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A Review of eHealth Interventions for Physical Activity and Dietary Behavior Change

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Abstract

Objective—To review eHealth intervention studies for adults and children that targeted behavior change for physical activity, healthy eating, or both behaviors.

Data Sources—Systematic literature searches were performed using five databases: Medline, PsychInfo, CINAHL, ERIC, and the Cochrane Library to retrieve articles.

Study Inclusion and Exclusion Criteria—Articles published in scientific journals were included if they evaluated an intervention for physical activity and/or dietary behaviors, or focused on weight loss; used randomized or quasi-experimental designs; measured outcomes at baseline and a follow-up period; and included an intervention where participants interacted with some type of electronic technology either as the main intervention or an adjunct component. All studies were published between 2000 and 2005.

Results—Eighty-six publications were initially identified, of which 49 met the inclusion criteria (13 physical activity publications, 16 dietary behaviors publications, and 20 weight loss or both physical activity and diet publications), and represented 47 different studies. Studies were described on multiple dimensions, including sample characteristics, design, intervention, measures, and results. eHealth interventions were superior to comparison groups for 21/41 (51%) studies (3 physical activity, 7 diet, 11 weight loss/physical activity and diet). Twenty-four studies had indeterminate results, and in four studies the comparison conditions outperformed eHealth interventions.

Conclusions—Published studies of eHealth interventions for physical activity and dietary behavior change are in their infancy. Results indicated mixed findings related to the effectiveness of eHealth interventions. Interventions that feature interactive technologies need to be refined and more rigorously evaluated to fully determine their potential as tools to facilitate health behavior change.

Introduction

The numerous health benefits of physical activity and healthy eating are well known, yet large proportions of modern societies do not meet recommended guidelines for these behaviors. In turn, inactivity and poor diet are the primary explanations for increasing obesity levels in these

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populations.[1,2] Intervention programs aimed at changing activity and eating behaviors range from individual-level approaches to community-wide campaigns in a variety of settings, with generally small to moderate effects on physical activity, diet, and weight loss.[3] Reasons for the lack of substantial impact have been postulated as a lack in effectiveness, reach, and sustainability.[3]

A growing area of research has been the incorporation of eHealth technologies to allow for more individualized behavior change interventions.[4-6] The term "eHealth" has become increasingly common with the proliferation of the Internet and the ability to provide access to a broad range of health information. A 2001 report titled, "The eHealth Landscape" provided a broad definition: "eHealth is the use of emerging information and communication technology, especially the Internet, to improve or enable health and health care.[7]"

Interactive, computerized technologies offer several potential advantages for designing behavioral interventions. Computer-based programs can tailor information and messages to participants to personalize their experience, and may enhance the cultural sensitivity of an intervention.[4,8] Access to information is quicker and it is easier to keep information accurate and updated. Computer interventions also offer some level of anonymity to users that may encourage individuals to seek out sensitive health information. The technology allows for asynchronous communication through Internet electronic bulletin boards that are always available online so individuals can exchange information, provide mutual support, and search for services at their convenience.[9,10] Computer-based programs can be designed as games to make a health intervention more appealing and entertaining to help engage participants.[4]

Kroeze, Werkman and Brug [6] recently conducted a systematic review on randomized trials of computer tailored interventions for physical activity and dietary behaviors. Kroeze et al. identified 30 studies that were delivered to adult participants without person-to-person contact (i.e., by mail, computer, or other media device). The authors concluded that the evidence in favor of computer tailored interventions for dietary behaviors was strong but there was little evidence for effective computer-based physical activity interventions.

A distinction can be drawn between interventions that use computer-tailored materials (such as pamphlets, newsletters, and reports) and interactive computerized interventions where participants actually use the technology (such as websites and handheld computers). These applications can be thought of as "first" and "second" generation computerized interventions, respectively.

The present systematic review differed substantially from the review by Kroeze and colleagues [6] both in purpose and included studies. The purpose of this review is to present a description of studies that feature second generation computerized interventions for physical activity and diet behaviors. Here, eHealth is defined as any form of interactive technology (e.g., e-mail, Internet, CD-ROM program, handheld computer, kiosk, etc.) used by program participants to facilitate behavior change. The intention was to include a broad survey of studies that evaluated interventions where the interactive technology was either the main component or subcomponent of the intervention. This review provides a descriptive evaluation of interactive eHealth interventions for physical activity, dietary behaviors and combined activity and dietary interventions for weight loss. For each study, we assessed the quality of the study design, types of intervention technologies, use of behavior change theory, and the nature of the findings.

Method

Data Sources and Search Terms

Systematic literature searches were performed using five databases (Medline, PsychInfo, CINAHL, ERIC, Cochrane Library) to retrieve articles written in English relating to eHealth interventions for physical activity, dietary behaviors, or weight loss among adults, as well as children. No beginning time limit was employed for search criteria as studies involving eHealth technology were expected to be relatively current. Searches were performed through 2005. Literature searches were conducted separately by two researchers for each domain and results compiled. The reference lists of retrieved articles were scanned for additional articles. A number of search terms were used to represent eHealth (e.g.: web, computer, e-mail, multi-media, Internet, PDA, cell phone) and the target domains of nutrition (e.g.: diet, fruit, vegetable, fat, healthy eating), physical activity/exercise, and obesity (e.g.: weight loss, body mass index, obesity).

Selection Criteria

Several criteria were established for inclusion. Articles published in scientific journals were included. Book chapters, abstracts from conference proceedings, and dissertations were excluded. Studies that intervened on physical activity, dietary behaviors or a combination of both were included. Only studies utilizing randomized or quasi-experimental designs were included. Target outcomes had to be measured at baseline and at follow-up. Studies examining the effectiveness or feasibility of interventions were included, while those focusing on acceptability or descriptions of technology-based interventions were excluded. Interventions had to be delivered using some type of electronic technology either as the main intervention component or as an adjunct component in the intervention program. Participants were not required to input information into the technology application (either for assessment or tailoring purposes) but they did have to receive information (such as educational messages) and directly interface with the eHealth technology. Therefore, interventions utilizing computer-assisted tailored feedback with no participant interaction were excluded. For example, some studies were identified where participants received computer generated tailored print materials but the participants did not interact with the technology (e.g., [11-13]).

Data Synthesis

Study quality was rated on nine methodological characteristics and each study was given a score calculated as the percent of the maximum obtainable score. Tabulated quality scores along with scoring criteria rules are presented in Appendix A (see online Appendix at www.ajpm-online.net). Two researchers independently ranked each study and then compared rankings for agreement. Ranking disagreements were discussed among the co-authors and an agreed upon score was assigned. Each study was also characterized by the level of support for the eHealth intervention enhancing behavior change compared to a control condition. This index was a three-level ranking based on statistically significant effects where "+" indicated favoring the eHealth intervention condition, "o" indicated indeterminate findings, and "–" indicated the eHealth intervention condition resulted in worse outcomes than the comparison condition.

Because of the heterogeneity of studies with respect to study designs, participants, measures and outcomes; a meta-analysis was not conducted to estimate a pooled effect size. For studies with designs that specifically isolated and tested the effect of the eHealth technology in comparison to a control group that did not receive the technology), effect sizes were estimated. Effect sizes (r) were interpreted as 0.10, small effect; 0.24, medium effect; 0.37 large effect.[14]

Results

Eighty-six studies were initially identified for potential inclusion. Thirty-seven studies were excluded due to: lack of behavioral outcomes (17 studies), no participant interaction with the eHealth technology (12 studies), focus on descriptions of the eHealth intervention with no data provided (3 studies), articles that were sub-studies of included studies (2 studies), articles that were published abstracts (2 studies), and an indeterminate nature of the study intervention (1 study). A list of excluded studies is available from the first author.

Of the 49 included articles, 13 articles focused on physical activity, 16 on dietary behaviors, and 20 on both physical activity and dietary behavior change. All articles were published between 2000 and 2005. Table 1 presents the study design quality scores for each study. The average design scores were 56% for physical activity, 68% for dietary behaviors, and 72% for the combined activity and diet studies. While most studies included a control group (91%), used individual randomization to treatment groups (74%), and validated measures of behavior change (79%); many studies did not isolate the eHealth technology in the design (51%) or present a rationale for sample size (38%).

Physical Activity Interventions

Of the 13 physical activity interventions (Table B1, see online Appendix at www.ajpm-online.net), study sample sizes ranged from 28 to 655 (median *n*=78). Eleven studies focused on adults and two on children. Most samples had primarily female participants with seven of the studies including 64% to 100% females. Studies with adults recruited from the community,[15,20,26] worksites,[16,17,19,21,23] primary care,[25,27] and online.[22] The two studies with children were conducted in schools. Diabetic patients were the focus of two studies [22,27]; the remaining 11 studies aimed at improving general health.

The most commonly used eHealth components were: website and e-mail,[21–23] websites,[15,20,24,27] and e-mail only.[16,17,19,26] One study delivered the intervention program using a CD-ROM [18] and another used a computer automated telephone system to engage participants in counseling for physical activity.[25] Three studies used pedometers as a tool for monitoring walking activity.[15,16,27]

The majority of studies (11 out of 13) were based on Social Cognitive Theory (SCT), the Transtheoretical Model (TTM) or a combination of the two. Two studies did not state a theoretical basis and another was based on a social-ecological model of diabetes self-management.[22] Two studies manipulated theoretical elements in their experimental design to test the effect of the interventions' theoretical fidelity on physical activity behavior. Hageman and colleagues [20] found no differences in physical activity levels after participants received either stage tailored or standardized newsletters through the Internet. Rovniak and colleagues[26] found that women significantly decreased their 1-mile walk test time when given precise and specific self-monitoring and feedback compared to women who received more general instruction and feedback.

Intervention durations ranged from 1 to 6 months with 8 programs lasting 2 months or less and four programs lasting greater than 3 months. Length of the intervention could not be determined in one study.[27] Most studies had a final post-test assessment immediately following the intervention with the exception of one study with a 10 week follow-up after an 8 week intervention[21] and one study with a 1 year follow-up after a 12 week intervention.[26] Study completion rates ranged from 59% to 100% with 10 studies reporting completion rates of at least 75%.

Tests of the eHealth interventions could be assessed in 10 of the 13 studies (Table 1). Three studies had findings favoring eHealth interventions influencing physical activity.[23,25,26] In six studies, the findings were statistically indeterminate [15,19,20–22,24] and in one study there was a between group difference at post-test that favored the control group for moderate physical activity levels.[18]

Dietary Behavior Interventions

Sixteen publications had interventions targeting dietary behavior (representing 14 different studies), (Table B2) with study sample sizes ranged from 72 to 1,578 (median *n*=288). Twelve studies focused on adults and two on children in school settings.[29,37] Seven of the adult studies recruited 70% to 100% women. Studies with adults were in worksite settings,[30,36,39,40] primary care,[33,34,38,41,43] and community settings.[28,31,32] Three interventions were designed for treating populations with specific diseases (i.e. diabetes,[34,38] and cardiovascular disease [43]).

The eHealth components included: websites, [32,37,38,40,43] computer programs,[34,41] interactive multi-media (IMM),[29,36] a CD-ROM program,[31] e-mail,[30] interactive phone technology,[33] and kiosks in grocery stores.[28] One study featured a psycho-education multimedia game called “Squire's Quest!” designed for children.[29] Thirteen studies targeted specific dietary behaviors, most commonly a combination of fat reduction and increasing fruit and vegetable consumption, while one study focused on general diabetes management.[38] There was a sizable range in interventions' duration. In one study, the intervention was a single interaction with the intervention technology.[31] Study participants had access to the intervention for 2 to 15 weeks in seven studies, while six studies had longer-term programs lasting from 6 to 12 months.

Only one of the studies did not mention a theoretical basis for the intervention with most based on SCT, TTM, the Precaution Adoption Process, or a combination of theories. Study completion rates were generally high and ranged from 45% to 95%. All but one study evaluated the intervention with a study design that included at least one comparison group. Thirteen studies measured dietary behavior outcomes usually assessed through validated self-report FFQs or dietary recalls. Five studies measured anthropometric or physiologic outcomes (e.g., BMI, serum cholesterol, HbA1c).

Tests of the eHealth interventions could be assessed in 13 of the 14 studies (Table 1). Seven studies indicated some evidence in favor of eHealth interventions influencing dietary behavior changes, [28,29,31,33,36,40,42] five studies provided indeterminate evidence, [35,37–39,43], and one study had findings that favored weekly in-person meetings compared to an internet-based intervention.[32]

Combined Interventions for Physical Activity, Dietary Behaviors, and Weight Loss

Twenty publications had interventions that targeted both physical activity and dietary behaviors (Table B3) and study sample sizes ranged from 35 to 2,121 (median *n*=111). Twelve studies focused on adults with 49% to 100% female participants; while one study included only men in the U.S. Air Force.[60] Seven of the adult studies specifically recruited overweight participants and focused on weight loss and/or weight maintenance. Seven studies focused on children. Two studies recruited African American girls and enrolled child-parent dyads.[45,61]

The adult studies were based in the community,[44,49–51,58,59,61,62] primary care,[46,53,63] worksites,[54,57] and the military.[60] Three of the studies with children were conducted through schools; one through a day camp, one in primary care, and anther in a community setting. In

addition to general health improvement and weight loss or weight maintenance, one study focused on diabetes prevention[58] and one study on enhancing fitness.[60]

The eHealth components included: websites,[45,47–52,57,58,60–62] computers or kiosks,[46,53,55,59,63] or e-mail.[44,54] All studies included some aspect of physical activity and dietary behavior change. Intervention programs ranged from 1 session to 1 year in length with 13/20 (65%) of the programs lasting 4 months to 1 year.

Ten studies were theory-based with nine referencing the TTM, often in combination with SCT or TPB. One study tested the commercially available ediets.com program.[62] All studies assigned participants to one of at least 2 study arms. However, in two studies all participants received the eHealth component of the intervention but were randomized to different follow-up conditions.[46,53] Most studies (15/20; 75%) had post-test assessments occurring immediately following the intervention without any subsequent follow-up assessment. Extended follow-up assessments ranged from 6 weeks [52] to 6 months [50,51,59] post-intervention in five of the studies. Study completion rates ranged from 66% to 98%. Physical activity and dietary behavior change was generally assessed with self-report instruments. Only two studies reported measuring physical activity with accelerometers and diet with 24-hour recalls.[45,55] Two studies did not measure behavior change[60,62] but were among the 10 studies that measured body weight as a study outcome.

Tests of the eHealth interventions targeting multiple behaviors could be evaluated on at least one of the outcomes of physical activity, a dietary behavior, or weight loss for all 20 studies (Table 1). Of the 17 studies that measured physical activity, six favored eHealth interventions for increasing physical activity.[47,48,52,54,55,59] Of the 17 studies that measured dietary behaviors, six favored eHealth interventions for changing dietary behaviors.[47,48,52,54,59,61] Of the 11 studies that measured weight change, four studies favored eHealth interventions,[56–58,60] and two studies found eHealth interventions to be less effective for weight loss compared to an in-person therapist [50] and a standardized weight loss manual.[62] Eleven of the 20 studies found evidence in favor of eHealth interventions on at least one of three outcomes of physical activity, dietary behavior, or weight loss.[47,48,52,54–61]

Effect Size Estimates for Studies that Isolated the eHealth Technology

Table 2 presents estimated effect sizes for the 24 studies that specifically compared eHealth technology to a non-technology control group. Effect sizes were generally in the small to medium range. Notable exceptions were Prochaska and colleagues who reported results for the subsample of boys physical activity in the large effect size range,[55] and Harvey-Berino[50] and colleagues who found an estimated medium effect size for Internet support being less effective for weight loss maintenance compared to an in-person therapist.

Discussion

This review provided a systematic description of 47 studies of eHealth interventions for behavior change related to physical activity and/or dietary behaviors. All studies were published between 2000 and 2005 and featured some type of interactive technology that was expected to facilitate the behavior change process and represent a “second generation” of eHealth technology that go beyond using computer-tailored print materials. As a result, only five studies [28,36,39,59,63] in this review overlap with the 30 studies reviewed by Kroeze and colleagues.[6] However, both reviews indicate that more rigorous research is needed to evaluate eHealth intervention technologies and understand the program mechanisms that promote physical activity and dietary behavior changes.

This study found that support for the interventions' efficacy for improving physical activity, diet, or facilitating weight loss over and above other intervention components can not be definitively discerned from the current body of research. Twenty-one of 41 (51%) studies had outcomes favoring the eHealth technology group compared to a control group. While some studies had high study design scores [21,43,54] and used randomized designs with control groups, less than half isolated the technology component and compared the intervention to a non-technology control group. Several studies included the eHealth intervention for all participants making it difficult to determine whether behavior changes were due to the eHealth application or other intervention components.[16,17,27,34,35,38,46,53]

The effect sizes estimated from the subset of studies that did isolate the eHealth technology in their study design tended to have small to medium effect sizes. This suggests that while eHealth interventions do not seem to have higher efficacy than other types of interventions [3], the potential reach of eHealth programs combined with their efficacy can result in a significant public health impact.[64] However, meta-analysis of specific types of eHealth intervention for particular population segments is warranted to more accurately estimate efficacy.

This review included many studies that scored high on the quality of the study design and resulted in positive findings supporting the eHealth technology for behavior change.[23,26,29,52,54,57,58] These studies are exemplars that may be of particular interest for researchers to learn more about the nature of the interventions and how they were evaluated. Detailed descriptions of the eHealth interventions, which may be of special interest to researchers designing similar interventions are provided in many of the studies.[15,16,19,23,26,27,29,30,36,43,45,48,50] Some of these were small pilot or feasibility studies, which although they did not contain strong evaluations, did include extensive description of the intervention content.

Overall, the studies mainly aimed at improving physical activity and dietary behaviors in the context of preventing chronic diseases, but this review also included eight studies that focused on these behaviors to target weight loss or weight maintenance. However, many of the studies that targeted only behavior change sampled participants with an average BMI or percent body fat in the overweight to obese range, which is consistent with the majority of the adult U.S. population being overweight or obese.[65] All of the reviewed studies met our inclusion criteria because they applied common principles of behavior change through interactive technology, which is relevant to primary prevention and weight loss.

"What Works in eHealth?"

In an effort to understand how eHealth interventions can facilitate health behavior change several issues surfaced. The reviewed studies can serve as a guide for continued development of eHealth interventions with consideration of topics such as measuring program utilization and dose, mode of intervention delivery, use of theoretical components, and targeting single versus multiple behaviors for change.

Program Utilization and Dose—An important issue for eHealth interventions is getting participants to use the interactive technologies at a high enough frequency over a specified duration to receive an optimal dose of the intervention. Utilization rates give an index of how often participants used the eHealth component. Common utilization measures for website usage are "hit" rates (the number of times a web page is opened) and log-on rates. Intervention dose can be measured as the amount of intervention materials (e.g., modules, sessions, worksheets, assessments, self-monitoring) a participant completes during the course of the program. A benefit of using eHealth interventions is that utilization and dose can be objectively measured, though only some studies tracked this data. Studies with higher utilization and dose tended to have better behavior change outcomes.[22,33,57,58,61,63] Outcomes were improved for subsamples that completed a certain amount of sessions.[47] Still, many studies suffered

from low dose and poor utilization with a majority of participants failing to engage in more than half of the expected eHealth activities[25,33,43,45] or had few website log-ons.[21] For web-based interventions, log-on rates tended to decrease over time.[22,57] Participants had higher utilization of behavior change websites compared to educational or control websites in several studies.[22,57,58,61] Higher log-on rates were found when the Internet program included peer support compared to programs without peer support.[38] Others have suggested that a user-centered perspective, in which the way users interact with technology is engineered into interventions, is also critical for greater uptake of eHealth programs.[66]

The majority of studies did not explicitly state how often participants were expected to use the website or eHealth intervention making it difficult to assess whether dose adequacy. Only participants in one study had log-on rates at the expected level.[22] Several studies did include self-reported measures of e-mail recall and found that most participants read information received electronically.[19,23,44] Another study found a more modest number of participants reading e-mails.[21]

In studies where dosing information was available, the data suggested that most participants received inadequate doses. Methods are needed to motivate participants to use and reuse eHealth programs, so that optimal intervention doses are received by participants. For example, incentives and telephone prompts may help increase utilization rates in the short term.[29] Alternatively, more engaging, dynamic website programs may help keep participants engaged as evidenced with a multimedia game[29] that had high completion rates and positive findings.

Mode of Intervention Delivery: Internet vs. Face-to-Face—Few of the reviewed studies were designed to make comparisons between programs delivered through eHealth technology versus in–person, face-to-face sessions. Those that did suggest that participants may not be ready to rely solely on computerized programs. Wylie-Rosett et al. [63] found that participants preferred face-to-face meetings and phone calls, and these interventions outperformed web/workbook groups. Harvey-Berino et al.'s studies found mixed results. In one study,[50] results indicated that in-person groups outperformed an internet-based program for weight loss. However, follow-up research[51] indicated that internet support was superior to in-person groups for weight loss maintenance. It may be that eHealth programs are optimal for implementing certain intervention tasks (e.g., such as conducting assessments and providing an information resource), which can then give health professionals more time to help patients with problem-solving and information synthesis.

Two studies addressed whether the accountability that comes from in-person meetings can be facilitated or mimicked via interactive technologies.[15,58] Tate[58] examined the effects of individualized e-counseling in a weight loss program and found that therapist contact improved outcomes. This method still required therapists to create tailored messages for each participant, which can be time-intensive. Bickmore[15] examined a method for computerizing this individualized therapist contact via “agents”. These agents were computer-generated and had the ability to closely mimic human communication strategies through emotional and relational interactions. While the study found that participants were able to establish bonds and rapport with their agent, this did not translate into behavior change in the short term.

Implementing Theoretical Components—The majority of reviewed studies explicitly cited a behavioral theory as a guide in intervention design. Most prevalent was the Transtheoretical Model (TTM) and Social Cognitive Theory (SCT). Many intervention strategies are common to multiple health behavior theories. Goal setting was a frequently used behavioral strategy. One possibility of eHealth technology is the improved ability to break down large goals into smaller ones. For example, Croteau adjusted step count goals biweekly by 5% or 10% to slowly increase daily physical activity to the desired levels, and found large

and significant effects over time.[16] By assessing smaller milestones more frequently, the technology has the ability to automatically create new, slightly more challenging goals to enhance the likelihood of reaching the overall health behavior recommendation.

Another common strategy for health programs involves behavioral self-monitoring with specific feedback. Technology can facilitate this process as participants can fill out electronic logs for physical activity or food consumption, and then send them via email to a health professional who can respond with personalized feedback in a timely manner. For example, Tate and colleagues used a website for daily to weekly online submissions of calorie and fat intake, and energy expenditure.[57,58] Both studies found significant weight loss for the intervention participants who received timely feedback from counselors via email. These findings demonstrate eHealth's potential for tracking and reinforcing behavior.

Unfortunately, the design of many studies precluded tests to determine whether the interventions were working through hypothesized theoretical constructs. As a result, when an intervention program resulted in weak findings, conclusions could not be drawn as to whether the lack of findings was due to a lack of theoretical fidelity or to other threats to study validity.

Targeting Single vs. Multiple Behaviors—Two studies tested hypotheses specifically about targeting multiple health behaviors. Prochaska and Sallis [55] found no benefit when concurrently targeting physical activity and diet compared to targeting physical activity alone among school children. Conversely, Vandelanotte and colleagues [59] found some evidence that simultaneous targeting of physical activity and dietary fat reduction was more effective than sequentially targeting these behaviors.

Multiple behavior interventions have more content and likely take more time than single behavior interventions. Many individuals may feel they do not have time to complete assessments, receive feedback, read educational materials, set goals and engage in other behavior change strategies for both physical activity and diet concurrently. This presents the challenge of trying to use eHealth technologies to facilitate the behavior change process as a multidimensional lifestyle approach. Experiments are needed to test programs with different combinations and sequences of behavior targets. It may be that a menu of simultaneous and sequential behavior change intervention options may be needed to meet the needs of different individuals.

Conclusions

The rapid developments in interactive technologies in terms of processing power, data transmission and data storage leads to a continuing evolution of eHealth interventions. Programs have evolved from first-generation programs that facilitated intervention tailoring with computers to generate printed materials.[67,68] What we have termed “second generation” e-health interventions allow for direct interaction between the participant and the technology to increase capabilities beyond tailored feedback messages. This second generation of interventions has allowed participants to select relevant psychoeducational information,[39,59] report on goals and track their progress,[57,58] and provide and receive social support either via bulletin boards [30,51] or synchronous chat rooms.[49]

This review was broad in scope to meet the objective of featuring eHealth technology implemented in interventions for changing physical activity and dietary behaviors. Because of the heterogeneity of studies, meta-analysis to determine pooled effect size estimates of eHealth interventions was not conducted. However, the review was systematic in addressing a specific research question, having explicit selection criteria, evaluating study quality, and describing study findings. Our summary of the support for eHealth interventions indexed by statistical

significance is a limitation of this review and more narrowly focused meta-analytic reviews are needed to better quantify the effect of eHealth interventions.

A third generation of eHealth technologies is already emerging. The interventions in the current review consisted of desktop applications. However, mobile devices such as handheld computers, cellular telephones, and text messaging devices are emerging as new platforms for delivering health information. These platforms are also incorporating new functions such as sensing, monitoring, geospatial tracking, location-based knowledge presentation, and a host of other information processes [69] that will potentially enhance the ability for accurate assessment and tailored feedback. Research has already been conducted using PDAs for ecological momentary assessment (EMA), where real-time self-report data is collected throughout a person's day.[70,71] The EMA concept can be expanded to "ecological momentary intervention,"[69] such as "just in time" prompting for a behavior change based upon some set of predefined conditions.

eHealth behavior change interventions are still in the preliminary stages of development and the potential of novel technologies to impact health behaviors is just beginning to be evaluated.[72] While eHealth is progressing, it is clear that more research is needed to better determine how technology can be incorporated into programs to enhance behavior change outcomes. We presented a description of the "state of the science" of recently published studies in this area that can serve as a guide to what has been accomplished and what future development and evaluation of eHealth interventions is needed.

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Table 1

Sample size, coded behavior change, and study design quality score for included in the studies.

Study	N	Physical activity	Dietary behaviors	Weight loss	Design score (% of maximum)[a]
Physical activity					
Bickmore (2005)[15]	101	o			56%
Croteau (2004)[16]	37	+[b]			44%
Dinger (2004)[17]	43	+[b]			33%
Goran (2005)[18]	207	o/−			44%
Hager (2002)[19]	525	o			44%
Hageman (2005)[20]	31	o			67%
Marshall (2003)[21]	655	o			100%
McKay (2001)[22]	78	o			67%
Napolitano (2003)[23]	65	+			78%
Palmer (2005)[24]	233	o			33%
Pinto (2002)[25]	298	+/o			78%
Rovniak (2005)[26]	61	+			67%
Yoo (2003)[27]	30	+[b]			22%
Dietary behaviors					
Anderson (2001)[28]	277		+		67%
Baranowski (2003)[29]	1578		+		89%
Block (2004)[30]	84		+[b]		33%
Block (2004, July)[31]	481		+		67%
Carpenter (2004)[32]	98		−		78%
Delichatsios (2001)[33]	298		+		78%
Glasgow (2000, 2002)[34,35]	320		o		67%
Irvine (2004)[36]	517		+		78%
Long (2004)[37]	121		o		67%
McKay (2002)[38]	160		o		67%
Oenema (2005)[39]	616		o		67%
Papadaki (2005)[40]	72		+		56%
Stevens (2002, 2003)[41,42]	616		+		78%
Verheijden (2004)[43]	146		o		100%
Combined activity, diet, weight loss					
Abroms (2004)[44]	93	o	o		40%
Baranowski (2003)[45]	35	o	o	o	80%
Calfas (2002)[46]	173	o	o		70%
Frenn (2005)[47]	103	+	+		60%
Frenn (2003)[48]	130	+	+		40%
Harvey-Berino (2002)[49]	122	o	o	−	80%
Harvey-Berino (2002)[50]	46	o	o	o	70%
Harvey-Berino (2004)[51]	255	o	o	o	90%
Kypri (2005)[52]	218	+	+		70%
Patrick (2001)[53]	117	o	o		60%
Plotnikoff (2005)[54]	2121	+	+		90%
Prochaska (2004)[55]	138	+/o	o		100%
Southard (2003)[56]	104	o		+	90%
Tate (2001)[57]	91	o	o	+	80%
Tate (2003)[58]	92	o	o	+	80%
Vandelanotte (2005)[59]	771	+	+		60%

Study	N	Physical activity	Dietary behaviors	Weight loss	Design score (% of maximum)[a]
Veverka (2003) [60]	39			+	60%
Williamson (2005) [61]	57		+	o	90%
Womble (2004) [62]	47			−	60%
Wylie-Rosett (2001) [63]	588	o	o	o	70%

[a] Tabulation of study design score is located in Appendix A.

[b] Study did not include a control group to allow for adequate assessment of effectiveness of the eHealth intervention on behavior change.

Direction of the behavior change was coded as: '+' = favoring the eHealth intervention, 'o' = indeterminate, and '−' = eHealth intervention condition resulted in worse outcomes than the comparison condition.

Table 2

Effect size estimates for studies with designs that isolated the eHealth technology.

Study	Effect size (r)			
	Physical activity	Dietary fat	Fruit & vegetable servings	Weight loss
Bickmore (2005) [15]	0.17			
Marshall (2003) [21]	−0.03			
Napolitano (2003) [23]	0.31			
Palmer (2005) [24]	0.02			
Anderson (2001) [28]		0.18	0.22	
Baranowski (2003) [29]			0.09	
Carpenter (2004) [32]			0.29	
Irvine (2004) [36]		0.24	0.10	
Oenema (2005) [39,a]		0.06	0.06, 0.09	
Papadaki (2005) [40,a]			0.05, 0.07	
Stevens (2002) [41]		0.11	0.12	
Stevens (2003) [42]		0.27	0.23	
Verheijden (2004) [43,b]				0.15
Abroms (2004) [44]	NS*		NS*	
Frenn (2005) [47,c]	0.19	0.28		
Harvey-Berino (2002) [49,d]	NS*			−0.31
Harvey-Berino (2002) [50,d]	NS*			NS*
Harvey-Berino (2004) [51,d]	NS*			0.19
Kypri (2005) [52]	0.12		.15	
Plotnikoff (2005) [54,e]	0.07			
Prochaska (2004) [55,f]	0.43		NS*	
Southard (2003) [56]	NS*	NS*	NS*	.29
Vandelanotte (2005) [59,g]	0.01	0.15		
Veverka (2003) [60]				0.19

Note. Effect size (r) is interpreted as 0.10, small; 0.24, medium, 0.37, large.

NS* = results reported as non significant and not enough information reported to estimate an effect size.

[a] effect sizes reported separately for fruit servings and vegetable servings, respectively.

[b] BMI at 4 months.

[c] effect sizes for subgroup completing at least half of intervention sessions.

[d] non significant effect reported for energy intake.

[e] effect size for healthy eating practices r = 0.10.

[f] physical activity effect for subsample of boys.

[g] effect sizes for percent of sample meeting recommended guidelines.

Appendix A

Study Design Quality Tabulation and Coding Criteria[a]

Physical Activity Studies

	Individual randomization	Control group	Isolate technology	Pre/ post	Retention ≥80%	BL groups equiv	Missing data	Sample size calc	Validated measures	Score (% of maximum)
Bickmore (2005) [15]	Y	Y	Y	N	Y	UK	N	Y	N	56%
Croteau (2004) [16]	N	N	N	Y	Y	N	Y	N	Y	44%
Dinger (2004)[17]	N	N	N	Y	Y	N	N	N	Y	33%
Goran (2005)[18]	N	Y	N	Y	N	Y	N	N	Y	44%
Hager (2002) [19]	Y	Y	N	Y	N	N	N	N	Y	44%
Hageman (2005) [20]	Y	Y	N	Y	Y	UK	N	Y	Y	67%
Marshall (2003) [21]	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
McKay (2001) [22]	Y	Y	N	Y	Y	Y	N	N	Y	67%
Napolitano (2003) [23]	Y	Y	Y	Y	Y	Y	N	N	Y	78%
Palmer (2005) [24]	N	Y	Y	Y	N	UK	N	N	N	33%
Pinto (2002) [25]	Y	Y	N	Y	Y	Y	Y	N	Y	78%
Rovniak (2005) [26]	Y	Y	N	Y	Y	Y	N	N	Y	67%
Yoo (2003)[27]	N	N	N	Y	Y	N	N	N	UK	22%

Dietary Behaviors Studies

	Individual randomization	Control group	Isolate technology	Pre/ post	Retention ≥ 80%	BL groups equiv	Missing data	Sample size calc	Validated measures	Score (% of maximum)
Anderson (2001) [28]	Y	Y	Y	Y	N	Y	N	N	Y	67%
Baranowski (2003)[29]	Y	Y	Y	Y	Y	N	Y	Y	Y	89%
Block (2004) [30]	N	N	N	Y	N	UK	Y	N	Y	33%
Block (2004) [31]	Y	Y	N	Y	Y	Y	N	Y	N	67%
Carpenter (2004) [32]	Y	Y	Y	Y	Y	Y	Y	N	N	78%
Delichatsios (2001) [33]	Y	Y	N	Y	Y	Y	Y	N	Y	78%
Glasgow (2000, 2002)[34,35]	Y	Y	N	Y	Y	Y	N	N	Y	67%
Irvine (2004)[36]	Y	Y	Y	Y	Y	Y	N	N	Y	78%
Long (2004)[37]	N	Y	Y	Y	UK	Y	N	Y	Y	67%
McKay (2002)[38]	Y	Y	N	Y	Y	Y	N	N	Y	67%

Dietary Behaviors Studies

	Individual randomization	Control group	Isolate technology	Pre/ post	Retention ≥ 80%	BL groups equiv	Missing data	Sample size calc	Validated measures	Score (% of maximum)
Oenema (2005) [39]	Y	Y	Y	Y	N	Y	N	N	Y	67%
Papadaki (2005) [40]	N	Y	Y	Y	N	N	Y	Y	N	56%
Stevens (2002, 2003) [41,42]	Y	Y	Y	Y	Y	Y	N	N	Y	78%
Verheijden (2004) [43]	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%

Combined Activity, Diet, and Weight Loss Studies

Authors	Individual Randomization	Control Group	Isolate Technology	Pre/ Post	Retention ≥ 80%	BL groups equiv	Missing Data	Sample Size Calc	PA validated measures	Diet validated measures	Score (% of maximum)
Abroms (2004) [44]	N	Y	Y	Y	N	N	N	N	Y	N	40%
Baranowski (2003) [45]	Y	Y	N	Y	Y	N	Y	Y	Y	Y	80%
Calfas (2002) [46]	Y	Y	N	Y	Y	Y	N	N	Y	Y	70%
Frenn (2005) [47]	N	Y	Y	Y	N	Y	N	N	Y	Y	60%
Frenn (2003) [48]	N	Y	N	Y	N	UK	N	N	Y	Y	40%
Harvey-Berino (2002) [49]	Y	Y	Y	Y	N	Y	Y	N	Y	Y	80%
Harvey-Berino (2002) [50]	Y	Y	Y	Y	Y	N	N	N	Y	Y	70%
Harvey-Berino (2004) [51]	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	90%
Kypri (2005) [52]	Y	Y	Y	Y	Y	Y	N	Y	N	N	70%
Patrick (2001) [53]	Y	Y	N	Y	N	Y	N	N	Y	Y	60%
Plotnikoff (2005) [54]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	90%
Prochaska (2004) [55]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Southard (2003) [56]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	90%
Tate (2001) [57]	Y	Y	N	Y	N	Y	Y	Y	Y	Y	80%
Tate (2003) [58]	Y	Y	N	Y	Y	Y	Y	N	Y	Y	80%
Veverka (2003) [60]	Y	Y	Y	Y	Y	Y	N	N	NA	NA	60%
Vandelanotte (2005) [59]	Y	Y	Y	Y	N	UK	N	N	Y	Y	60%
Williamson (2005) [61]	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	90%

Combined Activity, Diet, and Weight Loss Studies

Authors	Individual Randomization	Control Group	Isolate Technology	Pre/ Post	Retention ≥ 80%	BL groups equiv	Missing Data	Sample Size Calc	PA validated measures	Diet validated measures	Score (% of maximum)
Womble (2004)[62]	Y	Y	N	Y	N	Y	Y	Y	NA	NA	60%
Wylie-Rosett (2001)[63]	Y	Y	N	Y	Y	N	N	Y	Y	Y	70%

Study Quality Coding Criteria

Table heading	Scoring criteria
Individual randomization	Were participants randomized to study conditions? If so, was randomization at the individual level? Stratified and blocked randomization is acceptable. Studies that used individual randomization combined with a small proportion of randomized matched pairs are also considered YES. Appropriately designed and powered group randomization would also be acceptable if group was also unit of analysis. Individual randomization is NO when the authors fail to mention randomization, specify that another method of assigning group status was used, or randomize at the group level and analyze at the individual level.
Control group	Did the study include a comparison group? Comparison group could be a no treatment, treatment as usual, or alternate treatment group.
Isolate technology	Did study design allow for test of effectiveness of the technology? E.g., web-based delivery verses no treatment. To isolate the technology, the authors had to test the technology alone and compare to a group with no technology (YES). Packaged interventions where the technological components can't be parsed out are coded as not isolating the technology (NO).
Pre/post test design	Was assessment of behavior completed pre intervention and post intervention?
Retention	Was study retention at least 80% of subjects who initially agreed to participate in the study? Retention is calculated for the entire sample and not by group. For studies that did not report retention or dropout rates, retention can be calculated using the sample sizes used for analyses (e.g. 300 randomized, but only 250 were included in analyses = 83.3% retention).
BL Groups equivalent	Were tests conducted to determine if groups were equivalent at baseline on important variables (e.g., gender, age, weight)? If no tests mentioned, then = UK. If subset of tests indicated any group differences at baseline, then = NO.
Missing data	Were analyses conducted with consideration for missing data that maintains the fidelity of the randomization (e.g., intent-to-treat, imputation). Listwise case deletion (completer analysis) = NO, if only analysis conducted. If 100% retention then completer analysis is appropriate = YES. If authors compared the 'dropped subgroup' to the selected or randomized sample, but did not consider the impact of the dropped subgroup on randomization (e.g. ITT or imputation), then code as NO.
Sample size calculation	Was power analysis reported to determine study sample size?
Validity of measures	Did description of measures include reliability and validity information? If reference or coefficients, then YES. If well established measure that is known to be validated, then YES. For objective measures without validity evidence, if the objective measure is used as a proxy (e.g. food receipts for nutrition intake), then NO. If the objective measure is used as a direct measure of behavior (e.g. food receipts for food purchase), then YES. If validity not reported and measure unknown, then UK.
Total	Sum of Yes's

[a] All quality criteria rated as yes (Y), no (N), or unknown/unclear (UK)

Table B1

Summary of physical activity intervention studies.

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change strategies	Study design	Intervention technology	Control condition	Results
Bickmore (2005) [15]	N = 101 Ret = 81.2% Mean age = 24.8 55% Female Mean BMI = 24.4 Community based	PAR-Q; # days/week over 30 min; # days/ week over 10K steps	SLT, CBT GS, SH, RF, SM, EDU, PS	QE Randomized by individual; Posttest only for PA	Non-relational group received interactive computer agent, continuous access lasting 5-10 min each session. Relational group received non-relational intervention + computer agent w/social, emotional communication style.	Web forms only. Never interacted w/computer agent	No significant differences between groups on # days exceeding time or step count criterion. Marginally significant difference favoring combined intervention groups. Post test only comparisons.
Croteau (2004) [16]	N = 37 Ret = 100% Ages 23-64; Mean age = 44.3 78.4% Female, 100% Caucasian Worksite (college campus) based	Pedometer; Perceptions of Physical Activity Survey (PPA); Physical Activity Survey (PAS); Height/Weight	Not stated GS, SM personal action plan	One group experimental design	One counseling session followed by wkly emails reminders, motivational tips, and educational information over 8 wks	None	Significant increase over time in # steps, PAS & PPA outcomes. Significant and large increases for both goal groups. Stratified by BMI, only significantly increases were w/obese group.
Dinger (2004) [17]	N = 43 Ret = 83.7% Ages 25-54; Mean age = 41.7 100% Female, 88.9% Caucasian	PAR-Q; IPAQ long	TTM SM, EDU, BB, GS, PS, TL, SS, PR, RF, TS	One group experimental design	Wkly brief emails that contained information & strategies to change TTM constructs over 6 wks	None	Significant increases in total walking mins, # mins walking at work, for leisure & for transportation
Goran (2005) [18]	N = 207 Ret = 58.9% 4th grade classes; Mean age = 9.4 60% Female 58% Hispanic Mean BMI = 19.5	Height/weight; body fat; Accelerometer	SCT GS, ML, SM, RF, CE, SE	QE Randomized by school	Interactive CD-ROM game, 8 lessons + 4 classroom lessons & 4 family based assignments. 45 min per lesson over 8 wks for 12 hrs total contact	Variety of popular CD-ROMs not related to health topics	No significant differences between groups on total PA, & unexpected significant decrease in moderate PA for treatment group. Significant sex-by-treatment interaction for BMI & % body fat. Treatment girls had lower BMI & no change for boys.
Hager (2002) [19]	N = 525 Ret = 76.6% Mean age = 42.0 56% Female 94%Caucasian University based	7 Day PA Recall Questionnaire; Health Insurance Plan of New York Questionnaire; Stages of change	TTM RF, CE, GS, Self liberation; helping relationships; consciousness raising; counter-conditioning; relapse prevention	RCT	Action group received BL online message & 5 follow up emails over 6 wks tailored to action & maintenance stages only (e.g. one size fits all message). Received BL online message & 5 follow up emails over 6 wks tailored to specific SOC.	5 wkly email messages over 6 wks encouraging proper nutrition. No tailored messages.	No significant differences in PA or stage of change. Within group, action group significantly increased total PA. Significant increases in Staged & Action groups for leisure PA & only action group increased occupational PA. All groups significant & positive increase in average SOC.
Hageman (2005) [20]	N = 31 Ret = 96.8% Ages 50-69; Mean age = 56.1	Modified 7-day Activity Recall, Rockport Fitness Walking Test;	Pender's Health Promotion Model & SCT TL, DB, SE, GS	RCT Randomized by individual	3 internet tailored newsletters w/ 5-7 brief articles delivered at BL, 1 & 2 mo. Articles	3 internet non-tailored newsletters each w/ 5-7 brief articles	No significant group effects on activity. Both groups significantly increased sit & reach test. VO2 Max & %

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change strategies	Study design	Intervention technology	Control condition	Results
	100% Female 93.5% Caucasian	Height/weight; Body composition (BIA); Modified Sit & Reach Test			tailored on BL assessment	delivered at BL, 1 & 2 mos	body fat significantly decreased for control group & no change in the tailored group.
Marshall (2003) [21]	N = 655 Ret = 78.2% Mean age = 43.0 51% Female Mean BMI = 24 University (Australian) based	IPAQ Short; Stage of Change	TTM TL, RF, GS, SM, PR, SS	RCT Stratified by stage of change, Randomized by individual	Stage-tailored interactive Active Living web-site w/ animated features, stage-based quizzes & personalized sections. Continuous access + 4 personalized reinforcement emails over 8 wks	Stage-tailored printed Active Living booklets + 4 reinforcement letters over 8 wks	For whole sample, no significant differences in stage progress or total PA between or within groups. When analysis restricted to inactive group, significant increase in total PA favoring Print group, & a significant decrease in time sitting on a weekday favoring Web group.
McKay (2001) [22]	N = 78 Ret = 87.2% Ages 40+; Mean age = 52.3 53% Female 82% Caucasian US & Canada w/Type 2 diabetes	PAR-Q; BRFSS (select work & nonwork physical activity items)	SEM GL, FB, PS, SS	RCT Randomized by individual	Continuous access over 8 wks to online tailored website w/ goal setting & planning modules, personal online coach & feedback w/in 48hr, peer-to-peer support area, graphing, & access to articles, tips, & motivational stories	Continuous access over 8 wks to website's library of diabetes specific articles + real-time blood glucose tracking w/graphic feedback	No significant difference by group over time in moderate to vigorous PA or walking. Both groups significantly increased PA & walking over time.
Napolitano (2003) [23]	N = 65 Ret = 80.0% Mean age = 42.8 86% Female 91% Caucasian Mean BMI = 26.6 Worksite (Hospital) based	PAR-Q; PA Stages of Change; BRFSS Physical Activity Items	SCT & SOC TS, GS, SM, SS, RF, PS, TL, activity planning	RCT Randomized by individual	Continuous access to website for 12 wks w/ weekly email tip sheets & helpline. Stage tailored information	Wait list control	At 1 mo, significant changes in moderate PA mins & walking mins favoring intervention group. At 3 mo compared to 1mo, only walking mins significantly greater for intervention group.
Palmer (2005) [24]	N = 233 Ret = 73.8% 5th graders 55.8% Females School based	Weekly Activity Checklist (WAC)	Not stated FB, EDU, DB	QE Non-randomized	Internet delivered instruction twice wkly for 50 min during school. Got tailored information, quizzes, writing activities with graphics & animation. Unknown duration.	Wait list control	No significant between group differences. Within group, both groups increased from BL to T3. Interaction also significant where first group increased from BL to T2 & T2 to T3. However, waiting list control significantly increased from BL to T2
Pinto (2002) [25]	N = 298 Ret = 81.5% Mean age = 45.9 72% Female, 45% Caucasian 45% African American Mean BMI = 28.7 Group Medical Practice based	Self reported BMI; 7-day PAR; Stage of Motivational Readiness for Physical Activity	TTM, SCT, decision making theory GL, TL, PS, DB	RCT Randomized by individual	Received Telephone Linked Communication (TLC) focused on PA change Wkly calls for 10 min for 3 mos, then biweekly till 6 mo	Received TLC focused on healthy eating behaviors	Intention to treat found significant between group differences in % meeting recommendations of combined moderate & vigorous PA at 3 mo only. No significant 6 mo effects.

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change strategies	Study design	Intervention technology	Control condition	Results
Rovniak (2005) [26]	N = 61 Ret = 82.0% Mean age = 40.2 100% Female 82% Caucasian Mean BMI = 26.9	Height/weight; 1 Mile Walk Test; National Health Interview Survey (PA questions)	SCT ML, GS, SM, FB	RCT Stratified by age & walk test time, Randomized by individual	Email, goals, & contact components standardized for both groups. Intervention group received brief modeling demo, more specific goals & feedback relative to norm & past performance over 12 wks. Provided stopwatch & walking routes.	Weekly email log, general email prompts, & tips targeting social support, environmental cues, injury prevention w/ feedback over 12 wks	Significant between group increases in walk test time & heart rate favoring high fidelity group at posttest & marginally significant increases VO2 max. At 1 year marginally significant differences in mins walked favoring high fidelity group.
Yoo (2003) [27]	N = 30 Ret = 93.3% Mean age = 56.1 64.3% Female Hospital based (Korea) w/Type 2 diabetics	VO2 max; blood glucose; Stage of Exercise Behavior Scale (SEBC); Activity Assessment Questionnaire (AAQ); PA diaries; Pedometers	TTM TL, FB, GS, SM, PS	One group experimental design	Website included program manual, help materials, links to sites, general info, exercise test & prescription, stage-matched intervention & Q&A board. Contact lasted 50-105 min on first visit, 20-50 mins for pre-contemplation & contemplation stages, & 60 min for other stages. Unknown Duration	None	Significant increases over time in PA measured by accelerometer, & level of PA. Significant increases in VO2 max, blood glucose, pc 2hr glucose, & HbA1c.

Note: Theoretical Models: CBT = Cognitive Behavioral Therapy; MI = Motivational Interviewing; SCT = Social Cognitive Theory; SEM = Social Ecological model; TRA = Theory of Reasoned Action; TTM = Transtheoretical Model; Behavior Change Strategies: CE = Changing the environment; DB = Decisional Balance (benefits and barriers); EDU = Education and/or knowledge; FB = Feedback; GS = Goal Setting; ML = Modeling; PC = Pros and cons; PR = Prompts/Cues; PS = Problem Solving (PS); SE = Self-efficacy; SH = Shaping; SM = Self-monitoring; SS = Social Support; RF = Reinforcement, rewards; TL = Tailoring; TS = Tip Sheets; Design: RCT = Randomized Controlled Trial; QE = Quasi-experimental

Table B2

Summary of Dietary behavior intervention studies

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change strategies	Study design	Intervention Technology	Control condition	Results
Anderson (2001) [28]	N = 277 Ret = 45% 96% Female 92% Caucasian Community based	Food shopping receipts; FFQ (created composite)	SCT SM, Planning food purchases and meal prep, GS, FB, RF	RCT Stratified by race, education, family size	Treatment group received Nutrition for Lifetime System (NLS) delivered at kiosks in 5 supermarkets 15 wkly segments with 4 to 6 mo follow-up period	No treatment control	Composite fat decreased by 9%, composite fiber increased by 19%, composite FV increased by 20% favoring intervention group
Baranowski (2003) [29]	N = 1578 Ret = 95% Ages 8-12 52% Female 44% Caucasian 30% Hispanic School based	Food Intake Recording Software System (four 24 hr diet recalls)	SCT GS, Assignments, Decision making regarding outcome expectancies	RCT Schools matched in pairs and randomly assigned	10 session multimedia game delivered over 5 wks	No treatment control	1 svg increase in FJV consumption favoring the intervention group
Block (2004) [30]	N = 84 Ret = 56% Ages 21-63 73% Female Worksite based	Block screening questionnaires Stage of change	Weinstein's Precaution Adoption Process TTM EDU, GS, RF, SS	Non-randomized One group feasibility study	Automated emails—Worksite Internet Nutrition (WIN) received over 12 wks	None	Fat decreased and svgs of FV significantly increased 65% moved forward in stage of change for fat and 74% moved forward for FV
Block (2004) [31]	N = 481 Ret: 100% Mean age = 50.1 100% Female 51.6% Caucasian Community based	California Dietary Practices; Stage of change	Not Stated FB, GS	RCT Stratified by race; Randomized to receive one-time interaction w/ computer program or computer program + 2 phone calls	Two groups: One-time interaction with Little by Little CD-ROM program; CD-ROM program + 2 phone calls 2 mo follow-up	CD-ROM for stress-management	Both computer groups increased FV intake over stress group Telephone group had significant increase in stage beyond stress group
Carpenter (2004) [32]	N = 98 Ret=94.9% Mean age = 49.6 60% Female Predominantly Caucasian Community based	Modified Healthy Eating Index (MHEI); 3-day diet records	SCT, TTM Processes of change, SM, DB, Making healthful eating fun	RCT Randomized to 1 of 3 groups: wkly mtg; intervention materials biweekly by mail + website; usual care	Two groups: Wkly small group mtgs over 20 sessions; Mailed materials + access to interactive website for 6 mos	Usual care received nutrition book	Weekly meeting group improved MHEI scores and increase in fruit relative to other groups
Delichatsios (2001) [33]	N = 298 Ret = 83% Mean age = 45.9 72% Female 44.9% Caucasian 44.6% African American Mean BMI = 28.7	FFQ; PrimeScreen Instrument; Stage of change	SCT FB, GS, RF	RCT	Received Telephone Linked Communication (TLC) focused on dietary changes Expected to call 1x/wk for 6 mos	Received TLC focused on PA change	Increased dietary fiber grams/day and fruit svgs/day; decreased percent of energy intake from saturated fat in intervention compared to controls

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change strategies	Study design	Intervention Technology	Control condition	Results
	Physician office based						
Glasgow (2000, 2002) [34,35]	N = 320 Ret = 89% 40+ years of age; Mean age = 60 56% Female ≈ 90% Caucasian Physician office based; Type 2 diabetics	Kristal Fat & Fiber Behavior Scale NCI Block Fat Screener; HbA1c Lipid ratios	SCT/self-management, MI GS, RF, PR, PS, FB, TL, Barriers, Empowerment principles	RCT	All groups received computerized assessment & feedback at BL, 3, 6 mos Assigned to no further contact, phone support, community support, or combined follow-up groups.	None	All groups had improvements in fat, weight, lipids at 3 and 6 mos At 12 mos, significant decrease for fat, HbA1c, lipids for all groups
Irvine (2004) [36]	N = 517; Ret = 90% Mean age = 43 73% Female 85% Caucasian Worksite based	Diet habits questionnaire; F&V intake items (from "5 A day"); Stage of change	TTM, TRA, SCT Eating strategies, GS, Barriers, Vignettes, ML	RCT Participants were paired in blocks for assignment by gender, age, ethnicity, worksite	Interactive multimedia (audio, video, graphics, printouts) in each worksite for 60 days	Wait list control could access program after 30 days	Decrease in fat, increase in FV for treatment group at 30 days and for both groups at 60 days
Long (2004) [37]	N = 121 Ret: unknown 52% Female Ages 12 – 16 Median age = 13 46% Caucasian 41% Hispanic School based	Health behavior Questionnaire; FV Consumption SE Scale; Youth and Adolescent FFQ	SCT, TTM EDU, Mastery, ML, Repetition, FB	QE Pre-test, post-test	5 hrs of web-based nutrition education and 10 hrs of classroom curriculum over 1 mo	Nutrition education embedded in curriculum	No difference in consumption of FV or fat
McKay (2002) [38]	N = 160 Ret = 84% Ages 40 – 70; Mean age = 59.3 53.1% Female Physician office based; Type 2 diabetics	Total cholesterol; HbA1c; Block Fat Screener; Kristal Fat & Fiber Behavior Questionnaire	Self-management EDU, Skills training, SS, FB, GS, Barriers	RCT Randomized to 1 of 4 groups	All received D-Net website for 3 mos Assigned to: Information only; Personalized self-management coach; Peer support; Combined	None	Decreases in fat intake and poor diet practices for all groups
Oenema (2005) [39]	N = 616 Ret = 79% Mean age = 42 43% Female Worksite based	Personal intake levels, intention to change and intake with FFQ	Precaution Adoption Process Model FB, Increase awareness, GS, ML	RCT Randomized to 1 of 3 groups	2 intervention groups using web-site through work intranet or CD-ROM: Tailored nutrition information; Generic nutrition information	No information control	Lower intake of vegetables for controls than intervention ($p < .10$). No intake differences for fruit and fat.
Papadaki (2005) [40]	N = 72 Ret = 77.8% Mean age = 40 100% Female Worksite based	7 day Food Diaries; Lipids; Blood pressure; Height/Weight	Precaution adaptation model, SCT, TTM GS, FB, Barriers, SE	QE Worksites assigned to intervention or control condition	Tailored feedback e-mail letters and questionnaires completed online every 6 wks over 6 mos	Minimally tailored feedback and education	Significant changes favoring the intervention group on FV, saturated fatty acid ratio, and HDL-cholesterol
Stevens (2002, 2003) [41,42]	N = 616 Ret = 85% Ages 40 – 70; Mean age = 53.5	24 hr food recalls; Fat and Fiber Behavior Questionnaire;	TTM, SCT, MI FB, GS, TL, Barriers, SE	RCT Randomly assigned to intervention or control	One time touch-screen computer assisted assessment for fat behavior	Control group focused on breast cancer screening	At 12 mos percent of calories from fat decreased more in intervention group

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change strategies	Study design	Intervention Technology	Control condition	Results
	100% Female ≈ 93% Caucasian Mean BMI = 30 HMO based	Block FFQ; Cholesterol			Received tailored counseling, Nutrition materials, Phone calls Follow-up at 4 and 12 mos		F&V increased significantly more in intervention group Saturated, monounsaturated, and polyunsaturated fat decreased significantly for intervention group
Verheijden (2004) [60]	N = 146 Ret: 89.0% Mean age = 63 45% Female Physician office based; People with increased CVD risk	Anthropometry; Blood pressure; Cholesterol	TTM TL Self-assessment SS	RCT Randomly assigned to intervention or control groups	Intervention received Heartweb Assessed stage of change and tailored information once per mo for 8 mos Assessed at 4 and 8 mos	Usual care	No differences in stage of change, social support, anthropometry, blood pressure, cholesterol levels

Note: FFQ, food frequency questionnaire; FV, fruit and vegetables; FJV, fruit, juice and vegetables; **Theoretical Models**: CBT = Cognitive Behavioral Therapy; MI = Motivational Interviewing; SCT = Social Cognitive Theory; SEM = Social Ecological model; TRA = Theory of Reasoned Action; TTM = Transtheoretical Model; **Behavior Change Strategies**: CE = Changing the environment; DB = Decisional Balance (benefits and barriers); EDU = Education and/or knowledge; FB = Feedback; GS = Goal Setting; ML = Modeling; PC = Pros and cons; PR = Prompts/Cues; PS = Problem Solving (PS); SE = Self-efficacy; SH = Shaping; SM = Self-monitoring; SS = Social Support; RF = Reinforcement, rewards; TL = Tailoring; TS = Tip Sheets; **Design**: RCT = Randomized Controlled Trial; QE = Quasi-experimental

Table B3

Summary of combined activity and diet intervention studies

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change Strategies	Study design	Intervention Technology	Control condition	Results
Abroms (2004) [44]	N = 93 Ret = 75.3% Ages 15-17; Mean age = 15.7 100% Female 80% Caucasian Shopping mall based	Youth Risk Behavior Surveillance (F&V intake only); Nurses Health II Interview Study Active & Inactivity Questionnaire	Not stated	QE Non-randomized	Intervention group received 10 issues of wkly interactive e-mail magazine; Magazine consisted of biwkly emails, advice column, brief quizzes & answers, & promotional information about PA over 7 mos	Community based in-person workshops, postcards, flyers, & magazines	No significant differences between groups for F&Vor PA
Baranowski (2003) [45]	N = 35 Ret = 88.6 Age 8 100% Female 100% African American Community/ family based	BMI; Waist circumference; DEXA; Nutrition Data System for Research; Accelerometers; GEMS Activity Questionnaire; Preferences for PA and sweet beverages	SCT SE, EDU, RF, SS, SM, CE, GS	RCT Randomly assigned to treatment or control	Attended 4 wk summer camp & 8 wks of internet program Intervention website focused on PA and FV; asked to log-on weekly; Parent website too	Attended different day camp Control website focused on general health Asked to log-on once/mo	No difference in BMI. Lower total calories, percent calories from fat, higher water and FJV consumption and less sweet beverage consumption for treatment group No differences for PA
Calfas (2002) 46	N = 173 Ret = 86% Mean age = 37.5 69% Female 72% Caucasian Mean BMI = 25 Primary care based	PA stage of change; Block Simplified Fat Screener; Servings of FV; Overeating behaviors	TTM, SCT GS, DB, SS, EDU	RCT Randomly assigned to intervention or control groups	All completed computer assessment of behaviors Assigned to: No further contact; 8 bimonthly mailings; infrequent phone & mail; frequent phone & mail 4 mo follow-up	None	All groups improved in dietary fat, FV, and overeating over time
Frenn (2005) 47	N = 103 Ret = 77% Ages 12-14 67% Female Majority Hispanic School based	Child and Adolescent Activity Log; Food Habits Questionnaire	Health promotion/ TTM Consciousness raising, Self-reevaluation, CE, DB	QE Assigned to intervention or control based on classrooms	8 sessions of Blackboard delivered internet with videos & tailored feedback based on stage; Discussion boards with individualized email feedback for 1 mo period	Usual class assignments	Intervention group who completed more than ½ of sessions increased moderate PA by 22 min while controls decreased by 46 min ($p = .05$) Significant decreases in fat for intervention groups doing 50% of sessions, no difference for controls
Frenn (2003) 48	N = 341 Ret=38.1% Ages 12-15 52% Female 36% Caucasian 45% African American School based	Food Habits Questionnaire; Child and Adolescent Activity log	TTM Awareness, PC, MD, CE, DB	QE Assigned to intervention or control group by classroom	4 sessions of internet & video intervention, healthy snack session, & a gym class over 1 mo	Usual school curriculum	No significant differences for dietary fat Less of a decrease in moderate PA for intervention group compared to control

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change Strategies	Study design	Intervention Technology	Control condition	Results
							Girls decreased fat more in intervention than control group (except for Asians); Boys in control group decreased fat more than intervention for each racial group
Harvey-Berino, (2002) [49]	N = 122 Ret = 76% Mean age = 48.4 85% Female ≈ 98% Caucasian Mean BMI = 32.2 Community based	Weight; Block FFQ; Paffenbarger Physical Activity Questionnaire	Self management SM, SS, RF, GS, PS, EDU	RCT All attended 24 wk weight control program Randomized to 1 of 3 maintenance groups: internet support; in-person support; or minimal in-person support for 12 months Assessments at BL, 6, 12, 18 months	Internet support group had website access with electronic self-monitoring forms, diet analysis, chat room, bulletin board, therapist-led internet video sessions; e-mails from group therapist	In-person support Minimal in-person support	Internet group gained more weight than in-person support at 6 mos and had smaller weight loss than both other groups at 18 mos All groups significantly decreased energy intake at 6 mos; In person group maintained decreased intake at 18 mos All groups increased PA during treatment at 6 mos and in-person group remained higher at 18 mos
Harvey-Berino (2002) [50]	N = 46 Ret = 96% Mean age = 46.3 80% Female Predominantly Caucasian Mean BMI = 32.2 Community based	3-day food records; Paffenbarger Physical Activity Questionnaire; Weight	Self management SM, SS, RF, GS, PS, EDU	RCT All attended 15 wk behavioral weight control program Randomized to 1 of 3 maintenance groups for 22 weeks	Internet group had website access for biweekly internet chat sessions, self-monitored on website; viewed video of group therapist, e-mail from therapist, bulletin boards	In-person therapist led No treatment control	No differences in weight, BMI, diet, or exercise change during maintenance All lost weight, decreased calorie and fat intake, and increased energy expenditure
Harvey-Berino (2004) [51]	N = 255 Ret = 69% 82% Female Predominantly Caucasian Mean BMI = 31.8 Community based	Weight; Block FFQ; Paffenbarger PA Questionnaire; Weight	Self management SM, SS, PS, RF, GS	RCT All attended 6 mo behavioral weight control intervention via interactive TV (ITV) Randomized to 1 of 3 weight maintenance groups for 12 mos Assessments at BL, 6, 12, 18 mos	Internet group had website access for biweekly chat sessions, self-monitoring on website, e-mails from group therapists, bulletin boards	Frequent in-person support via ITV Minimal in-person support via ITV	No differences in amount of weight lost at 18 mos All groups significantly increased PA All groups decreased energy intake over initial 6 mos
Kypri (2005) [52]	N = 218 Ret = 86% Mean age = 20.2 49% Female 75% European University based	Daily fruit and vegetable intake; Physical activities participated in	EDU	RCT Randomly assigned to 1 of 3 groups: computerized assessment, feedback and advice on health habits;	Web-based assessment and personalized feedback group received feedback & advice on health habits	Minimal contact	Compliance with FV and PA recommendations better in assessment and feedback group than minimal contact group

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change Strategies	Study design	Intervention Technology	Control condition	Results
				computerized assessment only; minimal contact	Web-based assessment only with no feedback Assessed 6 weeks later		
Patrick (2001) [53]	N = 117 Ret = 79% Ages 11-18; Mean age = 14.1 37% Female 43% ethnic minorities Physician office based	Self-reported PA and nutrition	TTM, SCT, Relapse Prevention Model GS, SS, PS, DB	RCT All received computerized assessment & counseling from provider Randomly assigned to 1 of 4 follow-up treatment groups	Interactive computer program assessed behaviors, compared to health goals, gave feedback, reviewed with physician Extended intervention groups: frequent mail, infrequent mail & phone, frequent mail & phone Assessed at BL and 4 mos	No further contact	All groups significantly improved over time for moderate PA, FV intake, fat intake No significant improvement for vigorous PA
Plotnikoff (2005) [54]	N = 2121 Ret = 98% Mean age ≈ 45 ≈ 74% Female Mean BMI ≈ 27 Worksite based	Godin Leisure Time Exercise Questionnaire; Dietary variables; Diet stage of change	SCT, TTM, Protection Motivation Theory, Theory Planned Behav. EDU	RCT Randomized to intervention or control	Weekly combined PA and nutrition messages sent to e-mail addresses for 12 wks Access to study website with information & archived messages	No treatment control	Intervention group increased total activity level while controls decreased; Both groups had higher PA levels at work Both groups had healthier eating practices and balance of food and activity at time 2 but more pronounced in intervention group Stage of change for different dietary behaviors increased for both groups with some effects being more pronounced for intervention group
Prochaska (2004) [55]	N = 138 Ret = 98% Mean age = 12.1 65% Female 28% Caucasian School based	1-week accelerometer; 3 day food records	SCT, TTM FB, GS, Relapse Prevention	RCT All completed computerized health assessment Randomized to 1 of 3 groups: multibehavioral intervention (PA and nutrition); PA only; no treatment control Assessments at BL and 3 months	PA & nutrition and PA only group received tailored feedback from assessment	No treatment control	PA increased in both intervention groups and decreased in control group for boys; For girls, PA decreased in all conditions Boys' FV decreased for mutli-behavior group and increased for PA only and control groups (non-significant) For girls, FV increased in both intervention groups and decreased for controls (non-significant)

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change Strategies	Study design	Intervention Technology	Control condition	Results
Southard (2003) [56]	N =104 Ret = 96.2% Mean age = 62.3 25.0% Female, 97.1% Caucasian Mean BMI = ~ 30 Hospital and practice based; Cardiovascular disease patients	Height/weight; Blood Pressure; Duke Activity Status Index; MEDFICTS (dietary survey); Lipid Profiles	Not stated EDU, SM, FB, RF, SS	RCT Stratified by minority status, participation in cardiac rehab & CV event; Randomized by individual	Communication w/ case manager via website, education modules, online measurement & discussion group, access to other participant's email addresses, links to info on web, access to online registered dietitian. Wkly contact for 30 mins over 6 mos	Usual Care	Significant differences between groups on weight & BMI. No significant differences in self-reported exercise & dietary intake
Tate (2001) [57]	N = 91 Ret = 78% Mean age = 40.9 89% Female 84% Caucasian 100% overweight or obese Worksite (Hospital) based	PAR-Q; Weight; waist circumference; Paffenbarger Activity Questionnaire; Block FFQ	Not stated GS, PR, SS, EDU, FB, SM	RCT Randomized by individual	Same access to website as control + electronic diary for self-monitoring, therapist access, wkly emails w/ weight loss lessons, tailored feedback from therapist, and community bulletin board access.	Continuous access to Internet education website w/ brief weight loss info & resources on diet, exercise, and behavior change strategies over 24 wks	Completer analysis found significant difference favoring intervention group at 3 and 6 mos. From baseline to 3 mo, intervention group lost more weight & greater waist circumference reduction. Both groups maintained weight loss from 3 to 6 mo. Similar results for intention to treat analysis.
Tate (2003) [58]	N = 92 Ret = 84% Mean age = 48.5 90.2% Female 89.1% Caucasian 100% overweight or obese At risk for Type 2 diabetes	PAR-Q; Weight; Waist circumference; Blood glucose; Paffenbarger Activity Questionnaire; Block FFQ	Not stated FB, SM, RF, SS, GS, PR	RCT Randomized by individual	Same access to website as control + access to weight loss therapist via email and daily web diary. First month, 5 emails/wk from therapist & weekly emails remaining 11 mos	Continuous access over 52 wks to internet website w/weight loss tutorial, resources & message board. Weekly tip sheets, links, and email reminders.	Intention to treat analysis found intervention group had greater reductions in weight, % of initial body mass, BMI, and waist circumference. Significant reduction in glucose at 3 mo, but not 12 mo. Marginally significant reductions in caloric intake favoring intervention group. No significant differences in energy expenditure.
Vandelanotte (2005) [59]	N = 771 Ret = 75.4% Mean age = 39.1 64.5% Female Mean BMI = 24.5 Belgium	IPAQ –long; 48 item FFQ	Theory of Planned Behavior; TTM TL, FB, SE, SS, EDU, BB, TP, PR	RCT Randomized by individual to 1 of 3 groups: simultaneous PA/ diet goals; PA then fat goals at 3 mos; fat then PA goals at 3 mos	All groups received one time intervention for each behavior for 50 mins to get computer tailored feedback. Follow-up assessment at 6 mo	Wait list control	Both sequential and simultaneous groups significantly increased total PA compared to control. No significant difference between sequential and simultaneous groups. Significant interactions between those meeting

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change Strategies	Study design	Intervention Technology	Control condition	Results
							recommendation and not for PA and diet.
Veverka (2003) [60]	N = 39 Ret = 93% Ages 30-44 0% Female Air force men	Height/weight; VO2; body fat; blood pressure; waist to hip ratio; heart rate	TTM TL, EDU	RCT Randomized by individual	Continuous access over 24 wks to website w/stage matched diet & physical activity content in newsletter form	No access to website	Significant difference in weight, BMI, body fat, waist to hip ratio and resting heart rate favoring intervention group. Marginally sig. systolic blood pressure decrease. Significant interaction between group and pretest for DBP and cholesterol.
Williamson (2005) [61]	N = 57 Ret = 87.7% Ages 11-15; Mean age = 13.2 100% Female 100% African American Mean BMI = 36.3 Family based (One overweight parent; Mean age = 43.2; Mean BMI = 38.5)	Height/weight; DEXA; 24 hr Food Recall; Block FFQ; Weight Loss Behavior Scale (WLBS)	Family treatment methods TL, SS, RF, SM, GS, ML, PS	RCT Stratified by BMI & age; Randomized by individual	Same as control + weekly online training sessions and quizzes, graph to track exercise, online counseling, food monitoring worksheets w/instant feedback on choices, online behavioral strategies, and structured programs prompting low calories diets and increased PA.	Continuous access over 12 wks to website w/ links to nonspecific educational health sites, interactive graphing, healthy menu ideas, and email access to counselor	Significant differences favoring intervention girls in fat intake, fat mass, and marginally significant differences in BMI & body weight. Parents in intervention group lost more weight, lower BMI and increased exercise significantly. No difference in body fat.
Womble (2004) [62]	N = 47 Ret = 66% Mean age = 43.7 100% Female 100% overweight or obese; Mean BMI = 33.5	Height/weight; blood pressure; fasting biochemical profile; Food diaries; Eating inventory	Not stated PR, SS, GS, TL, FB, PR	RCT Randomized by individual	Access to commercial weight loss website over 1 year. Included virtual visit w/dietitian, prescribed foods, moderated online mtgs and support groups, buddy program, animated fitness instructor, 24-hr help desk, and email reminders & goals, & biweekly email newsletter. Five meetings with psychologist.	Weight loss manual w/16 step-by-step lessons	Intention to treat. Significant difference favoring control group on weight loss at week 16 and 52. Same results for completer analysis but results non-significant. No significant between group differences in eating behaviors, blood pressure, glucose, lipids or lipoproteins.
Wylie-Rosett (2001) [63]	N = 588 Ret = 81% Mean age = 52.5 82.3% Female 83% Caucasian Mean BMI = 35.6 HMO based; overweight w/ 1 risk factor for	Height/weight; body composition; waist to hip ratio; cholesterol level; Block fat screener; Paffenbarger Physical Activity Questionnaire	CBT, TTM TL, GS, BB, SE, RF, PR, SS	RCT Randomized by individual to 1 of 3 groups: workbook only; workbook + computer; workbook + computer + staff	Workbook + multimedia computers and kiosks with expert system in waiting room. Included text, animation, graphics, interactive quizzes, and video clips. Instructed to use	Workbook w/self help sheets	Significant differences favoring intervention group on weight, BMI, % body fat, and % weight loss. Most intensive group lost significantly more weight than control group. No significant

Authors	Sample characteristics	Measures	Theoretical framework; Behavior change Strategies	Study design	Intervention Technology	Control condition	Results
	cardiovascular disease				system wkly 20-30 min during first 3 mo, and monthly up to 12 mo Workbook + computer + staff: Same as above + 6 grp workshop sessions, and up to 18 phone calls or face-to-face mtgs with RD over 12 mo		differences for intermediate group.

Note: FFQ, food frequency questionnaire; FV, fruit and vegetables; FJV, fruit, juice and vegetables; **Theoretical Models**: CBT = Cognitive Behavioral Therapy; MI = Motivational Interviewing; SCT = Social Cognitive Theory; SEM = Social Ecological model; TRA = Theory of Reasoned Action; TTM = Transtheoretical Model; **Behavior Change Strategies**: CE = Changing the environment; DB = Decisional Balance (benefits and barriers); EDU = Education and/or knowledge; FB = Feedback; GS = Goal Setting; ML = Modeling; PC = Pros and cons; PR = Prompts/Cues; PS = Problem Solving (PS); SE = Self-efficacy; SH = Shaping; SM = Self-monitoring; SS = Social Support; RF = Reinforcement, rewards; TL = Tailoring; TS = Tip Sheets; **Design**: RCT = Randomized Controlled Trial; QE = Quasi-experimental