Original Research
A Systematic Review of e-Health Interventions for Physical Activity: An Analysis of Study Design, Intervention Characteristics, and Outcomes

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Abstract
Objective: This systematic literature review of e-health interventions targeting physical activity (PA) from January 2006 to November 2010 provides an updated and critical picture of the state of e-health as a facilitator for PA interventions. Materials and Methods: A systematic search yielded 31 articles that fit into the inclusion/exclusion criteria, which were analyzed in terms of study design quality, intervention characteristics, and support for e-health in PA interventions. Results: The included articles met most of the study design criteria, but many did not isolate e-health technologies or use power analyses to calculate sample sizes. The interventions reflected a variety of technologies, audiences, and methods, and showed consistent use of theoretical frameworks to guide the interventions. Results regarding support for e-health’s effectiveness in PA interventions were mixed and cannot provide definite conclusions. Only seven studies used pure control groups, and of those, four demonstrated support for e-health but the others showed no significant differences. The majority of studies using comparison groups showed no significant differences between conditions. No notable patterns emerged among the studies that did show support for e-health. Conclusions: Future research should utilize more rigorous methods that allow for better comparison across studies, such as power analyses, pure control groups, and objective PA measurements, which could lead to more definitive results regarding e-health’s effectiveness for PA interventions.

Key words: e-health, telehealth, technology

Introduction
Overweight and obesity are significant health problems in the United States as well as globally. Recent statistics from the U.S. Centers for Disease Control and Prevention demonstrate that 62% of American adults are either overweight or obese.1 Additionally, the World Health Organization (WHO) estimated that, in 2005, ~1.6 billion adults aged 15 years and older were overweight and 400 million were obese worldwide. WHO projects that this number will increase, with 2.3 billion adults overweight and 700 million obese by the year 2015.2

One contributing factor to these high numbers is a lack of physical activity (PA) required for maintaining health. Data from the United States show that 33% of adults are inactive and only 35% engage regularly in leisure-time PA.3 Similarly, WHO estimates that at least 60% of individuals worldwide do not engage in the recommended amount of PA,4 which, for both WHO and the U.S. Department of Health and Human Services, is either a minimum of 150 min of moderate-intensity PA per week or 75 min of vigorous-intensity PA, or an equivalent combination of both.4,5 Engaging in PA can have numerous health benefits; in addition to addressing obesity, it can aid in the prevention of many chronic diseases, such as cardiovascular disease, diabetes, cancer, and hypertension, as well as in the prevention of premature death.6

Considering the positive outcomes linked to PA, it is easy to understand why many have attempted to encourage PA among various populations. E-health is an increasingly popular method of carrying out PA interventions, as it capitalizes on the prevalence of technology, can cover far distances, improves access, and allows for more flexibility in treatment. Norman et al.7 conducted a systematic review of PA and dietary change interventions through the year 2005, analyzing 13 peer-reviewed articles describing PA interventions, which utilized various technologies, such as e-mail, interactive compact discs (CD-ROMs), or Web sites. Overall, results showed a need for more rigorous research in the evaluation of e-health interventions.

This research seeks to continue where Norman et al.7 left off and is a systematic review of e-health PA interventions from January 2006 to November 2010. Because of the increase in frequency of published e-health articles since then, this review is more exclusive, as it limits the sample to only PA interventions while leaving out those examining dietary change, and it also focuses only on studies employing randomization to see whether more conclusive findings have been demonstrated. The following research questions guided this systematic review and aided in the assessment of the current state of e-health PA interventions:

RQ1: What is the quality of the study designs used in the PA interventions?
RQ2: What are the characteristics of the PA interventions, in terms of their technologies used, intervention periods, and theories utilized?
RQ3: What are the characteristics of the PA interventions’ samples?
RQ4: Do the outcomes of the PA interventions provide support for e-health as an effective intervention medium?

The remainder of this article will explain the methods used in this review to answer these research questions, provide an overview of the studies examined, discuss the results, and address the implications of the findings.
Materials and Methods

ARTICLE COLLECTION

A systematic literature review was conducted to locate scientific peer-reviewed journal articles detailing e-health PA interventions from January 2006 to November 2010. Searches were performed in the Web of Science and PubMed databases, with each search including a technology keyword, a topic keyword, and the word “intervention.” Technology keywords included “Internet,” “web,” “multimedia,” “personal digital assistant,” “mobile phone,” “cellular phone,” “computer,” “email,” “e-mail,” and “game.” Topic keywords included “physical activity,” “exercise,” “weight loss,” “obesity,” and “body mass index.” Additionally, a citation search was conducted by examining the reference lists of the selected articles as well as by examining articles that cited those that were collected.

SELECTION CRITERIA

Inclusion and exclusion criteria are listed in Table 1. The criteria were chosen to ensure that only rigorous studies were included in the analysis. Additionally, the analysis contained PA-only interventions to narrow the realm of study, examine approaches specifically related to this topic area, and analyze their overall effectiveness on the PA of individuals.

DATA SYNTHESIS

Each study was rated for its design quality on the basis of nine methodological characteristics, taken from the analysis of e-health interventions by Norman et al.7 These criteria include whether or not the study employed individual randomization, had a control group, isolated the technology (i.e., control group participants were not exposed to any form of intervention materials), used a pre- and post-test, had retention ≥ 80%, demonstrated equivalence between groups at baseline, accounted for missing data, calculated the necessary sample size, and utilized validated measures. For the retention ≥ 80% criterion, study participation was assessed at the last recorded measurement. Details of these criteria can be found in Appendix A. Each study’s score was then calculated as a percentage based on how many of the criteria it met out of the maximum criteria possible. The studies were rated independently by one researcher, and a check was performed on all of the articles by another researcher to establish reliability. Disagreements were discussed until differences were reconciled.

Additionally, the studies were assessed according to the amount of support they provided for e-health interventions. This analysis distinguishes between pure control studies (in which the technologies were completely isolated) and studies with comparison groups and was based upon the last reported measurement of PA in the study. Studies were classified according to whether or not significant differences were reported and whether these differences were in relation to pure control or comparison groups. For more details on this comparison, see Table 2.

Results

Following the literature search, 185 studies were initially selected and abstracts were obtained for potential inclusion. After applying the inclusion and exclusion criteria to the studies based on the abstracts, 36 remained. Full texts of these articles were acquired, and upon further examination and refinement of the criteria, nine more studies were removed from the analysis. Reasons for removal included a lack of randomization, follow-ups to articles already included, a lack of discussion of control group outcomes, a lack of actual PA levels reported in the results, and descriptions of only a subsample of an intervention already discussed in an included article. These attributes were then added to the inclusion and exclusion criteria. Following this process, four more articles were added based on a citation search of the included publications. This left a total of 31 articles7-30 to be included in the final analysis.

RQ1: DESIGN QUALITY SCORES

The average design score across all of these technologies was 66.7%, reflecting an average of six of the nine design quality criteria being met. The range of scores was from 44.4% to 88.9%. Full results of the design quality assessment can be found in Table 2. All of the studies met the control group and pre- and post-test criteria, and a majority met the individual randomization (26/31, 83.9%), the validated measures (25/31, 80.6%), and the equivalent baseline groups (23/31, 74.2%) criteria. Conversely, only 8 studies met the “isolate technology” criteria and only 11 calculated the sample size for their intervention.

<table>
<thead>
<tr>
<th>Table 1. Inclusion and Exclusion Criteria</th>
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<tr>
<td><strong>INCLUSION CRITERIA</strong></td>
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<tr>
<td>Peer-reviewed scientific journal articles</td>
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<tr>
<td>Interventions promoting physical activity</td>
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<tr>
<td>Utilize the Internet, computers, e-mail, PDAs, mobile phones, or digital games</td>
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<td>Use randomization</td>
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<td>Report quantitative PA outcomes</td>
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<td><strong>EXCLUSION CRITERIA</strong></td>
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<td>Goal is to target a specific illness or individuals with an illness (aside from obesity)</td>
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<tr>
<td>Reviews or meta-analyses</td>
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<td>Use computers, but only for tailoring messages that are delivered without technology</td>
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<td>Describe a small part of a larger intervention that is already included in articles</td>
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<td>Follow-up studies to interventions</td>
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<td>Analyze intervention groups only</td>
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<td>Encourage any other behavior in addition to PA (e.g., nutrition)</td>
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<td>PA, physical activity; PDA, personal digital assistant</td>
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### Table 2. Study Design Scores and e-Health Support

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<th>Control Group</th>
<th>Isolate Technology</th>
<th>Pre/Post</th>
<th>Retention ≥ 80%</th>
<th>Baseline Groups Equiv</th>
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*Validated measures were assessed only for the PA measurement.

¹Difference is for leisure-time PA only (not overall PA).

²Validated measure was coded as “N” because authors did not feel the reliability calculations established true validity of the measure.

³Analysis did not allow for comparison between pure control and e-health technology, although there was a pure control group present.

⁴Spontaneous users not included in assessment of baseline equivalence.

+ +, e-health intervention resulted in significant improvements in PA compared with control group; = =, e-health intervention resulted in no significant differences in PA compared with control group; +, e-health intervention resulted in significant improvements in PA compared with nontechnology comparison group; =, e-health intervention resulted in no significant differences in PA compared with nontechnology comparison group; 0, support for e-health indeterminate from results or study had a lack of a pure control or nontechnology comparison group; Y=yes; N=no; UK, unknown.
LAPLANTE AND PENG

RQ2: INTERVENTION CHARACTERISTICS
The included studies used a variety of technologies: 10 used Web sites (without e-mail), 3 utilized e-mail only, 3 used mobile phones, 3 used digital games, 3 used offline computer-tailored interventions powered by software or a CD/digital video disc (DVD)-ROM, and 9 used multiple technologies (often a combination of e-mail and Web sites). Intervention periods ranged from 2 weeks to 13 months. Twenty-seven of the studies (87.1%) incorporated theory into their interventions; the most common theories mentioned were social cognitive theory (13/31, 41.9%), the transtheoretical model (11/31, 35.5%), and either the theory of reasoned action or the theory of planned behavior (9/31, 29.0%). More details on the interventions can be found in Table 3.

RQ3: SAMPLE CHARACTERISTICS
Overall, the sample sizes for interventions discussed within the articles ranged from 20 to 1,531 individuals. Nine studies were conducted with child or adolescent populations, 7 with college students, 13 with adult populations, and 2 with middle-aged individuals. Additionally, seven studies included only females, and one study included only males. Seven of the studies were exclusively targeted toward overweight, sedentary, or insufficiently active populations.

RQ4: INTERVENTION OUTCOMES
This research focused only on the reported PA outcomes of the studies, although many other types of outcomes were also reported (e.g., psychological, weight loss, and fitness). The studies used a variety of measures to assess participants' PA. Seven studies objectively measured PA through the use of either a pedometer or an accelerometer, whereas the rest relied on self-report. The most common questionnaire used to measure PA was the International Physical Activity Questionnaire (7/31, 22.6%), which has various forms.

The analysis of the studies' support for e-health interventions revealed that seven of the studies could be analyzed for their support when compared with a pure control group (22.6%). Of these, none reported that the e-health interventions fared worse than the control, three reported no significant differences between the groups, and four reported outcomes in favor of the e-health technology. Thirteen studies could be analyzed for e-health support when compared with a comparison group (41.9%). Of these, four reported outcomes in favor of the e-health technology, nine reported no significant differences between groups, and none reported that the e-health interventions fared worse than the comparison group. Eleven studies (35.5%) could not be analyzed for e-health support because of indeterminate results or a lack of necessary information reported. Full results of this analysis are shown in Table 3.

Discussion
This systematic review demonstrates that it is becoming increasingly common to use e-health technologies to address PA. The analysis by Norman et al. included only 13 PA articles, and this review included 36 while using more stringent inclusion/exclusion criteria and a smaller time frame. Thus, as technology has become more ubiquitous and accessible, the use of e-health to facilitate PA interventions has increased and will likely continue to do so.

STUDY DESIGNS AND QUALITY
Overall, the articles analyzed demonstrate high-quality methods in terms of their use of pre- and post-tests, individual randomization, validated measures, and equivalent baseline characteristics of groups. However, there remains room for improvement regarding study design, as none of the articles analyzed met all of the study design criteria. Future research should use power analyses to calculate sample sizes, as the scarce use of this method may explain why a majority of the articles were not able to find statistically significant differences between intervention groups. Future work would also benefit from comparing e-health technologies to pure control groups, as not doing so makes it difficult to account for other variables that might be affecting PA outcomes and hence weakens arguments for the intervention's effectiveness. A lack of pure control groups also inhibits the synthesis of research, as the comparison groups are not consistent across studies. It should be noted that pure control groups are difficult to achieve in “real-world” settings because of the potential for contamination and exposure to other health materials. This can be addressed, however, by utilizing groups that are unlikely to interact and by requiring that participants not participate in any other PA programs during the study period.

INTERVENTION CHARACTERISTICS
The interventions analyzed were very diverse in terms of their target audiences, sample sizes, technologies utilized, and intervention lengths. For example, targeted age groups ranged from 7-year-old children to adults in their 60s, and both healthy and underactive individuals were included within study populations. This increasingly widespread and varied use of e-health to facilitate PA interventions is positive, as it is evidence of continued innovation in this field and shows the potential of technology to bring healthcare services to many different population segments. However, improvements could be made in terms of involving more racial and ethnically diverse audiences in interventions. Of those studies that reported racial/ethnic demographics, almost all had a Caucasian majority. Such homogenous samples could have skewed the results and makes it difficult to generalize them to wide populations.

Another positive finding is that so many of the articles utilized theory to guide their interventions. This shows that researchers are using past literature to inform their efforts, it furthers the field of e-health by integrating it with established research traditions, and it will ultimately allow studies to build upon one another more effectively if they are using consistent frameworks and constructs between interventions. Additionally, research investigating Internet-based health interventions found that a more extensive application of theory was associated with greater effect sizes of behavior.

One way in which future e-health PA interventions could be improved is by increasing the use of objective measurements of PA, such as accelerometers, pedometers, or body bugs/sensors, as only...
# REVIEW OF E-HEALTH PHYSICAL ACTIVITY INTERVENTIONS

## Table 3. Summary of e-Health Physical Activity Studies

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>INTERVENTION TECH</th>
<th>INTERVENTION LENGTH</th>
<th>CONTROL CONDITION</th>
<th>SAMPLE CHARACTERISTICS</th>
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<tbody>
<tr>
<td>Carr et al.⁵⁹</td>
<td>Interactive Web site w/self-paced training program, strategies, and journal</td>
<td>16 weeks</td>
<td>Delayed intent-to-treat</td>
<td>N=67 randomized; Int.=37, Ctrl.=30; N=52 in final analysis (all below stais refer to this group) 87% F Int.: n=14, Avg. age = 41.4±3.7, Avg. BMI = 32.3±13; Ctrl.: n=18, Avg. age = 49.4±1.7, Avg. BMI = 30.6±0.8; Sedentary and overweight rural adults</td>
<td>Steps/day measured by pedometer</td>
<td>TTM, SCT</td>
<td>Int. sig. increased PA by 1,384 steps/day; No sig. increase in PA for Ctrl. (increase of 614 steps/day); Increase in Int. not significantly more than increase in Ctrl.</td>
</tr>
<tr>
<td>De Bourdeaudhuij⁶⁰</td>
<td>Web site; tutorial and tailored advice</td>
<td>3 months</td>
<td>Generic (no-tailored) advice (not clear if delivered via technology or not)</td>
<td>N=1,063; Avg. age = 14.5±1.4; 49% F; Int.: n=469; Ctrl.: n=581; Inactive at baseline: n=488 (Ctrl.: n=221, Int.: n=277); Adolescents in schools</td>
<td>Self-reported min/week of various PAs; Self-reported min/week of MVPA (IPAQ-A)</td>
<td>TPB; SCT; attitude, self-efficacy, and social influence model</td>
<td>Int. had sig. effect on min/week spent cycling for transportation; Int. had sig. effect on walking in leisure time; Int. had sig. effect on leisure time moderate PA; Int. had sig. effect on leisure time vigorous PA; Int. had sig. effect on total MVPA; Stronger effects observed for subsample of adolescents not meeting PA guidelines at baseline (all from baseline to final measure)</td>
</tr>
<tr>
<td>Dinger et al.⁶¹</td>
<td>E-mail reminders (plus pedometer and step logs)</td>
<td>6 weeks</td>
<td>Did not receive e-mail strategies based on TTM or three brochures, used pedometer and sent in step logs</td>
<td>N=74 randomized; N=56 analyzed; Int.: n=52, Ctrl.: n=24; 100% F; Study completers: 89% Caucasian, Avg. age: 41.5±7.6, 57% w/BMI&gt;30; Insufficiently active women</td>
<td>Self-reported min/week walking (IPAQ-A short form)</td>
<td>TTM</td>
<td>All participants sig. increased min/week walking; No differences between groups</td>
</tr>
<tr>
<td>Dunton and Robertson⁶²</td>
<td>Web site; wPA assessment and tailored feedback, e-mail newsletters, and reminders</td>
<td>3 months</td>
<td>Wait-list control</td>
<td>N=156; Avg. age = 42.8; 100% F; 65% Caucasian Int.: n=85, Avg. BMI = 58±5.5, 60% Caucasian Ctrl.: n=71, Avg. BMI = 26.2±6.4, 71% Caucasian; Healthy and ethnically diverse adult females</td>
<td>Self-reported min/week of various PAs (from Life in New Zealand National Survey)</td>
<td>HBM, TTM</td>
<td>Greater increase in min/week walking for Int. than in Ctrl.; Sig. faster rate of increase in walking for Int. group than Ctrl. Greater increase in total MVPA for Int. than in Ctrl.; Sig. group difference in rate of change for total MVPA (Int. had faster increase)</td>
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### Table 3. Summary of e-Health Physical Activity Studies continued

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<tr>
<td>Ferney et al.</td>
<td>Local neighborhood environment-focused PA Web site; e-mails, w/PA strategies and Web site invitations</td>
<td>26 weeks</td>
<td>Motivational-Information Web site</td>
<td>N=106&lt;br&gt; Avg. age = 52 ± 4.6&lt;br&gt; 72% F&lt;br&gt; Int.: n=52, 68% overweight or obese&lt;br&gt; Ctrl.: n=54, 47% overweight or obese Middle-aged inactive adults</td>
<td>Self-reported min/week walking&lt;br&gt; Self-reported min/week in MVPA (AAD)</td>
<td>SCT</td>
<td>Total PA, total walking and neighborhood walking all increased over time for Int. Sig. interaction effect for total PA. Sig. increases in walking and total PA observed in both groups Sig. more walking at end of intervention for Int. group participants who used the Web site more often</td>
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<td>Fjeldsoe et al.</td>
<td>Tailored motivational mobile SMS, combined with in-person goal setting consultations</td>
<td>13 weeks</td>
<td>Fewer PA consultations and info, no SMS</td>
<td>N=88&lt;br&gt; Avg. age = 30 ± 6&lt;br&gt; 100% F&lt;br&gt; Int.: n=45, Avg. BMI = 27 ± 5&lt;br&gt; Ctrl.: n=43, Avg. BMI = 27 ± 5&lt;br&gt; Prenatal women</td>
<td>Self-reported days/week with 30 min of MVPA or walking for exercise&lt;br&gt; Self-reported min/week of MVPA and walking for exercise (AWAS)</td>
<td>SCT</td>
<td>Sig. effect on PA frequency in Int. (+1.82 days/week at 13 weeks) Sig. effect on walking for exercise frequency in Int. (+1.08 days/week at 13 weeks) Positive trends observed for min/week of PA and walking for exercise</td>
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<td>Haerens et al.</td>
<td>Computer-tailored PA advice (non-Internet) w/assessment and feedback</td>
<td>3 months</td>
<td>No intervention, assessment only</td>
<td>Final sample: n=281&lt;br&gt; 52% F&lt;br&gt; Avg. age: 13.2 ± 0.7&lt;br&gt; 61.6% did not meet PA recommendations&lt;br&gt; Int.: n=139, Ctrl.: n=142&lt;br&gt; Seventh grade students</td>
<td>Self-reported min/day of PA (school related PA, leisure time sports, leisure active transportation) (IPAQ)</td>
<td>TPB; SCT; TTM, attitudinal, self-efficacy, and social influence model</td>
<td>No sig. Int. effects on total PA, leisure time sports, and leisure time active transportation Sig. main effect of condition on school-related PA (Avg. increase of 3.8 min/day in Int., none in Ctrl)</td>
</tr>
<tr>
<td>Haerens et al.</td>
<td>Computer-tailored PA advice (non-Internet)</td>
<td>3 months</td>
<td>Generic (non-tailored) PA advice (not clear if delivered via technology or not)</td>
<td>N=1,171&lt;br&gt; 55% F&lt;br&gt; Avg. age: 14.8 ± 1.2&lt;br&gt; Int. (tailored): n=563&lt;br&gt; Ctrl. (non-tailored): n=608&lt;br&gt; Adolescent students</td>
<td>Self-reported min/week of various PAs (IPAQ-A)</td>
<td>TPB, TTM</td>
<td>No sig. main effects for condition All PA scores except for &quot;moderate activity in leisure time&quot; increased in both groups</td>
</tr>
<tr>
<td>Huang et al.</td>
<td>Informational PA Web site w/PA SoC tailored messages or generic PA messages</td>
<td>8 weeks</td>
<td>Lectures only, no Web site access</td>
<td>N=130&lt;br&gt; SoC Int.: n=45&lt;br&gt; Non-SoC Int.: n=42&lt;br&gt; Ctrl.: n=43&lt;br&gt; 100% F&lt;br&gt; Avg. age: 18 ± 0.55&lt;br&gt; University freshmen enrolled in nursing class</td>
<td>Self-reported PA frequency/week</td>
<td>TTM</td>
<td>Both Int. groups increased PA levels Ctrl. group PA levels decreased from beginning of study period Subjects in SoC tailored Int. improved most in PA levels, followed by the non-SoC tailored Int. at immediate post-test For all groups, ANCOVA test showed PA levels at post-test reached a sig. level, but w/ small effect size (0.155)</td>
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| Hurley et al.17           | Interactive PA Web site w/tailored info, feedback, option for delivered e-mail, or SMS reminders and info | 10 weeks            | Less-interactive version of PA Web site | N = 75  
Avg. age = 35  
Int.: n = 28, Avg. age = 34.0, 72% F  
Crl.: n = 24, Avg. age = 34.9, 78% F  
Reference group: n = 15  
(did not commit to whole Int. period), Avg. age = 34.7, 71% F  
Adults aged 23-54 | Response to question “I’ve been getting more exercise in the last few months than I was at the beginning of the year” (Likert scale) | Social comparison, decisional balance, ELM | Int. had sig. higher responses to PA question than Ctrl. |
| Hurley et al.18           | Web site w/PA log, planning, assessment, feedback, information; email, and SMS reminders | 9 weeks             | Verbal PA advice, wore accelerometer, no feedback or access to site | N = 87  
Avg. age = 40.4 ± 7.6  
Avg. BMI = 26.3 ± 3.4  
Int.: n = 47, 64% F, Avg. BMI = 26.2 ± 2.8, 100% Caucasian  
Crl.: n = 30, 70% F, Avg. BMI = 26.5 ± 4.1, 97% Caucasian  
Healthy adults, not vigorously active | Min/week of PA measured by accelerometer and self-report (IPAQ- long form) | Social comparison; Decisional balance, ELM | No sig. difference between Int. and Crl. of self-reported overall PA  
Sig. higher increase in leisure-time PA in Int.  
Sig. trend for Int. group toward more time spent in moderate PA than Ctrl. (based on accelerometer) |
| Jago et al.19             | Web site w/info, goal-setting, goal attainment reporting; games, problem-solving tool | 9 weeks (two Int. periods: Fall and Spring) | Received fruit and vegetable Int. | N = 473  
Avg. age = 13  
First Int. period: Int.: n = 90, Crl.: n = 64  
Second Int. period: Int.: n = 148, Crl.: n = 166  
Boy Scouts | Min/day of PA as measured by accelerometer | None | No effect on MVPA  
A sig. 3-way interaction (group * time * wave) showed 12-min increase in light intensity PA in second Int. period (Spring)  
Three-way interaction (group*time*wave) approaching sig. showed 12-min reduction in sedentary behavior in second Int. period (Spring) |
| King et al.20             | FDA for monitoring PA and providing feedback, goal setting, and support | 8 weeks             | Received standard written PA informational materials | N = 37  
Int.: n = 19, Avg. age = 60.7 ± 6.8, 42.1% F, 73.7% Caucasian  
Crl.: n = 18, Avg. age = 59.6 ± 7.6, 44.4% F, 83.3% Caucasian  
Sedentary adults 50 or older | Self-reported min/week in MVPA (CHAMPS)  
Caloric expenditure in kcal/kg/week  
Caloric expenditure in kcal/week | SCT | Int. group spent sig. more min/week in MVPA than Crl.  
Int. group had sig. greater mean estimated caloric expenditure levels in MVPA than Ctrl. |
| Luszczynska and Tryburek21 | E-mail intervention promoting exercise self-efficacy | 30 days             | Received e-mail message about importance of regular exercise and effects of seeking help from family/friends | N = 320  
Int.: n = 170  
Crl.: n = 150  
Final sample (after dropouts): n = 187, Int.: n = 100, Crl.: n = 87  
Avg. age = 28.3 ± 9.46, Avg. BMI = 22.86 ± 3.71  
Adults, both healthy and with chronic conditions | Self-reported days/2 weeks engaging in PA (6-pt scale ranging from never to every day) | SCT | Int. group showed nonsig. increase in exercise levels  
Sig. difference in exercise levels between Int. group participants with diabetes/CVD and Ctrl. group participants with diabetes/CVD |
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| Malone et al.    | Exergame: Dance Revolution         | 28 weeks            | Wait-list control       | N = 60  
Avg. age = 7.5 ± 0.5  
Avg. BMI = 17.6 ± 2.7  
50% F  
Int.: n = 40, Avg. BMI = 12.2 ± 2.4, Avg. age = 7.5 ± 0.5, 80% Caucasian  
Ctrl.: n = 20, Avg. BMI = 18.0 ± 3.3, Avg. age = 7.6 ± 0.5 60% Caucasian Children aged 7–8 | Min/week of PA measured by accelerometer  
Steps/day measured by pedometer | None                  | No differences between Int. and Ctrl. in vigorous, moderate, light, or sedentary PA  
Sig. increase in vigorous PA in Int. group  
Light PA decreased in both groups at week 10  
For Int. group, increase in vigorous PA and reduction in light PA continued from baseline to final assessment and remained statistically different from baseline |
| Marcus et al.    | Tailored Web site w/ information, goal setting, PA logs, assessment; e-mail reminders | 12 months           | Three conditions,  
(1) Tailored print  
(2) Tailored Web site  
(3) Public Web site | N = 249  
Avg. age = 44.5 ± 9.3  
Avg. BMI = 29.4 ± 6.1  
Cond. 1: n = 86, 83.7% F, Avg. BMI = 29.1 ± 6.2, 77.9% Caucasian  
Cond. 2: n = 81, 81.5% F, Avg. BMI = 29.7 ± 6.5, 82.7% Caucasian  
Cond. 3: n = 82, 82.9% F, Avg. BMI = 29.5 ± 5.5, 84.1% Caucasian Healthy sedentary adults | Self-reported min/week of PA (PAR) | TTM, SCT | No sig. differences between the 3 conditions for PA |
| Marks et al.     | PA Web site w/ games, quizzes, planning tools, and demos | 2 weeks              | PA print workbook identical to Web site in content, graphics, and organization | N = 359, Int.: n = 181, Ctrl.: n = 178  
Avg. age: 12  
100% F  
Final sample characteristics:  
Int.: n = 158, Avg. age = 12.2, Avg. BMI = 20.5  
Ctrl.: n = 161, Avg. age = 12.1, Avg. BMI = 20.9  
51% African-American Female adolescents grades 6–8 | Self-reported days/week of various physical activities (Questions from YRBSS) | SCT, TRA | Self-reported PA increased sig. in Ctrl. group only |
| Ni Mhurchu et al. | Exergame                           | 12 weeks            | No intervention, assessment only | N = 20  
Avg. age: 12 ± 1.5 years  
40% F  
Int.: n = 10, Avg. age = 11 ± 1, 40% F, Avg. BMI = 20.4 ± 3.6  
Ctrl.: n = 10, Avg. age = 13 ± 1, 40% F, Avg. BMI = 19.0 ± 3.6 Children aged 10–14 | PA measured by accelerometer  
Self-reported min/week of PA (PAQ-C) and video game playing | None                  | Avg. objectively measured PA time was higher in Int. compared to Ctrl. (At 6 weeks, p = 0.04, at 12 weeks, p = 0.06)  
No sig. differences in time spent in MVPA between the two groups as measured by accelerometer |
## Table 3. Summary of e-Health Physical Activity Studies (continued)

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</table>
| Parrott et al. | Persuasive e-mails (negatively or positively framed) | 3 weeks | No intervention, assessment only | N=105 38% F  
Avg. age: 20.2±0.9  
94% Caucasian  
Positively framed message: Int.: n=57, 49% F, Avg. age: 20.4, 95% Caucasian  
Negatively framed message: Int.: n=57, 39% F, Avg. age: 20.2, 93% Caucasian  
Ctrl.: n=48, 36% F, Avg. age: 20.0, 95% Caucasian Sedentary college students | Number of self-reported MVPA sessions (GITEQ) | TPB | Positively framed message condition had higher PA levels than negatively-framed messages and Ctrl. group at follow-up and retention. |
| Prestwich et al. | SMS reminder messages | 4 weeks | 2 Ctrl. groups: Cond. 1 only completed measures  
Cond. 2=cond. 1 + motivational messages  
2 Int. groups: Cond. 3 = cond. 2 + implementation intention messages  
Cond. 4 = cond. 3 + SMS reminders | N=155 59% F  
Avg. age: 23.76±4.64  
40% sedentary adult university students | Self-reported bouts of PA/week (at least moderate intensity and 20–30 min) | Implementation intentions, PMT | Participants in cond. 4 increased PA frequency significantly more than other conditions. Individuals receiving SMS had greater improvements than those that did not. |
| Prestwich et al. | SMS reminder messages (either PA plan reminders or PA goal reminders) | 4 weeks | Given basic PA information, encouraged to exercise | N=149  
Avg. BMI: 22.91±3.96  
Avg. age: 23.44±3.60  
64% F  
Cond. 1 (plan reminders): n=47, Avg. age: 22.19±5.01, Avg. BMI: 22.40±3.60, 60% F  
Cond. 2 (goal reminders): n=52, Avg. age: 24.38±6.30, Avg. BMI: 23.23±3.67, 63% F  
Ctrl.: n=50, Avg. age: 23.82±4.49, Avg. BMI: 23.06±4.28, 68% F University students | Self-reported days w/b brisk walks of 30+ min  
Days w/30+ min of PA (SWET) | Implementation intentions | Both Int. groups increased days w/brisk walking sig. more than Ctrl., without any sig. reductions in other PA. Participants in cond. 1 engaged in sig. more PA than those in Ctrl. |
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<tr>
<td>Quintillani et al.²⁹</td>
<td>Web site w/tailored PA messages, either chosen by participant or expert</td>
<td>1 month</td>
<td>Nontailored Web-delivered message about reducing stress</td>
<td><em>N</em> = 408 100% F 51.9% aged 18-21 73.0% Caucasian Cond. 1 (participant choice): n = 143, 100% Caucasian, PA as topic: n = 65 Cond. 2 (expert): n = 133, 78% Caucasian, PA as topic: n = 93  Ctrl.: n = 132, 87% Caucasian Female college students</td>
<td>Self-reported min/week of MVPA (BFI55)</td>
<td>TIM, TRA, HBM</td>
<td>Change in vigorous PA was sig. greater in expert group (Cond. 2) compared to Ctrl. group</td>
</tr>
<tr>
<td>Skar et al.³⁰</td>
<td>Brief planning intervention delivered online (either AP or coping plans)</td>
<td>8 weeks</td>
<td>Not reported</td>
<td><em>N</em> = 1273 Avg. age: 22.8 ± 6.7 63.4% F Avg. BMI: 23.6 ± 5.4  AP Int.: n = 310 Coping Plans (CP): n = 313 AP + CP: n = 335  Ctrl.: n = 313 University students</td>
<td>Self-reported no. of times participating in 30+ min of leisure time PA Attendance at fitness center measured by ID card swipes at entrance</td>
<td>TB</td>
<td>No main or interaction effects of AP or CP on PA or fitness center visits</td>
</tr>
<tr>
<td>Slootmaker et al.³¹</td>
<td>Web site w/tailored PA advice coupled with a PAM</td>
<td>3 months</td>
<td>Received single written general PA brochure</td>
<td><em>N</em> = 102 Avg. age: 31.8 ± 3.5 60% F Avg. BMI: 25.2 ± 4.1  Int.: n = 51, Avg. age = 32.5 ± 3.4, Avg. BMI = 25.9 ± 4.5  Ctrl.: n = 51, Avg. age = 31.2 ± 3.5, Avg. BMI = 24.4 ± 3.5  Adult office workers</td>
<td>Self-reported min/week of PA (AQUAA)</td>
<td>SCT</td>
<td>No sig. intervention effect was observed for sedentary behavior, light PA, moderate PA, vigorous PA and MVPA No sig. intervention effect was observed in the PA outcomes at the 8-month follow-up</td>
</tr>
<tr>
<td>Slootmaker et al.³²</td>
<td>Web site w/tailored PA advice coupled with a PAM</td>
<td>3 months</td>
<td>Received single written general PA brochure</td>
<td><em>N</em> = 87 Avg. age: 15.1 63% F  Int.: n = 41  Ctrl.: n = 41 Healthy adolescents (13-17 years)</td>
<td>Self-reported min/week of PA (AQUAA)</td>
<td>SCT</td>
<td>Int. group had sig. more moderate intensity PA than Ctrl. for girls after 3 months, but effect disappeared at 8 months Sig. reduction in sedentary time for boys in Int. group after 8 months (But not at 3)</td>
</tr>
<tr>
<td>Southard and Southard³³</td>
<td>Internet-based game for children promoting PA coupled with pedometer</td>
<td>4 weeks</td>
<td>Were monitored only w/ pedometer</td>
<td><em>N</em> = 81 37% F 88.9% Caucasian 9 years old: 29.6%, 10 years: 40.7%, 11 years: 29.6% 3.7% underweight, 56.8% normal, 13.9% at risk, 25.9% overweight  Children aged 9-11</td>
<td>PA measured by pedometer</td>
<td>None</td>
<td>Underweight and normal weight children show an increase in steps after 1 week Drop in steps reported by underweight and normal weight children in Ctrl. group Slight increase in PA for both groups among overweight and at-risk participants</td>
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| Spittaels et al.  
(2004)  | Web site w/tailored PA advice, feedback, and motivational e-mails (Cond. 1), or Web site only (Cond. 2) | 8 weeks             | Received standard advice via the Internet | N=826 randomized  
Cond. 1: n=174  
Cond. 2: n=175  
Ctrl.: n=177  
Final sample characteristics:  
N=579 analyzed  
Avg. age: 39.5±8.5  
Avg. BMI: 24.4±3.3  
30.6% F  
Cond. 1: n=116, Avg. age=39.7±8.9, Avg. BMI=24.3±3.0  
Cond. 2: n=122, Avg. age=39.3±8.7, Avg. BMI=24.4±3.5  
Ctrl.: n=141, Avg. age=40.9±8.0, Avg. BMI=24.4±3.1  
Healthy adults recruited from worksites | Self-reported min/week of MVPA  
(IPAQ-long version) | TTM, TPB | Total PA, moderate PA, and leisure-time PA sig. increased in all study conditions  
No sig. differences in PA between conditions |
| Steele et al.  
(2005)  | Web site w/education; PA log; e-mail access to support; used in conjunction w/pedometer | 12 weeks            | Wait-list control  | N=434  
68.1% F  
Avg. age=41.4±5.6  
Avg. BMI=24.6±3.6  
Cond. 1: n=173, Avg. age=43.3±5.7, Avg. BMI=25.0±2.7, 65.3% F  
Cond. 2: n=129, Avg. age=39.8±5.0, Avg. BMI=24.6±3.6, 66.7% F  
Ctrl.: n=132, Avg. age=40.7±5.3, Avg. BMI=24.1±3.5, 66.7% F  
Healthy adults | Self-reported min/week of MVPA  
(IPAQ-long version) | TTM, TPB | Sig. increase in PA level and decrease in time spent sitting at 6-month follow-up for Int. group compared to Ctrl. group  
Sig. increases were found for transportation PA and leisure-time PA in Int. groups  
No sig. differences were found between both intervention groups |
| Wadsworth and Hallam  
(2007)  | Web site w/educational materials, access to e-counselor, etc., e-mails | 6 months           | Given written information on PA  | N=81  
100% F  
Int.: n=45, Avg. BMI=26.92  
Ctrl.: n=46, Avg. BMI=27.97  
College females | Self-reported min/week of PA  
(IPAQ-short version) | SCT | No group * time interaction for PA  
No main effects for group  
Main effect on PA for time (increases) observed for each group  
All groups were statistically equivalent post intervention, but not at follow-ups |

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seven studies analyzed did so. It has become much easier to use such methods in recent years, as these technologies have become more advanced and have decreased in price, which is especially the case for pedometers.50 Objective measurements are ideal, because they increase reliability of measurement by decreasing the potential for human error. Also, more widespread use of these technologies would allow for easier research synthesis because of the consistent measurement methods.

SUPPORT FOR E-HEALTH

The support provided by the analyzed studies for e-health technologies is mixed, at best. It is disappointing that 11 of the studies could not be analyzed in terms of their support for e-health, which shows a need for more rigorous methods and reporting of results. Of the studies that compared e-health with pure control groups (n = 7), just over half showed a significant positive difference favoring e-health. The rest of these studies showed no difference between the e-health and control groups, meaning that the interventions were no more effective than everyday life for the participants, which is a discouraging finding for the use of e-health in this area. In examining the studies wherein the primary e-health technologies were compared with another form of intervention (n = 13), either print or technology based, results showed that only 31% led to significant positive differences between the groups in favor of e-health. The other 69% of this group showed that e-health conditions were not significantly different than others in terms of PA outcomes. Altogether, these results make it difficult to argue for the benefits of e-health when compared with other forms of interventions.

However, these findings do not mean that e-health technologies should be entirely dismissed as a potential medium for PA interventions. The equivalence found between e-health and comparison groups is not necessarily a negative finding, because if e-health is equivalent to more traditional intervention forms, then their use could enable expanded reach, accessibility, and efficiency without sacrificing positive outcomes. Also, none of the studies showed that e-health conditions fared worse than others, implying that these interventions can at least do no harm. Finally, the presence of studies with results supporting e-health compared with both pure control and comparison groups show that such interventions can be successful. It is difficult to determine, however, what characteristics of e-health interventions are more likely to lead to positive PA outcomes, as no significant patterns emerged among these studies in terms of their technologies used, audiences, or intervention lengths.

LIMITATIONS

The analysis of PA outcomes conducted in this review was always based on the last measurement reported and earlier survey results were not assessed; thus, in many cases, the outcomes reported here
refer to a follow-up survey conducted some time after the intervention was completed. This may have led to the review’s lack of positive results, as it is a difficult task to maintain intervention effects long after the participants have been exposed to it. However, only three of the studies analyzed had positive outcomes that were lost at follow-up assessments, so it appears as though the analysis of last reports measured did not have a significant impact on the results. Another potential limitation is the fact that this study only examined quantitative PA outcomes that were expressed in terms of levels of activity. Many of the articles also reported psychological outcomes related to PA, such as self-efficacy or stage of change, but these effects were not examined in this analysis to narrow the scope of study. Future research should examine the effects on such variables across studies, as it may point to the more subtle benefits of e-health PA interventions.

Conclusions

This systematic review of e-health interventions for PA has demonstrated that the use of e-health in this field is increasing, but that there is much room for improvement in the studies that are conducted. Research would greatly benefit from more systematic and rigorous methods, which would make it easier to synthesize results from multiple studies and better determine the progress of this field. The suggestions for improvement in future research put forth by this review include the use of power analyses to calculate sample sizes, pure control groups instead of comparison groups, more racial and ethnically diverse samples, theory to guide interventions, and objective measurements of PA.

Overall, in terms of support for e-health technologies in facilitating PA interventions, the results of this review cannot provide definitive evidence for the effectiveness of this medium. However, this does not mean that researchers should stop exploring the potential of e-health for PA, as there were some studies that did show support for it. Instead, this review points to the need for continued research and refinement of approaches. It is the authors’ hope that future researchers can learn from this review and the weaknesses can be identified to pursue more success in this line of research, as PA is an important issue that needs addressing.

Disclosure Statement

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REFERENCES


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(Appendix follows —)
### Appendix A. Study Quality Coding Criteria

<table>
<thead>
<tr>
<th>TABLE HEADING</th>
<th>SCORING CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual randomization</td>
<td>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, or if another method of assigning group status was used, or randomize at the group level and analyze at the individual level.</td>
</tr>
<tr>
<td>Control group</td>
<td>Did the study include a comparison group? Comparison group could be a no treatment, treatment as usual, or alternate treatment group.</td>
</tr>
<tr>
<td>Isolate technology</td>
<td>Did study design allow for a test of effectiveness of the technology? For example, Web-based delivery versus no treatment. To isolate the technology, the authors had to test the technology alone and compare with a group with no technology—participants had to receive assessment only (YES). Packaged interventions wherein the technological components cannot be parsed out are coded as not isolating the technology (NO).</td>
</tr>
<tr>
<td>Pre/post-test design</td>
<td>Was assessment of behavior completed preintervention and postintervention?</td>
</tr>
<tr>
<td>Retention</td>
<td>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). Retention rates were calculated based upon the last assessment reported.</td>
</tr>
<tr>
<td>Baseline groups equivalent</td>
<td>Were tests conducted to determine if groups were equivalent at baseline on important variables (e.g., gender, age, weight)? If no tests were mentioned, then NO. If subset of tests indicated any group differences at baseline, then NO. Baseline equivalency was coded as “YES” if groups were equivalent for the following reported correlates of PA according to age group: Children: sex, previous PA, parent overweight/obesity; Adolescents (age 13–18): age, ethnicity, sex, previous PA; Adults: age, gender, SES, educational attainment, overweight/obesity, race/ethnicity, previous PA in adulthood.</td>
</tr>
<tr>
<td>Missing data</td>
<td>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.</td>
</tr>
<tr>
<td>Sample size calculation</td>
<td>Was power analysis reported to determine sample size?</td>
</tr>
<tr>
<td>Validity of measures</td>
<td>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.</td>
</tr>
<tr>
<td>Total</td>
<td>Number of Yes answers out of number possible</td>
</tr>
</tbody>
</table>

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*Taken and adapted from Norman et al. Additions are written in boldface.

*Correlates identified from Sallis et al.*

*Correlates identified from Trost et al.*

UK, unknown; ITT, intention-to-treat analysis.