Lead Article

Factors that contribute to effective online nutrition education interventions: a systematic review

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Context: *The use of the internet and technology as a medium for delivering online nutrition education (ONE) has increased; however, evidence-based studies exploring factors that contribute to best practices in online interventions have not emerged.* ***Objective:*** *The purpose of this systematic review was to identify factors that contributed to successful ONE interventions in relation to research studies published between 2009 and 2018.* ***Data sources:*** *Following the PRISMA guidelines, relevant studies were identified through PubMed, Medline, Web of Science, Science Direct, and Education Resources Information Center (ERIC) databases.* ***Data extraction:*** *Five authors screened and determined the quality of the studies using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system and extracted the data from the articles.* ***Data analysis:*** *Twenty-seven studies were included: 21 studies were website-based, 3 were delivered through smartphone application, 2 were delivered as online courses, and 1 used text messages. Tailored messages/feedback, interaction between participants and investigators, identification of specific behaviors, use theory, adequate duration, and alignment between stated objectives and activities were factors that contributed to successful online interventions, while comparison bias and the lack of specific details on duration and dosage, tracking system, objective outcome measurements, and follow-up were factors that may have interfered with successful ONE interventions.* ***Conclusions:*** *The findings underscore the importance of developing ONE intervention designs that utilize factors unique to online platforms for effective interventions aimed at behavior change.*

INTRODUCTION

Nutrition education interventions have the potential to improve dietary habits[1] and encourage healthy food choices, resulting in lifestyle behavior changes.[2] However, for nutrition education interventions to be effective in changing behavior, it is critical for the interventions to identify desired behavior,[3] provide guidance on suitable dosages,[4–6] and include appropriate activities for the target population.[6,7] For example, the diabetes self-management education intervention targeting Mexican Americans, delivered by Brown et al,[4] found that the group that received an extended intervention – that included 24 hours of education and 28 hours of support groups – showed the greatest reduction in HbA1c (glycated hemoglobin HbA1c) values from baseline to 12 months compared to the group that received compressed intervention of only 16 hours of education and 6 hours of support groups. Similarly, Murimi et al[6] found that an intervention duration of at

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Key words: interventions, nutrition education, online interventions.

doi: 10.1093/nutrit/nuz032

least 6 months, with guidance on suitable dosages, contributed to the effectiveness of nutrition education interventions among elementary schoolchildren. In addition to the design factors, the mode of presentation – for example face-to-face or online – is critical in achieving the objectives of the intervention.

Traditionally, face-to-face nutrition education interventions have been effective in improving and increasing nutrition knowledge,[8,9] influencing healthy behavior changes,[9] and in some cases improving health outcomes.[10] Face-to-face interventions are delivered through either individual or group settings, which affords personal interactions between the intervention provider(s) and participants.[11] However, the face-to-face delivery method has major limitations in terms of reaching individuals who have time constraints or reside in different geographical locations.[12,13] In contrast, online intervention methods offer enhanced accessibility, cost-effectiveness, and time flexibility.[14,15]

In addition to the accessibility and convenience of online interventions, the global usage of internet forums has increased. For example, according to the Internet World Stats website,[16] almost two-thirds of the world's population has internet access. In addition, the internet has the potential to simultaneously disseminate a large number of messages and share nutrition and health-related information.[17,18] For instance, online learning programs have the potential to facilitate synchronized forms of communication between instructors and learners or between groups of different learners.[19]

Despite their popularity, the wide usage and convenience of online nutrition education interventions, the limitations of online delivery methods are concerning and include failure to adequately engage targeted audiences,[20] the introduction of bias by relying on self-reported data,[21,22] and failure to sustain the outcome of intervention.[23] To date, outcomes on the effectiveness of online nutrition interventions have been mixed, and unlike face-to-face delivery methods that have been tested for decades, online interventions are still relatively recent, and the best online practices are yet to be identified.[24] For example, the findings of a review by McAlpine et al[25] revealed that efficacy of online interventions targeting cancer patients was unclear, had limited duration for the intervention, and lacked validated outcome measures. Although one study by Van den Brink et al[26] showed significant promise in terms of improving health outcomes for cancer patients via a 6-week online intervention, the durability and longevity of benefits from this online intervention were not convincing. For example, invalidated outcome measures developed specifically for their studies were used, with some outcomes that were not sustained after the intervention. Similarly, a systematic review by Ajie and Chapman-Novakofski[27] highlighted that computer-mediated nutrition education interventions for adolescents resulted in only small, mainly short-term, changes in obesity outcomes, such as physical activity, diet, and nutrition knowledge.

Although the frequency of online interventions is promising, evidence-based studies aimed at exploring factors that contribute to best practices in online interventions have not yet emerged. Therefore, the purpose of this systematic review was to identify factors contributing to the efficacy of online nutrition interventions by evaluating successful online nutrition/health-related intervention studies that achieved their stated objectives. Selected factors of interest included use of theory, recruitment, and implementation methods; duration of the intervention; intervention delivery mode; engagement with participants; and the intervention fidelity of each study.

METHODS

Continuing the work of prior systematic reviews on factors that contribute to successful nutrition education interventions among adults[3] and children,[6] this systematic review was conducted with the aim of identifying factors that contributed to the success of online nutrition education interventions. For the purpose of this review, online nutrition education interventions were defined as interventions that were delivered via internet, computer, or text message.

Members of the research team

The research team included 5 members, of whom 2 held a doctoral degree and 3 were graduate students in nutritional sciences. The lead investigator was a full professor of nutrition and a registered dietitian. One researcher was a senior research associate with broad experience in conducting research related to nutrition, food, health, and consumer behavior. The three graduate students were trained by the lead investigator and had experience in conducting systematic reviews. A literature search of the articles was performed by 2 of the graduate students. The research team then independently screened the articles for quality and relevance based on the set criteria and extracted information on a spreadsheet for its further analysis.

Literature search strategy

This review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) recommendations and criteria.[28] Articles reporting on online nutrition education

Table 1 **PICOS criteria for determining inclusion and exclusion of studies**[a]

Category	Inclusion criterion	Exclusion criterion
Participants	All age groups: children, adolescents, and adults	Participants with special nutritional needs
Intervention	Online nutrition education interventions	Face-to-face interventions; nutrition education mixed face-to-face and online sessions
Comparator	With and without control group; face-to-face comparison group; mixed face-to-face and online comparison group	None
Outcomes	Nutrition-related outcomes, such as anthropometric measurements (eg, body mass index, waist circumference); biochemical measurements (eg, blood vitamin D concentration); dietary intakes; nutritional knowledge; preferences; attitudes; behaviors; self-efficacy; stage of change; dietary diversity score; or physical activity (time, attitudes, self-efficacy, behaviors)	No nutrition-related outcomes
Study design	Randomized control trials; pretest and post-test design; and quasi-experimental studies	Systematic review; meta-analysis; reviews; qualitative studies; cross-sectional studies; abstracts; study pilot; protocol; descriptive methodology study

interventions in promoting dietary behavior change were obtained through electronic searches of five databases: PubMed, Medline, Web of Science, Science Direct, and the Education Resources Information Center (ERIC). The search was limited to articles published between January 2009 and November 2018 and available in English. Key words were entered in varying combinations, including "nutrition education intervention," "online," and "web-based."

Inclusion and exclusion criteria

The database searches provided citations to 1099 articles published between January 2009 and November 2018. Two research members then excluded duplicated articles and articles that were not published in English. After the initial screening, the articles were divided among 2 research members, who evaluated whether they met the inclusion criteria using the PICOS (Population, Intervention, Comparators, Outcome, and Study design) model (Table 1).[28] Research articles were included in the review if they were (a) published between January 2009 and November 2018, (b) available in English, and (c) online nutrition education interventions. Articles were excluded if they (a) did not include a nutrition education intervention; (b) were review articles, systematic reviews, or meta-analyses; (c) were poster abstracts, qualitative studies, or cross-sectional studies; (d) were study protocols or pilot studies; (e) reported on targeted populations with special nutritional needs (eg, hospitalized children, patients with diabetes); (f) reported on face-to-face interventions or nutrition education combined with face-to-face and online sessions; or (g) were evaluations of programs. In cases where multiple studies were conducted on the same program or same data set, the most recently published study incorporating a detailed methodology section was included.

After screening for inclusion criteria, a total of 29 articles were included for the assessment of quality and divided between 4 research members. A flow diagram illustrating the article filtering process is shown in Figure 1.

Assessment of study quality and risk of bias

The research members were trained on quality assessment before the analysis was conducted, to minimize bias in accordance with the PRISMA recommendations.[28] Each article was assessed by 2 independent reviewers. After the initial assessment, the reviewing authors exchanged the articles without sharing the assessment results. Once both reviewers had finished their quality assessment, a discussion was held between the reviewing authors to confirm whether they agreed or disagreed on the assessment results. All the articles were then discussed by the lead investigator and the research team before a final decision was made on whether articles were eligible for the final analysis, based on the results of the quality assessment.

The quality of the studies was determined according to the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system for rating quality of evidence.[29] A thorough assessment of the study's description, design, measurements, data analysis, interpretation of results, power, and outcome formed the criteria for quality assessment, as discussed in previous systematic reviews.[3] Quality scores ranged from 1 to 6, with three rating levels: low risk of bias if the articles scored 5-6; moderate risk of bias if they scored 3-4; and high risk of bias if they scored 1-2. If the quality score for an article differed between the two

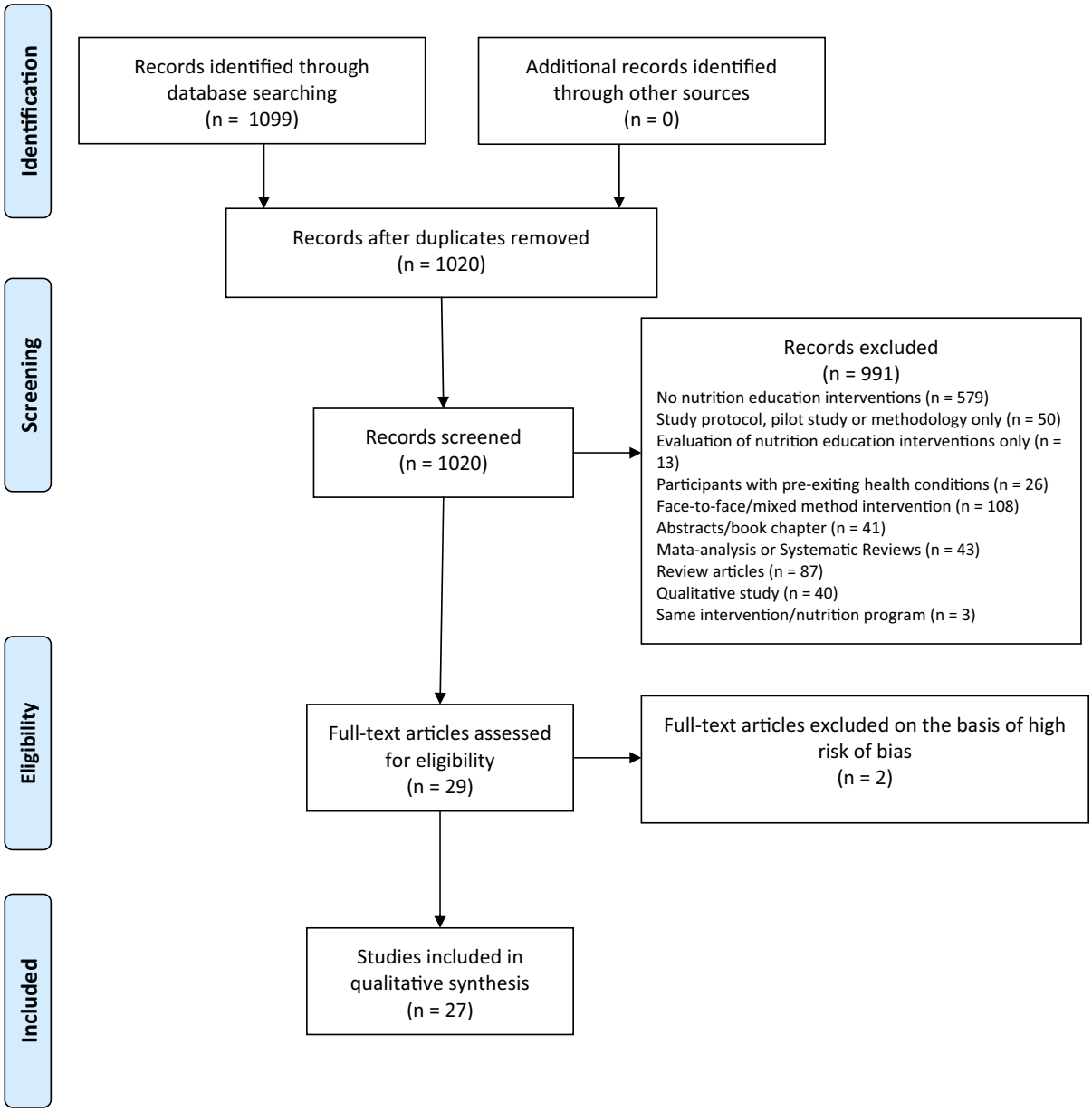

Figure 1 **PRISMA flow diagram of the literature search process**

reviewers, the article was discussed by the research group until a consensus was reached. Of the 29 articles that met the inclusion criteria, 2 were excluded from the final analysis because they were categorized as having a high risk of bias.

Analysis approach

A total of 27 articles were finally included in the data extraction step, where five reviewing authors independently extracted data from the 27 articles and transferred this information to a spreadsheet for analysis. Table 2[30–56] provides a summary of important information relating to the analyzed studies. The primary analytic goal was to determine the effectiveness of online nutrition education interventions in modifying nutrition or physical activity behaviors among the general population. To determine whether an intervention was successful, the outcome of the study was compared with the stated purpose or objective of the study. Once the successfulness of the intervention had been determined, the following contributing factors were analyzed: (1) use of theory, (2) recruitment and implementation methods, (3) duration of the intervention, (4) intervention delivery mode, (5) engagement with participants, and (6) the intervention fidelity of each study. The attrition criteria of the GRADE system[29] were adapted in this review, which classified a study as having low

Table 2 **Summary of online nutrition education interventions**

Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
Alexander et al (2010)[30]	2540 adults aged 21–65 yr	To assess the changes in FV intake in three different groups, including an online untailored program "*group 1*," a tailored behavioral intervention "*group 2*," and a tailored behavioral intervention plus motivational interviewing-based counseling "*group 3*"	RCT	12 mo (frequency not mentioned)	SCT, TTM, and HBM	Achieved	Low	The adjusted mean change in average FV servings was significantly greater in group 3 than in group 1 at 12 mo ($P = 0.05$). There were no significant differences between groups 1 and 2 or groups 2 and 3. FV intake significantly increased in group 2 ($P = 0.05$) and in group 3 ($P = 0.04$). FV servings increases corresponded with more website visits, regardless of group: mean daily intake of FV increased by 2.2 servings for participants who visited infrequently (<7 visits), 2.4 servings for participants who visited moderately often (7–13 visits), and 3.0 servings for those who visited very often (>13 visits) ($P < 0.001$, for all).
Au et al (2016)[31]	590 children aged 1–5 yr and their parents	To examine the influences of online and face-to-face group nutrition education on changes in knowledge, attitudes, and behaviors related to breakfast eating	RCT	15–20 min once only	No theory	Partially achieved	Low	The face-to-face group showed a greater improvement in knowledge of the correct answer to the question, "How much sugar can WIC cereals have per serving?" from baseline to post-intervention ($P < 0.001$). However, the face-to-face group showed a greater decline in retention from post-intervention to follow-up than the online group ($P = 0.03$). There were no significant differences, between the online and face-to-face groups, in the reductions in barriers to eating breakfast owing to

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Table 2 **Continued**

Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
								time constraints, not having enough foods at home, hunger, and difficulty with preparation. There was no significant difference in the SE scores between the online and face-to-face groups from pre-intervention to follow-up. There was a significant greater decrease in the vegetable intake at breakfast among children in the face-to-face group than among those in the online group (face-to-face, $P = 0.002$; online, $P = 0.81$; between face-to-face and online groups, $P = 0.02$).
Chen et al (2011)[32]	54 adolescents aged 12–15 yr and their family	To examine the efficacy of the "Web ABC" program in promoting healthy lifestyles and healthy weight in Chinese American adolescents	RCT	15-min weekly session for 2 mo	TTM and SCT	Achieved	Low	After the intervention, significantly more adolescents in the IG than in the CG decreased their waist-to-hip ratio (effect size = −0.01, $P = 0.02$) and diastolic blood pressure (effect size = −1.12, $P = 0.02$). In addition, the IG significantly increased PA as measured by an actigraph (effect size = 12.46, $P = 0.01$), increased FV intake (effect size = 0.14, $P = 0.0001$), increased PA knowledge (effect size = 0.16, $P = 0.008$), and increased dietary knowledge (effect size = 0.18, $P = 0.0001$) after the intervention. However, there was no significant change in BMI among adolescents in the IG after the intervention.

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Table 2 **Continued**

Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
Cullen et al (2017)[33]	126 families and their children aged 8–12 yr	To evaluate a web-based intervention to improve parent and child dietary behavior	RCT	Weekly session for 2 mo	No theory	Partially achieved	Moderate	Parents in the IG group showed a significant improvement in home food availability, such as 100% fruit juice ($P < 0.05$), vegetables ($P < 0.01$), and low-fat/fat-free foods ($P < 0.05$) at post-intervention, while parents in the CG only had a significantly greater frequency of drinking 100% fruit juice at post-intervention ($P < 0.05$). Overall, food preparation practices improved over the three time points among parents in both the IG and CG ($P < 0.05$, for all). However, child diet behavior did not improve over the three time periods in both the IG and CG. Children in the IG showed a significant increase in home juice availability ($P < 0.05$) at post-intervention. Home fruit availability was improved among children in both the IG and CG ($P < 0.05$, for all) after the intervention.
Duncan et al (2014)[34]	124 adult males aged 35–54 yr	To examine the effectiveness of an IT-based intervention ("ManUp") to improve PA, dietary behaviors, and health literacy in middle-aged males, compared to a print-based intervention	RCT	9 mo (frequency not mentioned)	SCT and SRT	Partially achieved	Moderate	There were no significant differences between IT-based and print-based groups in PA and dietary behaviors ($P > 0.05$) after the intervention. Self-reported minutes (3 mo: 95%CI 1.09–1.95, $P < 0.001$; 9 mo: 95%CI 1.14–2.10, $P < 0.01$) and sessions of PA were significantly higher at the

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								3rd and 9th mo than at baseline in both groups (3 mo: 95%CI 1.17–2.22, $P < 0.01$; 9 mo: 95%CI 1.17–2.00, $P < 0.01$). Dietary behaviors scores were significantly higher in both groups at the 3rd and 9th mo (3 mo: 95%CI 1.03–1.11, $P < 0.01$; 9 mo: 95%CI 1.05–1.13, $P < 0.01$). Both IT-based and print-based groups increased their intake of high-fiber bread and low-fat milk only at the 3rd mo. Nutrition literacy did not change over time.
Dunn et al (2014)[35]	1711 adults aged 22–82 yr	To compare the effectiveness of online delivery of a weight management program (ESMMWL) – using synchronous and online-education technology – with a face-to-face intervention	Pre-post	1-h weekly session for 15 wk	No theory	Achieved	Moderate	After the intervention, the average weight loss for online intervention participants was 8.0 pounds and for face-to-face participants 5.95 pounds ($P < 0.001$). Online intervention participants had significantly greater reductions in BMI ($P < 0.001$) and waist circumference ($P < 0.01$) than face-to-face intervention participants, and PA confidence scores increased more in the face-to-face intervention participants than in the online intervention participants ($P < 0.001$).

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Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
Elbert et al (2016)[36]	342 people aged ≥ 16 yr	To investigate the efficacy of a mobile phone intervention that delivers tailored persuasive information, as communicated via two different modes as text and audio, to stimulate FV consumption in comparison with a CG	RCT	Once a month for 6-mo	SCT	Achieved	Moderate	The audio group had a significantly higher fruit intake than the text group after the intervention ($P = 0.02$). Both text and control groups did not improve FV intake 6 mo after baseline. No significant main effect was found for vegetable intake among the audio group, text group, and CG. There was a significant increase in fruit intake after exposure to the auditory information, especially in recipients with a poor perceived own health ($P = 0.003$). A higher vegetable intake was found for recipients with high health literacy after exposure to auditory intervention, compared to the control group ($P = 0.004$).
Franko et al (2013)[37]	178 adolescent girls in grade 9–12	To test the efficacy of an internet-based program to examine its impact on positive body image in a diverse sample of high school students	RCT	Weekly 45-min lesson for 1 mo	SCT, TPB, and TTM	Partially achieved	Moderate	After the intervention, the mean scores on the Body Esteem Scale Appearance subscale increased for the IG in comparison with the CG ($P < 0.05$). Adolescent girls in the IG reported a significant decrease in mean EDI body dissatisfaction scale scores ($P < 0.05$) and PACS scale scores ($P < 0.05$) compared to those in the CG, from baseline to post-intervention. A significant interaction between group, time, and overweight status for body

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Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
								dissatisfaction was observed among girls, with overweight girls reporting greater decreases in EDI body dissatisfaction ($P = 0.012$). Ethnic minority girls reported greater increases in body appearance esteem ($P = 0.04$) and greater decreases in EDI body dissatisfaction ($P = 0.029$).
Gilson et al (2013)[38]	330 university employees	To increase walking step counts by an extra 1000 daily steps per week above baseline among university employees using Walk@Work program	Pre-post	Every 2 wk over a 6-wk period	No theory	Achieved	Moderate	Across the sample, step counts significantly increased from baseline to wk 4 of the intervention (1360 daily steps more), with these increases maintained at post-intervention (1477 daily steps; $P = 0.001$). Intervention effects varied according to participants' baseline activity status ($P = 0.001$): employees who were "somewhat active" at baseline demonstrated the lowest increase in workday walking at post-intervention (929 daily steps more). "Low active" (1464 more daily steps) and "inactive" (1837 more daily steps) employees benefited the most from the program.

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Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
Goodman et al (2016)[39]	109 adults aged 18–25 yr	To determine whether an intervention involving the use of the mobile VDC app leads to changes in intake, knowledge, and/or perceptions of VD by determining blood concentrations of blood 25(OH)D_3	RCT	3 times per week for 3 mo	TPB and PWM	Achieved	Moderate	Total mean VD intake increased significantly from 394 IU/d at baseline to 702 IU/d at post-intervention in the IG ($P < 0.01$), but the intake of VD did not increase for participants in the CG. No significant differences were found between the two groups for changes in blood 25(OH)D_3 concentrations at baseline or post-intervention. At post-intervention, the IG had higher overall perceived importance of VD supplementation than the CG ($P = 0.04$). The increase in mean VD knowledge from baseline to post-intervention was significantly higher ($P = 0.03$) in the IG than in the CG.
Grimes et al (2018)[40]	102 children aged 7–10 yr	To determine the efficacy of a web-based salt reduction program on children's salt-related knowledge, attitudes, and behaviors (KABs), self-efficacy, and intake of dietary salt	Pre-post	Weekly 20-min lesson for 5 wk	SCT	Partially achieved	Moderate	Among children who completed the intervention, there was no significant change in salt intake from before to after the intervention. There was no change in the proportion of children who exceeded the UL for salt intake before and after the intervention. There was a significant improvement in children's overall knowledge ($+3.6 \pm 0.4$ points; $P < 0.001$; CD, 1.16), behavior ($+1.3 \pm 0.1$ points; $P < 0.001$; CD, 1.08) and self-efficacy scores ($+0.9 \pm 0.2$ points; $P < 0.001$; CD, 0.64) after the intervention. There was no change in children's attitude score after the intervention.

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Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
Kattelmann et al (2014)[41]	1639 college students aged 18–24 yr	To access the effectiveness of a tailored theory-based, web-delivered intervention "YEAH" on weight status	RCT	Weekly 20-min lesson for 10 wk	TTM	Partially achieved	Moderate	There were no differences in BMI, weight, and waist circumference between the IG and CG after the intervention and at follow-up. The IG group slightly increased the total number of FV cups ($P = 0.02$), whereas the CG group decreased the total number of FV cups ($P = 0.02$). Both groups increased in moderate MET-minutes per week from baseline to post-intervention ($P = 0.002$). The IG maintained hours of sleep and reported no changes in hours of sleep from baseline to post-intervention and follow-up.
LaChausse (2012)[42]	320 college students aged 18–25 yr	To determine the impact of MSB, an internet-based obesity prevention program for college students	RCT	Weekly 2-h lesson for 3 mo	No theory	Partially achieved	Moderate	There were no changes in exercise SE, attitudes toward exercise, or frequency of aerobic exercise among any of the online group, face-to-face group, and CG. SE scores of FV consumption significantly increased from baseline to post-intervention for the online group ($P = 0.001$) but did not change for either the face-to-face group or the CG. At post-intervention, the frequency of fruit consumption significantly increased for the online group ($P = 0.001$) but did not change for either the face-to-face group or the CG. The frequency

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Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
								of vegetable consumption significantly increased for the online group ($P = 0.010$) but did not change for either the face-to-face group or the CG. Perceived stress significantly decreased from pre-test to post-intervention for the online group ($P = 0.033$). There was no change in BMI among participants in any of the 3 groups.
Lange et al (2013)[43]	1154 adolescents and adults aged 14–79 yr	To examine the feasibility of a minimal (1-h) online intervention in dietary planning and action control of fruit intake compared to a CG	RCT	45 min once only	TPB	Achieved	Moderate	The majority of the participants were well educated (70.3% college degree), employed (64%) and in a steady relationship (64.5%). Both groups increased their fruit intake, dietary planning, and action control ($P < 0.05$, for all).
Lein et al (2016)[44]	152 female college students aged 19–25 yr	To evaluate the effectiveness of theory-based osteoporosis prevention programs in relation to CA and VD intakes and osteoporosis health beliefs	RCT	10–15 min once only for face-to-face group (length and frequency not mentioned for online group and online + face-to-face group)	HBM	Partially achieved	Moderate	All 3 groups significantly increased their CA intakes after the intervention ($P < 0.001$, for all). However, there was no significant group difference between the 3 groups. None of the 3 groups significantly increased their daily consumption of VD after the intervention. All 3 groups had significant increases in perceived susceptibility and severity of osteoporosis, and significant decreases in perceived barriers to VD intakes ($P < 0.001$).

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Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
Lohse et al (2015)[45]	303 low-income women aged 18–45 yr	To produce and evaluate an online curriculum for low-income women that was aligned with ecSatter tenets and congruent with the best practices for nutrition education for low-income audiences with potential to be evidence-based and sustainable	RCT	Five 15- to 30-min lessons for 10 d	Satter model of eating competence	Partially achieved	Moderate	The IG significantly increased scores for budgeting food ($P = 0.008$), planning meals to include all food groups ($P = 0.002$), confidence about managing money to make healthy food available ($P = 0.001$), and utilizing nutrition facts on the food label to make choices ($P = 0.01$), and significantly reduced run-out-of-food scores ($P < 0\ 001$) after the intervention. The CG significantly increased scores for tracking food-related expenses ($P = 0.03$) and planning meals ($P = 0.03$). Participants who were food-secure had more confidence in managing money for food ($P = 0.002$) and keeping track of food-related purchases ($P = 0.02$) than food-insecure persons.
Milan and White (2010)[46]	408 female college students aged 18–29 yr	To examine the effectiveness of a web-based, stage-tailored folic acid intervention to promote folic acid–containing multivitamin use among college women	Pre-post	Each student had to read a web page for 5- to 10-min per week for a 1-mo period (number of sessions not mentioned)	TTM	Achieved	Moderate	More participants in the stage-tailored group reported taking a multivitamin at post-intervention than those in the non-tailored group ($P = 0.015$). The stage-tailored group in action/maintenance increased by 22% compared to a 10% increase in the non-tailored group. At post-intervention, the stage-tailored group had a significantly greater increase in SE with multivitamin use ($P = 0.000$) and in DB pro scores ($P = 0.038$) than the non-tailored group.

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Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
Monroe et al (2015)[47]	608 university students aged 18–24 yr	To investigate whether an online intervention focused around the sustainable aspects of GE could increase GE behaviors (local eating, reducing waste, and choosing environmentally friendly proteins) in university students.	Quasi-experimental	4 lessons over a 5-wk period	TTM	Partially achieved	Moderate	The IG increased their GE behavior score from baseline to post-intervention by significantly more than the CG ($P < 0.001$). The IG increased their DB "pro" scores by significantly more than the CG ($P < 0.05$). There were no differences in DB "cons" scores between the IG and the CG. However, DB cons scores significantly increased in the control group ($P < 0.001$). The IG significantly increased their SE school scores ($P < 0.001$) but there were no differences in SE home scores between the IG and the CG. The IG increased their GE knowledge by significantly more than the CG ($P < 0.001$).
Muzaffar et al (2014)[48]	216 adolescents in grade 6–8	To investigate whether TPB constructs would favorably change preventive behaviors for obesity and type 2 diabetes after completing a web-based intervention – the HOT project	RCT	Five 30- to 40-min lessons over a 1- to 2-wk period	TPB	Partially achieved	Moderate	Both the IG and the CG showed significant improvements from baseline to post-intervention survey for belief, attitude, subjective norm, perceived behavioral control, knowledge, and behavioral intention variables regarding preventive behaviors for obesity and type 2 diabetes ($P < 0.05$, for all). However, all 6 composites were significantly different (based on grades for the IG), with 7th grade having the highest scores ($P < 0.05$). There were significant differences in intentions, behavioral beliefs, behavioral control, and knowledge ($P < 0.05$, for all) between the two different schools in which the intervention was carried out.

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Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
Nakamura et al (2017)[49]	1500 adults aged 30–59 yr	To investigate the effects of a web-based nutrition education program on vegetable intake and patterns of changes in vegetable intake among low-and middle-income adults in Japan	RCT	5 wk, with a weekly lesson	TTM	Partially achieved	Moderate	At baseline, vegetable intake of the low-income participants was lower than that of the middle-income participants ($P = 0.003$). Vegetable intake increased in the low-income participants from baseline to post-intervention ($P < 0.001$). However, there were no changes in vegetable intake among the middle-income participants. At post-intervention and follow-up, there was no longer a difference between the income groups (post-intervention, $P = 0.16$; follow-up, $P = 0.045$). The low-income participants in the IG showed significant improvements in eating vegetables ($P < 0.001$), stage of changes ($P < 0.001$), perceived behavior control ($P < 0.001$), and knowledge ($P < 0.001$) at post-intervention, compared to baseline. In the middle-income participants, only improvements in knowledge were maintained from baseline to post-intervention, and from baseline to follow-up ($P < 0.001$).

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Table 2 **Continued**

Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
Neuenschwander et al (2013)[50]	137 adults aged 18 yr or older	To determine whether web-based nutrition education could result in equivalent nutrition-related behavior outcomes when compared with traditional face-to-face nutrition education in low-income adults	RBD	Three 30- to 40-min lessons	Kolb's Experiential Learning Model	Partially achieved	Moderate	After the intervention, the online and face-to-face intervention groups significantly improved their scores for eating more than one kind of fruit each day ($P < 0.001$, for both groups), using a list when grocery shopping ($P < 0.01$ and $P < 0.001$, respectively), using the nutrition facts label to decide what to buy ($P < 0.001$, for both groups), washing hands before preparing food ($P < 0.01$ and $P < 0.05$, respectively), running out of money for food before the end of the month ($P < 0.05$ and $P < 0.01$, respectively), increasing the amount of fruit and vegetable intake per day ($P < 0.001$, for both groups), eating breakfast ($P < 0.01$ and $P < 0.001$, respectively), and time spent doing physical activity ($P < 0.01$ and $P < 0.001$, respectively). Additionally, the online group significantly improved their scores for washing hands before eating food ($P < 0.001$), running out of food before the end of the month ($P < 0.05$), and drinking 100% fruit juice per day ($P < 0.05$). The face-to-face group improved the amount of

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Table 2 **Continued**

Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
								whole-grain consumed per day ($P < 0.01$). There were no significant differences in the change of scores for all behaviors between both groups, with the exception of using nutrition facts labels to decide what food to buy, where the face-to-face group had a greater change of score than the online group ($P = 0.04$).
Nikolaou et al (2015)[51]	20 975 young adults	To examine the effectiveness of e-learning approaches for prevention of weight gain and encouraging healthier lifestyles among young adults in higher education based on two different behavioral models	RCT	20 wk, with a weekly lesson	Rational model and Stealth model	Achieved	Low	Weight changes were significantly different between the online group NTICV, the online group GD, and the CG ($P < 0.0001$). The CG gained on average 2.0 kg, the NTICV group reduced on average 1.0 kg, and the GD group reduced on average 1.35 kg. No lifestyle changes were reported.
Poddar et al (2012)[52]	211 college students	To promote SE, self-regulation, outcome expectations, social support, and behavior related to total and low-fat dairy intake by college students	Randomized pre-post	8 wk, with a weekly lesson	SCT	Partially achieved	Moderate	After the intervention, the IG showed a significant increase in total dairy intake by 0.17 servings, whereas the CG showed a significant decrease in total dairy intake by 0.13 servings per day ($P = 0.01$ for comparison between the IG and CG).There were no significant increases in the intake of low-fat dairy intake per day in the IG, compared to the CG. There were no significant group differences in social support for total

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Table 2 **Continued**

Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
								dairy and low-fat dairy, in SE in achieving goals and low-fat dairy, and in positive and negative outcome expectation variables in relation to SCT. However, the IG showed greater increases in total dairy self-regulation (0.68/5 points) and low-fat dairy self-regulation (0.46/5 points) than the CG ($P = 0.00$, for all).
Rampersaud et al (2016)[53]	162 female college students aged 18–24 yr	To evaluate the impact of educational text messages on folate/folic acid knowledge and consumption, and to evaluate the impact of providing folic acid supplements on folate/folic acid intake among college-aged women	RCT	3 times a week over a 6-wk period	No theory	Partially achieved	Moderate	There was a significant increase in the mean knowledge score from 8.0 at baseline to 11 at post-intervention across the groups ($P < 0.0001$). There were no significant differences in any response variable (knowledge, intake, SE) for any time point and measures when comparing between groups that received TMs and groups that did not receive TMs. Mean total folate intake significantly increased from 396μg at baseline to 432μg at post-intervention ($P < 0.0001$) across study groups. Participants in the supplement groups had significantly higher mean intakes of folic acid and total folate at mid-study and post-intervention compared with baseline and compared with participants who did not receive a supplement ($P \leq 0.0006$).

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Table 2 **Continued**

Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
Springvloet et al (2015)[54]	1349 adults aged 20–65 yr	To evaluate the efficacy of two different versions of web-based, computer-tailored nutrition education interventions, compared to a CG, for self-reported intake of fruit, vegetable, high-energy snacks, and saturated fat	RCT	4 lessons over a 6-wk period	SRT, PAPM, and TPB	Partially achieved	Moderate	There were no differences in FV consumption over time between the 3 groups. Among participants who consumed <2 times of fruit at baseline, a significant difference in change over time was found between the groups ($P = 0.007$). The online group addressing basic- and environmental-level factors had a significantly larger increase in fruit intake than the CG, between baseline and post-intervention ($P = 0.01$) and follow-up ($P = 0.001$). The online group addressing cognition and self-regulation processes had a larger decrease in saturated fat intake than the other two groups between baseline and post-intervention ($P = 0.001$). Both online groups had a significantly larger decrease in high-energy snack intake than the CG between baseline and post-intervention ($P \leq 0.001$) and follow-up ($P < 0.05$).
Tsai and Liu (2015)[55]	115 female RNs working at least 2 mo in Taiwan	To evaluate the effects of nurses' health promotion received via an e-health intervention compared with conventional health promotion via handbook learning	Pre-post	3 mo (frequency not mentioned)	Theory of social support	Achieved	Moderate	The total HPLP score significantly increased in the IG ($P = 0.001$), especially for self-actualization ($P = 0.003$), nutrition ($P < 0.001$), and exercise ($P < 0.001$). No significant changes were found in the CG scores. There was no significant difference in the total HPLP scores between the IG and the CG.

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Table 2 **Continued**

Reference	Study sample	Objective of intervention	Study design	Length and frequency of intervention	Behavioral theory/ construct	Achievement of objectives	Risk of bias	Major findings
								The total SF-36 score was significantly improved only for the IG from baseline to post-intervention ($P = 0.017$). The IG score decreased significantly for BMI ($P = 0.02$), but there was no change from baseline to post-intervention between the IG and the CG.
Yen and Lewis (2013)[56]	93 women aged 45–65 yr	To assess the impact of a nutrition education intervention on food groups and omega-3 fatty acid consumption in middle-aged women	Pre-post	6 wk, with a weekly lesson	HBM	Not achieved	Low	After the intervention, there were no differences between the CG and the IG for the mean servings of the food groups in MyPyramid. The difference in consumption of omega n-3 FA between the CG and the IG was not significant. There was no difference in SE towards omega n-3 FA consumption among the IG and the CG. In addition, there was no difference in participants' SE over time to include food groups or n-3 FA in their diet.

Abbreviations: BMI, body mass index; CA, calcium intake; CD, Cohen's D, CG, control group; DB, decisional balance; ecSatter, the Satter model of eating competence; EDI, Eating Disorder Inventory; ESMMWL, Eat Smart, Move More, Weigh Less; FA, fatty acid; FV, fruit and vegetables; GD, Goddess Demetra; GE, green eating; HBM, Health Belief Model; HOT, Healthy Outcome for Teens; HPLP, health-promoting lifestyles profile; IG, intervention group; IT, information technology; IU, international unit; KABs, knowledge, attitudes, and behaviors; MET, metabolic equivalent task; MSB, My Student Body; NTICV, not the ice cream van; PA, physical activity; PACS, physical appearance comparison; PAPM, Precaution Adoption Process Model; PWM, Prototype Willingness Model; RBD, randomized block design; RCT, randomized control trial; RN, registered nurse; SCT, social cognitive theory; SE, self-efficacy; SF, short-form health survey; SRT, self-regulation theory; TMs, text messages; TPB, theory of planned behavior; TTM, transtheoretical model; UL, upper level; VD, vitamin D; VDC, vitamin D intake calculator; WIC, women, infants, and children; YEAH, Young Adults Eating and Active for Health.

attrition if at least 80% of the enrolled participants completed the study, and high attrition if more than 20% of the enrolled participants did not complete the study. It is important to mention that the included studies rarely reported the frequency or dosage of the intervention. Therefore, it is reasonable to report the total amount of time spent in online interventions in months.

The findings from the online nutrition education interventions were summarized using a semiquantitative approach. Results from the included online nutrition education interventions were dichotomized on the basis of whether they reported a statistically significant ($P < 0.05$) improvement in dietary intakes, physical activity, or other nutrition-related topics. This approach was used to allow for the diverse range of reported statistics, outcomes, and units of measurement.[54]

RESULTS

Included in this review were 27 studies describing online nutrition education (ONE) interventions and published in peer-reviewed journals between January 2009 and November 2018. The studies were assessed for their effectiveness on the basis of reported evidence that the interventions met their stated primary objectives. The majority of the studies (70.4%, n = 19) were conducted in North America (United States and Canada),[30–33,35,37–39,41,42,44–48,50,52,53,56] while the remainder of the studies were conducted in other continents, including 4 studies in Europe (United Kingdom, Netherlands, and Germany),[36,43,51,54] 2 in Australia,[34,40] and 2 in Asia (Taiwan and Japan).[49,55] An added advantage of online studies is the potential to recruit large sample sizes. In this review, 7 of the studies recruited more than 1000 participants[30,35,41,43,49,51,54]; of these, 1 had a sample size of more than 20 000 participants,[51] and 2 studies recruited more than 500 participants.[31,45]

Of the 27 studies included in this review, 17 recruited participants from a specific geographic location such as high school, university, hospital, or WIC (Women, Infants, and Children) clinic,[30–32,37,40–42,44,46–48,50–53,55,56] while 10 studies recruited participants from different geographic locations.[33–36,38,39,43,45,49,54] In this review, studies that used a broad and diverse approach in recruiting their participants were more likely to have a high attrition rate (n = 6) than studies that recruited participants from focused and specific locations (n = 2). For example, in one study conducted to promote fruit consumption, Lange et al[43] recruited participants through advertisements via radio, newspaper, television, or a university internet site. Although they recruited 1154 participants, they had lost approximately one third (34%) of the participants by the end of the intervention. In contrast, another study – conducted to evaluate the effect of an online intervention on breakfast eating behavior among WIC participants – recruited 590 participants from two WIC clinics. The study only lost 11.5% of the participants after the intervention.[31]

The majority of the studies (77.8%; $n = 21$) delivered their interventions through websites,[30–33,37,38,40–51,54–56] followed by smartphone application (12.5%; n = 3),[34,36,39] text messages (4.2%; n = 1), [53] and as an online course (8.3%; n = 2)[35,52] (Table 2).[30–56] The approaches and activities used for the delivery of the online interventions included the following: reading information available on the website or application (92.6%; n = 25)[30–34,36–42,44–56]; watching and/or listening to videos and audio files (44.4%; n = 12)[30,32,34,36–38,40,44,47,48,50,53]; using interactive activities or games (22.2%, n = 6)[32,36,37,40,48,50]; sending homework for the application of information learned (14.8%, n = 4)[32–34,49]; carrying out discussions via a forum or board (14.8%, n = 4)[33,34,36,55]; and teaching live lectures (3.7%, n = 1).[35] Slightly more than half (51.8%; n = 14) of the studies targeted the general adult population,[30,31,34–36,38,43,45,49–51,54–56] while slightly less than a third (29.7%, n = 8) targeted college students.[39,41,42,44,46,47,52,53] Moreover, 3 studies (11.1%) targeted adolescents aged 12-19 years,[32,37,48] and 2 studies (7.4%) targeted children aged 8-12 years.[33,40]

Ten out of the 27 studies (37.04%) met their primary objectives as evidenced by their reported results,[30,32,35,36,38,39,43,46,51,55] while 16 studies (59.26%) partially met their stated objectives[31,33,34,37,40–42,44,45,47–50,52–54] and only 1 study (3.70%) did not meet any of its stated objectives.[56] The findings of this systematic review identified 6 factors that were associated with successful ONE interventions, as follows: 1) use of tailored messages and/or individualized feedback; 2) participant engagement, as measured by the level of interaction between investigators and participants; 3) intervention duration ≥3 months; 4) identification of specific targeted behaviors vs general health; 5) alignment of intervention activities with stated objectives; 6) and use of theory-based interventions. In contrast, this review also identified several factors considered to represent poor design in ONE interventions, including comparison bias, lack of specific details on duration or dosage, lack of objective measurement, and lack of tracking system.

Tailored messages, individualized feedback, and attrition

Providing tailored messages based on individual progress and performance during the intervention resulted in engaged participants and increased the efficacy of the intervention. In this review, 6 of the 10 studies that met their stated objectives provided tailored messages based

on each participant's progress through regular automated or personalized messages during the intervention.[30,35,36,38,39,55] For example, one study, conducted by Alexander et al[30] on the promotion of consumption of fruits and vegetables, found that participants who received feedback on their intake of fruits and vegetables after each lesson significantly increased their subsequent intake of fruits and vegetables ($P \leq 0.05$). In contrast, a study by Lein et al[44] that promoted calcium and vitamin D intake as a means of preventing osteoporosis, but did not provide any feedback during the intervention, resulted in no significant change in calcium and vitamin D consumption between the intervention group and the control group despite the fact that the study had a clear objective and a good alignment between intervention activities and objective, and was theory-driven.

Level of interaction between investigators and participants

Online communication can engage participants in various ways and levels, including being available for questions in real time or through messages and emails. In this review, half of the successful interventions engaged their participants by the investigators being available for questions in real time, or through messages and emails.[30,35,36,51,55] For example, in a study by Dunn et al,[35] the participants interacted with the instructor and other participants via a chat box in real time. The instructor was also available via email to answer any questions from participants after the class. After the intervention, participants in this study significantly reduced their BMI (body mass index) ($P < 0.001$) and waist circumference ($P < 0.01$) and significantly increased their intake of healthy foods and their confidence in physical activity ($P < 0.001$). Conversely, interventions that lacked engagement and interactions between the participants and the researcher were more likely to be unsuccessful.[33,34,37,40–42,44,45,47,49,52–54,56] For instance, the study by Franko et al,[37] which examined the efficacy of an internet-based program on positive body image among high school students, but had no interaction between the researcher and participants, failed to significantly increase the scores of the body weight and body esteem subscales, or decrease the scores of the physical appearance comparison scale as outlined in their objectives, despite the fact that they had identified specific behaviors and the intervention was age-appropriate.

Duration of online nutrition education interventions

Studies with an intervention duration of $\geq$ 3 months were more likely to meet their stated objectives (60.0%, n = 6),[30,35,36,39,51,55] while studies with a duration of $\leq$ 2 months were less likely to meet all their stated objectives (88.2%, n = 15).[31,33,37,40,41,44,45,47–50,52–54,56] For instance, Tsai and Liu[55] implemented a study to examine the health-promoting effects of an e-health intervention among nurses for 3 months. The study revealed a significant increase in the Health-Promoting Lifestyle Profile score of the nurses ($P = 0.001$) at the end of the intervention. In contrast, a study conducted by Yen and Lewis[56] to increase consumption and intake of food rich in omega-3 fatty acids among middle-aged women for 1.5 months did not increase the consumption of food rich in omega-3 fatty acids.

Specific behaviors

Studies that identified specific behaviors to be addressed by the intervention vs general health were more likely to achieve their stated objectives.[30,35,36,38,39,43,46] For example, a study conducted by Goodman et al[39] aimed to improve knowledge, perceptions, and dietary intake of vitamin D. At the end of the intervention, participants had significantly increased their knowledge of vitamin D ($P = 0.03$), perceptions about vitamin D ($P = 0.05$), and total vitamin D intake ($P < 0.001$) compared to those who did not receive any education. In contrast, interventions that focused on broad topics not specific to a behavior were unsuccessful in meeting their objectives.[34,41,42,45,48,50,54,56] For example, the intervention by Kattelmann et al[41] focused on changing the Theory of Planned Behavior constructs regarding preventive behaviors for obesity and type 2 diabetes. However, they did not specify the targeted behaviors for obesity and type 2 diabetes. The study was general and broad, and failed to successfully meet their stated objectives.

Alignment of objectives with activities

Alignment of intervention activities with the stated objectives was critical to the success of nutrition education interventions.[30,32,35,36,38,39,46,51] For example, Gilson et al[38] developed the Walk@Work program to increase walking step counts by an extra 1000 daily steps per week above baseline over a period of 6 weeks. Participants were provided with pedometers in an effort to motivate them and track their workday steps. Support strategies, such as ideas and tips on how to increase walking during the workday, promotion of short walks to up to 10 minutes during tea/coffee breaks or one-on-one meetings, and encouragement of longer, moderate-intensity lunchtime walks of more than 10 minutes, were also provided. All these intervention activities aligned with the stated objectives of the

intervention. After the 6-week intervention, step counts significantly ($P = 0.001$) increased from 5892 steps at baseline to 7369 steps at post-intervention. On the contrary, a study by Duncan et al[34] to improve physical activity, dietary behaviors, and health literacy in middle-aged males failed to align their activities with all their objectives. While the intervention activities focused on physical activity and dietary behaviors, they failed to address health literacy. Although the intervention significantly improved physical activity and dietary scores ($P < 0.001$), it failed to improve health literacy.

Theory-based interventions

In this review, 21 studies (77.78%) were theory-based[30,32,34,36,37,39–41,43–52,54–56] and 6 studies (22.22%) did not use theory.[31,33,35,38,42,53] Analysis showed that 8 of the 21 (38.10%) studies that were theory-based achieved their stated objectives, and more importantly 8 of the 10 studies that achieved their primary objectives were theory-based.[30,32,36,39,43,46,51,55] For example, a study by Elbert et al[36] aimed at increasing fruit and vegetable intake was developed using the framework of Intervention Mapping and was based on several socio-cognitive determinants known to predict fruit and vegetable intake. They successfully achieved their objective of increasing fruit ($P = 0.003$) and vegetable intake ($P = 0.004$). Similarly, a theory-based intervention conducted by Milan and White[46] to promote folic acid consumption among college women systematically used the stages of change theory in the design and evaluation of the intervention. The results showed that more participants in the intervention group reported taking a folic acid–containing multivitamin at post-test than those in the control group ($P = 0.015$). In addition, more participants in the intervention group progressed from pre-action to action than from the control group, and significantly increased self-efficacy ($P = 0.001$) compared to participants in the control group.

Factors considered to represent poor design in the online nutrition education intervention studies reviewed

Analysis of this systematic review also showed major weaknesses in the online interventions reviewed, over and above the previously mentioned factors.

Treatment or comparison bias: Eight[31,34,35,42,45,46,50,55] of the 25[30–37,39,41–56] studies that included a control or comparison group did not use a comparable group or comparable treatment and as a result were at risk of introducing bias. For example, Lohse et al[45] conducted a study to evaluate a web-based and interactive program for low-income women aligned with the Satter eating competence model. The study placed a greater emphasis on the online intervention group than on the control group. For instance, the participants in the intervention group had access to the nutrition information on the USDA website for 50 days and received 10 email reminders to visit the website, while participants in the control group had access to the website for only 30 days and received only five email reminders. The treatment favored the online group, which may have biased the results of the study in such a way that the participants in the online group significantly improved more skills related to food resource management than the participants in the control group: the online group significantly improved 5 skills, while the control group improved 2 skills, related to food resource management ($P < 0.05$).

Lack of specific details, such as dosage, on the intervention: Online intervention dosage was not measurable in 9 of the 27 interventions (33.33%).[30,33,34,36,38,47,49,55,56] For example, the study by Elbert et al[36] was conducted over a 6-month period. Monthly emails were sent to the participants inviting them to visit the mobile phone app and read the health information; however, there was no mention of how often and how much time the participants spent viewing the information. In a study by Monroe et al[47] the participants received a nutrition module every week for 4 weeks; however, the authors did not mention or track the specific amount of time that the participants had spent on each module.

Tracking system: An important element of online communication includes the ability to document fidelity in dosage by tracking engagement automatically or using the tracking system to engage the participants by providing feedback. Only 4 studies in this review used a tracking system.[39,42,51,53] For example, one study conducted by Nikolaou et al,[51] which assessed the effect of online approaches to weight change, tracked how frequently participants logged in to the website and accessed online resources, and the length of time the participants spent on each resource.

Objective measurement: The remote delivery mode of online studies limits the use of objective measures and depends on self-reported measures even in sensitive variables such as weight measures. The majority (85.19%, n = 23) of the studies included in this review relied solely on self-reported information through online survey systems such as websites and smartphone applications or email.[30,31,33–37,40,42–53] A pretest and post-test face-to-face measurement was included by only 4 of the 27 studies, to ensure objective measures of important variables.[32,38,39,41] As an example, in the study by Kattelmann et al,[41] research assistants were trained to perform in-person anthropometric assessments at baseline, post-intervention, and follow-up,

including height, weight, and waist circumference measurements.

Lack of follow-up after the intervention: In this review, only 9 studies included follow-up measurements after the intervention period.[31–33,37,41,44,49,51,54] Six of the studies identified long-term effect of online interventions on behavior change.[31,32,44,49,51,54] For example, a study by Chen et al[32] that aimed to increase the intake of fruits and vegetables after an 8-week online intervention was able to document behavior sustainability 8 months after the intervention as a result of follow-up. By the end of the intervention, the participants had significantly increased their consumption of fruits and vegetables ($P = 0.001$) and significantly maintained the intake at 6-month and 8-month follow-up ($P < 0.05$, for both follow-up points). However, 18 studies (66.67%) did not include follow-up measurements.[30,34–36,38–40,42,43,45–48,50,52,53,55,56]

DISCUSSION

The purpose of this systematic review was to identify factors that contributed to successful nutrition education interventions in relation to online research studies published between January 2009 and November 2018. Six factors emerged as critical to successful ONE interventions: (1) use of tailored messages and/or individualized feedback; (2) human interaction between the participants and the investigators; (3) intervention duration ≥3 months; (4) identification of specific targeted behaviors vs general health; (5) alignment of intervention activities with stated objectives; and (6) use of theory-based interventions. In contrast, comparison bias, lack of details on duration and dosage, lack of objective measurement, and lack of tracking system emerged as major weaknesses of online interventions. While four of the six factors (factors 3, 4, 5, and 6) are important for both face-to-face and online interventions, factors 1 and 2, along with weaknesses in interventions, will be highlighted in this discussion as they are unique to online delivery. The findings of this systematic review are based on critical analysis of these six factors.

Use of tailored messages and/or individualized feedback

This review found that ONE interventions that included tailored messages and/or provided individualized feedback to the participants were more likely to achieve their stated objectives. In this review, 11 of the studies provided individualized or tailored feedback; of these, more than half (55%) achieved all their stated objectives, while 45% partially achieved their objectives. More importantly, a majority (60%) of the successful studies in this review provided regular tailored messages and individualized feedback during the intervention.[30,35,36,38,39,55] These findings confirm the findings of reviews conducted by Olson,[57] who concluded that tailoring information to individual's behavioral needs was important for the success of online dietary behavioral interventions. Similarly, a review conducted by Neve et al[58] on web-based weight loss interventions showed that interventions with individualized feedback were more effective in achieving weight loss than web-based interventions that did not provide individualized feedback. The authors of this review recommend including tailored messages or a form of individualized feedback in the design of online delivery methods.

Interaction between investigators and participants

In addition to tailored and individualized messages, this review found that studies that included regular interaction between investigators and participants over and above the online information, through personal contact such as email, phone, or posting questions on the intervention website, were more likely to achieve their stated objectives. This was evidenced by the fact that half of the successful studies in this review (50%) provided an opportunity for the participants to interact with the researchers through emails, phone, or posting questions on the intervention website.[30,35,36,51,55] This finding confirms the findings of a review conducted by Webb et al,[59] who found that effectiveness of internet-based interventions was associated with the use of additional methods of interacting with participants, such as personal contact via text messages, email, or online. Despite the fact that online interventions rely on technology for delivery, it is worth noting that interventions that included enhanced human interaction were more likely to be successful. Fortunately, features that accommodate human interaction, such as real-life questions and answers or chatting sessions, are available and easy to design for online interventions.

Intervention duration

According to this current review, the duration of the intervention was critical to the success of the online intervention. A majority of studies (60.0%) with an intervention duration of ≥ 3 months achieved their stated objectives.[30,34,35,38,48,52] These results confirm the findings of two previous systematic reviews conducted by Murimi et al[3,6] to identify factors contributing to the success of nutrition education interventions among adults and children. They found that nutrition

education interventions delivered face-to-face and implemented for more than 5 months (for adults) and 6 months (for children) were more likely to meet their objectives. In contrast, a review conducted by Olson,[57] to understand the components of efficacious interventions focused on dietary behaviors, found no difference between successful or unsuccessful interventions based on duration.

Specific behaviors

A finding from this current review suggests that interventions that target specific behaviors are more likely to achieve their stated objectives than broad and general interventions that do not target specific behaviors. For example, a majority (70%) of the successful studies identified specific behaviors to be addressed by their intervention, followed by clear objectives.[30,35,36,38,39,43,46] This finding supports the results of a review conducted by Murimi et al,[3] who found that dietary behavior change interventions among the adult population that targeted specific behaviors and goals were more successful than those with broad goals that did not target a specific behavior. Similarly, a systematic review on factors that contributed to the effectiveness of nutrition education interventions among children also found that targeting specific behaviors contributed to successful interventions, as measured by achieved objectives.[6]

Alignment of objectives with activities

This review found that planning activities that are aligned with intervention objectives and desired behavioral outcomes is an important determinant of intervention success. Most of the successful studies in this review (80%) involved intervention activities that aligned with the stated objectives and desired outcomes.[30,32,35,36,38,39,46,51] This finding is similar to findings from previous reviews,[6,60] which found that interventions involving activities aligned with the objectives and desired outcomes were more likely to be effective.

Theory-based interventions

Findings from the current review showed that the use of theory to develop online intervention contributed to the success of online interventions, as evidenced by the fact that a majority of the successful studies (80%) in this review were theory-based.[30,32,36,39,43,46,51,55] The current finding supports findings from a review by Webb et al,[59] who concluded that the effectiveness of internet-based interventions was associated with the use of theory. Similarly, a review conducted by Murimi et al[3] also found that studies that were theory-based were successful in achieving their objectives.

Factors considered to represent poor design in online nutrition education interventions

The current review found major weaknesses that may have interfered with the success of online interventions despite the use of the abovementioned factors. Main factors included comparison bias, lack of specific details on duration or dosage, lack of tracking system, lack of objective measurements of outcome, and lack of follow-up.

Introduction of comparison bias was evidenced by studies that aimed to assess the effectiveness of online interventions but used incomparable groups between treatment and comparison groups. Specifically, these studies placed a greater emphasis on the treatment group than on the comparison group; therefore, it remains unclear whether the success was determined by the delivery method or by the fact that the groups receiving the treatment received more attention and were more likely to be carefully designed than the comparison group.

Lack of reporting specific duration or dosage of the online interventions was a major omission. One-third of the included studies in this review did not mention how long and how often participants were expected to use the materials and activities. Behavior change is influenced by the dosage or exposure of the intervention, and the authors of this study were not able to determine the appropriate duration for those studies that did not state a duration or dosage for their intervention. The current finding is similar to findings from a review of e-health interventions for physical activity and dietary behavior change by Norman et al,[61] who showed that the majority of studies in their review did not explicitly state how often participants needed to use the website. Similarly, a review by Lentferink et al[62] found that most studies in the review did not report the intended usage for their intervention. In addition to the lack of specific dose, most of the studies in this review did not include a tracking system to track the log-on rates, online information accessed, number of times the information was accessed, and amount of time the participants spent viewing the information.

Overreliance on subjective measures over attempts to use objective measures is a major limitation of most online studies. A majority of studies in the review (85.19%) relied on self-reported measures through online surveys. This current finding is similar to the findings from a review by Olson,[57] who found that online interventions did not include any objective measures and relied instead on a self-reported measure for their

dietary outcomes. Given the growth of online interventions, it is critical that researchers develop objective measures in the future.

The current review has some limitations that should be acknowledged. First, this review included only articles published in English; thus, some recent and important findings that were published in languages other than English were possibly omitted. Second, this review did not include interventions that were delivered via mixed face-to-face and online methods; instead, it focused exclusively on the features of online interventions. Despite this limitation, the current review brings a systematic sample of online interventions and underscores important characteristics that contribute to the success of online interventions, which is helpful for the development of future online interventions. Third, publication bias could be present. The possibility exists that in some studies, the interventions had no significant effect on outcome and were therefore not published; thus, the analysis of studies presented in this review may have reported a more favorable degree of effectiveness than is actually the case. In addition, the interventions described in studies published from 2009 may differ, to some extent related to technological developments, from those described in studies published from 2018. For example, studies that reported on the use pedometers, included tracking systems, or were delivered via mobile phone and smartphone applications were published more recently.

Despite the limitations, the strength of this review lies in its systematic approach and its analysis of several factors that lead to the success of various types of online interventions. This is different from previous reviews, which focused on a single type of intervention and the related outcome.

CONCLUSION

This review suggests that online nutrition education interventions are more likely to be effective when they include tailored messages and/or individualized feedback and offer regular interaction between participants and investigators. In addition, it found that interventions that aligned desired dietary behavior outcomes with specific objectives and appropriate activities were more likely to succeed. Theory-based interventions and interventions that provided adequate durations were more likely to achieve desired behaviors. In contrast, the review revealed that poor design factors that interfered with the success of interventions included comparison bias, lack of specific details on duration or dosage, lack of objective measurements of variables, and lack of follow-up or tracking methods. Factors identified in this systematic review have the potential to improve the implementation of online nutrition education interventions. The findings underscore the importance of developing online intervention designs that utilize factors unique to online platforms for effective online interventions aimed at behavior change.

Acknowledgments

Author contributions. M.W.M. conceptualized the systematic review. M.W.M., B.N., A.F.M.-C., H.-J.L., and O.-H.P. conducted the literature search of literature, and screened, assessed the quality of, extracted the information from, and analyzed the included articles. H.-J.L. and O.-H.P. wrote the introduction. B.N. and A.F.M.-C. wrote the methodology. B.N. and M.W.M. wrote the results, discussion, and conclusion, and provided critical revision of the article. A.F.M.-C. edited the article. M.W.M. approved the final version of the manuscript.

Funding. This review received no external funding.

Declaration of interest. The authors have no relevant interests to declare.

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