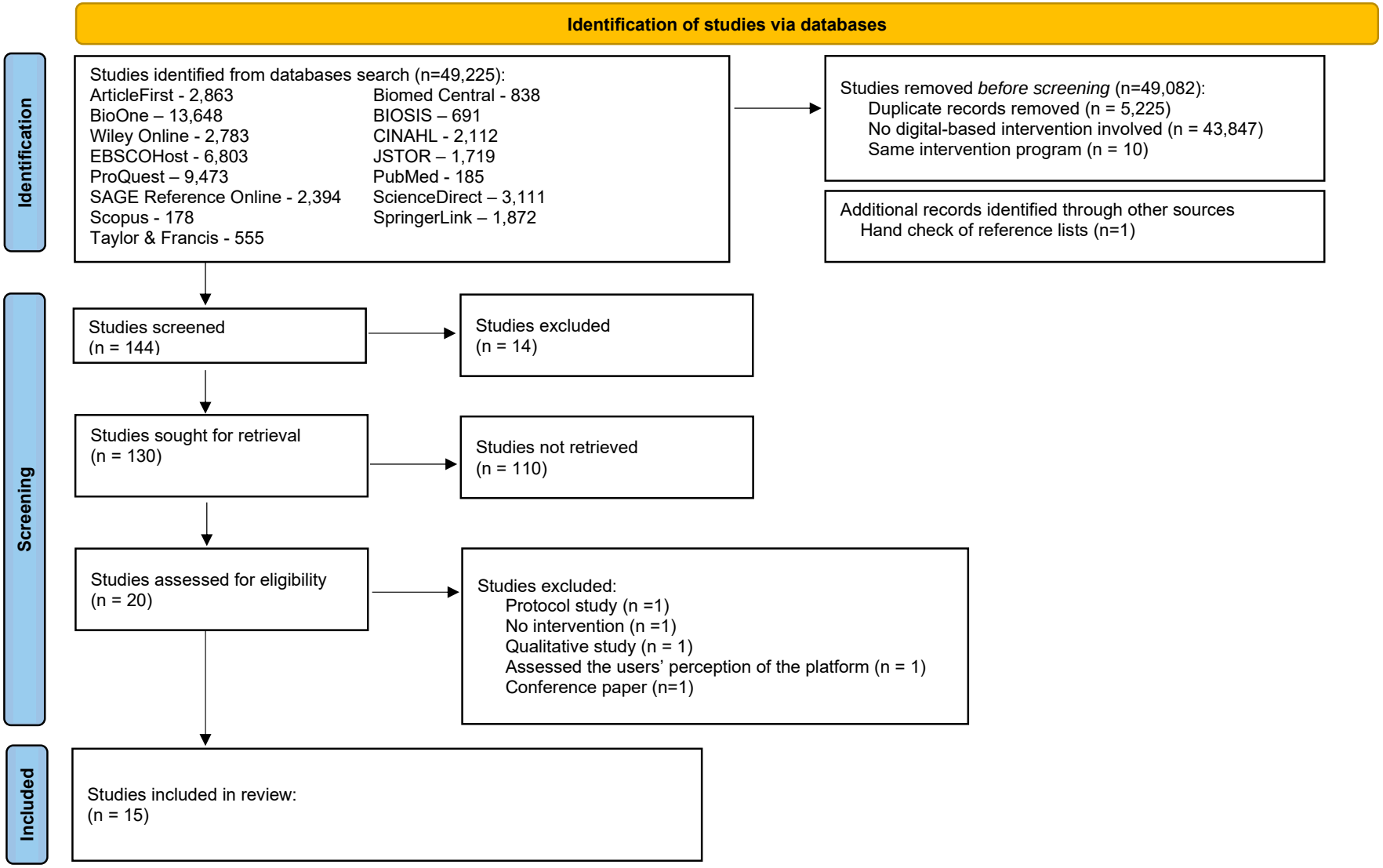

Table 1. PICOS Criteria for inclusion and exclusion of studies

Parameter	Inclusion Criteria	Exclusion Criteria
Population	All age groups	N/A
Morbidities	With or without morbidities	N/A
Intervention type	All digitally delivered interventions examining: - Adherence to the MDiet - Impact of MDiet on nutrition behaviors - Impact of MDiet on nutrition-related health outcomes.	Non digitally formatted or delivered interventions
Outcomes	Anthropometric measurements Body composition Blood pressure Glycaemia level Blood lipid profile Dietary fiber intake Physical activity Overall well-being	Non-numeric/categorical assessments
Effectiveness of the intervention to MDiet	Increased scores for MDiet adherence Increased MDiet Score for adults* Increased KIDMED score for children and adolescents** Positive changes in anthropometric outcomes Positive changes in biochemical outcomes	N/A
Language	English, French, Spanish, Arabic, or Italian	All other languages
Category	Peer-reviewed articles	Non peer-reviewed articles Commentaries Narratives Communications Conference papers Non-intervention based studies White papers Grey Literature Similar article types

**The score for MDiet is measured using the validated questionnaire composed of 14 questions. Each question is scored as 0 or 1. Thus, the total score ranges from 0 to 14. Adequate adherence to the Mediterranean diet is considered when the total score is ≥9 points (Schröder et al. 2011).*[26]

*** The KIDMED score is calculated using a 16-item questionnaire. It is constituted of 12 positive questions and 4 negative questions. After summing up the responses, the total score obtained is ranging from 0 to 12. The adherence and compliance to the KIDMED is categorized as follows: ≤ 3 (low), 4-7 (medium), and ≥8 (high) (Serra-Majem et al. 2003).* [27]

Table 2 Summary of literature search (*n*=15)

Authors (Year)	Quality Score -,θ, +	Target Population	Type of Study	Sample Size	Intervention	Theoretical Framework / Model	Measured Parameters	Main Results	Pre and post intervention MDiet scores	Main Recommendations
Aboul-Enein and Bernstein, 2014 [40]	+	College students male and female (age not indicated) USA	Single cohort pretest-posttest design	N = 65	Online undergraduate nutrition course module using the MDiet	Health Belief Model	Compliance to KIDMED index before and after the intervention	Significant improvement in total KIDMED scoring of participants (p<.001). Differences in KIDMED scores significantly according to ethnicity (p=.007) and family history of HD (p=.002).	Total KIDMED scoring: **Pre**: 4.12 **Post**: 8.45 p<.001.	A single pedagogical illustration of e-learning to promote MDiet patterns is delivered among college students to encourage an alternative nutritional guideline to control overweight and obesity. More research on nutrition intervention considering gender and patients with family history of HD is needed focused.
Papadaki and Scott, 2005 [35]	+	Healthy females (Age range: 25–55 years, age mean: 40.6 y.) Scotland	Quasi-experimental design	N=53 (intervention group) N= 19 (control group)	6-months intervention study internet-based, stepwise, tailored-feedback intervention	Tailored-feedback, not theory based	Consumption of 4 key components of the MDiet: vegetables, fruits legumes and MUFA: SFA ratio. HDL-c Total-c	Significant increase in intake of vegetables (p=.002), fruits, nuts and seeds (p=.025) and legumes (p=.001), as well as the MUFA:SFA ratio (p<.001) in their diet in	Mean total MDiet score **Pre**: 3.21 **Post**: 3.60 P= 0.035	This Internet-based, stepwise tailored intervention used to promote healthy eating in the context of the traditional MDiet presents a realistic approach to dietary behaviour change. This could promote the increase of plant

								the intervention group. Significant increase in plasma HDL-c levels (p<.001) and a reduced ratio of total:HDL-c (p<.001).		foods consumption and to reduce SFA fat and increase MUNFA intake in line with current Scottish dietary recommendations to promote health.
Papadaki and Scott, 2008 [38]	+	Healthy females, (Age range: 25–55 years, age mean: 40.6 years.) Scotland	Quasi-experimental design	N=53 (intervention group) N= 19 (control group)	6-months intervention trial + pre-test–post-test evaluation + a 3-month follow-up tailored dietary and psychosocial feedback + Internet education	Tailored-feedback, not theory based	Dietary intake Blood lipids	Over 9 months, there was a significant increase of vegetable intake (p<.001), legumes (p=.002) and MUFA/SFA ratio (p=.001) There was significant improvement in levels of HDL-cholesterol (p=.005) and ratio of total: HDL-c (p=.0025) in intervention group compared with control group.	Mean total MDiet score **Pre**: 3.21 **Post**: 3.60 P= 0.035	The success of the intervention is proved as indicated by sustainability of adequate changes in dietary and blood lipid profile. In terms of practical implications, this intervention can be effective to promote adopting a MDiet style diet in work settings.

Livingstone et al., 2016 [34]	+	Adults male and female (Mean age 39.9) 7 European countries (Ireland, Netherlands, Spain, Greece, United Kingdom, Poland and Germany)	Randomized controlled trial (Food4Me)	N = 1607	6-months intervention + internet based + PN	Personalized nutrition and Health Belief Model	Dietary intake (MDiet score) BMI PA level	At baseline, an association was obtained between MDiet scores and healthier lifestyles and lower adiposity ($p<.05$). After the intervention, MDiet scores increased in intervention compared to control group ($P = .002$). Dietary advice based on DNA resulted in major differences in MDiet scores ($P = .029$), however clinical application of this result is limited.	Mean total MDiet score **Pre**: 5.10 **Post**: 5.48 (No p-value was provided comparing before and after intervention).	It is recommended to provide individuals with detailed, tailored combining of diet, phenotype, and genotype. Internet-based approaches could promote a cost-effective offer scaling-up PN interventions.
Alonso-Domínguez et al., 2019 [42]	+	Male and female T2DM Patients 2 groups of age:	Randomized and controlled clinical	N=204	A 12-month multifactorial intervention:	No theory noted	Adherence to MDiet Diet Quality Index WC BMI	Adherence to the MDiet ($p<.001$) and diet quality index ($p<.001$) improved more	Mean total MDiet score **Pre**: 7.2 **Post**: 8.5 $P<0.001$	This multifactorial intervention including component of food workshop and a smartphone

		(Age range 25–50 and 51–70 years) Spain	trial with 2 parallel groups		Food workshop + a smartphone application + heart-healthy walks		Total cholesterol LDL-c HDL-c	in intervention group after 3 and 12 months follow up. There was a trend in maintaining the favorable changes in interventional group after 12 months and significant increase of consumption of olive oil (p<.001), nuts (p<.001), white meat more than red meat (p=.004) and use of sofrito sauce ≥2 servings /week (p=.004).		application showed moderate effect in increasing adherence to the MDiet and diet quality quality among patients with T2DM.
Choi et al., 2019 [43]	+	Male and female adult patients consulting to the cardiology clinic (Mean age: 56.6 years for male and 57.2	Randomized controlled trial	N=100	A 6 – months intervention Experimental group: received a smartphone app-based Mediterranean diet intervention	No theory noted	Knowledge of a Mediterranean diet Adherence to MDiet Height Weight, BP Laboratory biomarkers	BP, lipid parameters, HbA1c, or CRP did not show any significant difference between the two groups (p>.05).	Mean total MDiet score **Pre**: 7.15 **Post**: 8.8 P=0.02	Adherence to MDiet was effective with both traditional or smartphone app-based nutrition counseling.

		years for females) USA			Traditional standard-of-care group: received 2 additional sessions of in-person dietary counseling.		(HbA1c + CRP)	Weight loss was significant in experimental group (p=.03) compared to control group. The increase in adherence to MDiet and diet compliance was significant in both group over time (P<.001), with no difference between the groups.		
Garcia-Ortiz et al., 2018 [44]	+	Male and female adults Participants Mean age 51.8 years Spain	Randomized, controlled, multicenter clinical trial with 2 parallel groups	N=833	A 12 months intervention Control group : Counseling on PA and the MD Intervention group: Counseling on PA and the MDiet + training in the use of an app during 3-months.	No theory noted	Adherence to MDiet Adherence to smart phone apps PA	A decline in PA was registered in both groups at 12 months (p=.15). High app adherence lead to better behavior (p=.001). Adherence to MDiet increased in both groups at 12 months, no significant differences	Mean total MDiet score **Pre**: 7.55 **Post**: 8.05 (No p-value was provided comparing before and after intervention).	The stronger the adherence to the apps, the better the obtained results among participants in terms of healthy lifestyles.

								between both groups (p=.46).		
Recio-Rodríguez et al., 2016 [45]	+	Adult subjects (Mean age 51.7 years) Spain	Randomized, double-blind, multicenter, parallel group clinical trial	N=833	A 3-month intervention Control group: will receive counseling on how to adapt to the MDiet and on PA Intervention group: will receive counseling on how to adapt to the MDiet and on PA + training on how to use a smartphone application to promote a healthy diet and PA.	No theory noted	Adaptation to the adherence to MDiet PA Vascular structure and function: Central arterial pressure + radial augmentation index, +Pulse velocity, + Cardio-ankle vascular index, + Carotid intima-media thickness	Significant increase of leisure-time MVPA in intervention group (p=.02) but not in the control group only group; p=.38). No significant differences in increase of activity were found between the two groups. The accelerometer recorded a decrease in PA after 3 months in both groups Increased in adherence to the MDiet was obtained in both groups (p<.001), but no difference between groups (p=.86).	The reported change was given in overall score of mean of MDiet. Post intervention score increased by 0.42 points in the smartphone application + training group. Post intervention score increased by 0.53 points in the counseling group.	More research studies to be carried out to identify the population subgroups which would benefit mostly from interventions based on information and communication technologies.

Schwarzer et al., 2017 [22]	+	Adults males and females (age range 18–65 years) Italy, Spain and Greece	Intervention study	N= 454 at baseline and N= 112 at follow-up	A 2-month follow-up web- based intervention	Health Action Process Approach including stages of change, outcome expectancies, planning and action control	Dietary behaviours index MDiet scores Psychological constructs: outcome expectancies, planning, action control and stage of change	The MDiet scores increased (p<.01). Interactions were found between time and all four psychological constructs on the obtained changes (P<.05) Participants with low levels of baseline psychological constructs were found to demonstrate greater behavioural adoption (p<.01).	Mean total MDiet score **Pre**: 7.44 **Post**: 8.13 (No p-value was provided comparing before and after intervention).	The intervention is efficient in terms of improving MDiet consumption, with psychological constructs. It is recommended to take into account differences in readiness of individuals for change which would help adopting MDiet and the given treatment.
Lara et al., 2016 [36]	+	Adults regular internet users, within two years of retirement Northeast England	A single blinded, two-arm RCT with individual allocation	N= 70	A 2-month intervention Control group: receiving 'usual care' control Intervention group: LEAP: Receiving a	Health Action Process Approach	Adherence to a MDiet PA by accelerometry Healthy ageing outcomes: Measures of physiological function +	Participants had considerable scope for improvement in diet as assessed by MDiet score. The web platform LEAP was visited a median of 11	Mean total MDiet score **Pre**: 4.7 **Post**: 4.6 p>0.05	Feasibility and effectiveness of the trial procedures and the LEAP intervention using a web platform is demonstrated.

					web-based platform promoting healthy eating: MD + PA + meaningful social roles + a pedometer for self-monitoring of PA		Physical capability, cognition + Psychological and social wellbeing	times, for a mean total time of 2.5 hours. The module with highest visiting number are 'Moving more', 'eating well' and 'being social' were the most visited modules. LEAP participants emphasized on the importance and acceptability of that diet and PA within the context of healthy ageing.		
Bruñó et al., 2018 [39]	θ	Overweight or obese children and adolescents Spain	Randomized clinical trial	N=52	3 months intervention Mixed exercise (aerobic and resistance) + MDiet program either implemente	Theory of Planned Behavior	Percentage body fat Physical fitness (VO_2 peak), Handgrip strength, SBP DBP	Differences between groups was not significant ($p>.05$). Body fat percentage metrics over time significantly improved in	MDiet scores were not calculated.	Practice Implications: A 3-month intervention composed of MDiet and physical exercise program could be beneficial in improving the body composition of children and adolescents with overweight/obesity.

					d by means of printed material or via a web-platform (with or without e-mail support) 3 intervention groups: Print-based group Move-It group Move-It plus support group			for all three groups ($p<.05$). 10 min after the exercise-stress test, theVO_2 peak ($p=.027$), handgrip strength, and blood pressure variable values improved in the three groups, but significance found for SBP-10min only for "Move It plus support" group ($P<.009$).		
del Balzo et al., 2012 [33]	θ	Adult male and female (Average age 33.5±15 years) Italy	Intervention study	N=16546	Weekly lifestyle game	Health Belief Model	Well-being index Consumption of different food groups (MDiet) PA	The eating pattern obtained demonstrated variety among participants. Daily consumption of different food groups was registered, although in lower quantities than suggested.	MDiet scores were not calculated.	Efficiency of the web-based personalized intervention is demonstrated.

								Nutritional habits were different due to age and educational level.		
Gonzalez-Sanchez et al., 2019 [46]	+	Male and female patients, who attended a consultation with their family doctor 18-70 years Spain	Multicenter, randomized and controlled clinical trial	N=415 counseling + app group (IG) N= 418 counseling only group (CG).	12 months follow up intervention on PA and MD.	Health Belief Model	DBP SBP Total-c HDL-c HbA1c Glycemia BMI PA Global CVR	CVR did not change significantly at 3 or 12 months (p>.05). However, SBP (p=.013), DBP (p=.019), total-c (p=.011) and triglycerides (p=.035) were better in CG group compared to IG group (p>0.05)	MDiet scores were not calculated, as it was reported in a previous publication (Garcia-Ortiz et al., 2018).	The use of an app during 3 months in addition to a standard counseling had no supplementary positive long-term effects on either diet or PA.
Maher et al., 2020 [37]	+	Male and female inactive community-dwelling adults (Age: 45 to 75 years) Australia	Single-arm pre-post	N=81	12 weeks intervention artificially intelligent chatbot (Paola) + a Garmin Vivofit4 tracker to monitor daily steps + A website with	Health Belief Model and Theory of Planned Behavior	Feasibility of the intervention PA Diet Body composition Blood pressure	Significant increase of total daily steps compared with baseline (p<0.05) Significant improvement in MDiet scores with mean increase of 5.7 points, (p<.05)	Mean total MDiet score **Pre**: 3.8 **Post**: 9.6 p<0.05	Feasibility of life-style intervention based on the artificial intelligent virtual assistant is demonstrated.

					educationa l materials and recipes + A printed diet an activity log sheet.			Significant reduction of weight and WC, (p<.05) Feasibility and safety of the intervention are demonstrated.		
Fernández-Álvarez et al., 2020 [41]	+	Adolescent soccer players (mean age=14.19 years) Spain	A random ized pilot trial	N=319	Control group (CG) Interventio n group (IG): 6 months educationa l interventio n based on the use of posters, a web-app, and practical activities on MDiet	Behavior Change Wheel Model	Usage rate of MDiet adherence to MDiet Acquisition of knowledge MDiet	A significantly higher mean score on the knowledge questionnaire was obtained in IG compared to GC (p <.001). The correlation between diet knowledge and KIDMED scores was positive and weak (r =.222, p =.013). About 1/3 of the total post-test KIDMED score was explained by the total pretest KIDMED (p <.001) and diet knowledge (p =.05) scores	Mean total KIDMDiet score **Pre**: 6.34 **Post**: 6.39 p>0.05	Feasibility of the intervention combining the use of posters and a web app is demonstrated. It provides information on healthy eating habits to adolescent soccer players and how to maintain them.

Abbreviations

ABSI: Body shape index
BMI: Body mass index
CRP: C-reactive protein
CVR: Cardio-vascular risk
DBP: Diastolic blood pressure
HbA1c: hemoglobin A1c
HD: Heat Disease
HDL-c: High density lipoprotein cholesterol
KIDMED: Mediterranean Diet Quality Index for children and teenagers
LEAP: Living Eating, Activity and Planning through retirement
MDiet: Mediterranean Diet
MUFA: Monounsaturated fatty acids
MVPA: Moderate-to-vigorous physical activity
PA: Physical activity
PN: Personalized Nutrition
SBP: Systolic blood pressure
SFA: Saturated fatty acids
T2DM: Type 2 Diabetes Mellitus
Total-c: Total cholesterol
WC: Waist circumference