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Past, present and future of e- & mHealth research to improve physical activity and dietary
behaviors

Journal Section: Reports

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Abstract

As physical inactivity and unhealthy diets are highly prevalent, there is a need for cost-effective interventions that can reach large populations. e- & mHealth solutions have shown promising outcomes and have rapidly expanded in the past decade. The purpose of this report is to provide an overview of the state of the evidence for the use of e- & mHealth in improving physical activity and nutrition behaviors, in general and special populations. The role of theory in e- & mHealth interventions, and methodological issues are addressed. Key recommendations for future research in the field of e- & mHealth are provided.

Keywords

behavior change, intervention, diet, nutrition, physical activity, health, e-health, m-health, information technology, apps, smartphone, mobile, web-based, online, Internet

1 INTRODUCTION

2 Physical inactivity and poor dietary behaviors are major risk factors for a number of non-
3 communicable diseases including cardiovascular disease, type 2 diabetes and some cancers.¹⁻³
4 In 2010, it was estimated that collectively, physical inactivity and dietary risk factors
5 accounted for 10.2% of all disability adjusted life years globally.⁴ National estimates from
6 high-income countries including Australia, Canada, the United Kingdom and the United
7 States, suggest that 1% to 2.6% of total healthcare costs are directly attributable to physical
8 inactivity.⁵ Similarly, in the United Kingdom food related ill health is responsible for 10% of
9 morbidity and mortality and costs 6 billion pounds annually.⁶ As a consequence, improving
10 the population's physical activity (PA) and dietary intake is a recognized public health
11 priority.⁷

12 To address the increasing rates of obesity and chronic diseases, a multitude of behavior
13 change interventions that aim to improve PA and dietary behaviors of individuals have been
14 developed.⁸ Most of these interventions – whether targeting a single behavior (PA or dietary
15 behaviors alone) or multiple behaviors (PA and dietary behaviors in combination) – have
16 been delivered in face-to-face settings, which is expensive and inhibits large-scale
17 implementation.^{9,10} Thus, cost-effective interventions that can improve dietary behaviors and
18 PA in large populations are needed.^{11,12} Such interventions represent a public health approach
19 that could significantly impact the global burden of chronic disease whilst also being
20 affordable.⁴

21 Electronic and mobile health (e- & mHealth) technologies, including the Internet, mobile
22 devices and smartphone applications ('apps'), provide opportunities for population-wide
23 promotion of PA and healthy eating.^{13,14} The precise definitions of eHealth and mHealth vary
24 due to being applied in differing contexts and due to the ongoing development and
25 advancements of information technologies that lead to new applications for e- & mHealth.¹⁵

26 However, for the purpose of this report eHealth is defined broadly as *'the use of information*
27 *and communications technology, especially the Internet, to improve or enable health and*
28 *healthcare'*,¹⁶ and mHealth, which is a subdivision of eHealth, is defined as *'medical and*
29 *public health practice supported by mobile devices, such as mobile phones, patient*
30 *monitoring devices (e.g. heart rate monitor), Personal Digital Assistants (PDA) and other*
31 *wireless devices'*.¹⁷

32 By the end of 2014, it was estimated that there were almost 3 billion Internet users, and 2.3
33 billion mobile-broadband subscriptions globally.¹⁸ Given the rapid growth in internet
34 accessibility and improvements in technology it is not surprising that research into the use of
35 e- & mHealth interventions targeting lifestyle behaviors has burgeoned in the past decade.¹⁹⁻

36 ²⁵ This report sets out to provide an overview of the current state of the science of e- &
37 mHealth PA and dietary behavior intervention research. **The report further addresses the use**
38 **of e- & mHealth in underserved populations, the use of theory and methodological issues.**
39 **The report closes with providing recommendations for future research foci.**

40

41 **Status of e-Health in Behavioral Research**

42 Several reviews and meta-analyses of behavioral eHealth interventions have been conducted.
43 In relation to dietary interventions, a review by Harris et al.²⁶ concluded that eHealth
44 interventions to promote dietary behavior change do not produce clinically significant
45 changes in dietary behavior and, are at least as, expensive as other individual behavior change
46 interventions. However, a more recent review of reviews by Tang et al.²⁷ demonstrated
47 support for the effectiveness of self-directed (i.e. mostly eHealth approaches) weight loss
48 interventions, but indicated low quality for most reviews (14 out of 20), limiting confidence
49 in the outcomes.

50 In relation to PA, Davies et al.¹⁹ conducted a meta-analysis and found web-based
51 interventions significantly improved PA in the short-term (the Cohen's *d* effect size was
52 0.14), and particularly when targeted at inactive participants ($d = 0.37$). However, long-term
53 maintenance of behavior change, as well as engagement and retention of participants was
54 problematic. A review specifically focusing on eHealth interventions amongst children and
55 adolescents, demonstrated strong support for such interventions, with seven out of nine
56 interventions significantly improving PA.²⁸

57 Some reviews have focussed on eHealth interventions simultaneously targeting dietary
58 behaviors and PA. For example, a review by Hou et al.²⁹ found evidence for strong positive
59 outcomes for both PA and dietary behavior change in such interventions. The meta-analysis
60 by Cushing et al.³⁰ found positive outcomes for eHealth interventions in children and
61 adolescents, and highlighted differences in effect sizes for interventions that were purely
62 educational ($d = .03$) versus those that also included behavioral components (e.g. goal setting,
63 self-monitoring; $d = .35$). These outcomes are in line with a review of reviews by Kohl et
64 al,³¹ which highlighted low participant engagement with eHealth intervention platforms as a
65 key limitation to date, and contributing to small and unsustainable effect sizes. They
66 indicated that there is currently no need to conduct more 'effect studies', rather research is
67 needed to identify which components within eHealth interventions are effective, as little is
68 known about the determinants that drive effectiveness within these interventions.

69 One specific intervention component that has received great attention when evaluating
70 eHealth interventions is the use of computer-tailoring where participants receive personalized
71 feedback based on answers to an online survey. Neville et al.^{32,33} conducted two reviews on
72 the effectiveness of web-based computer-tailored interventions which found overall positive
73 outcomes; in one review they found that 10 out of 16 interventions significantly improved
74 PA; in the other review they found that eight out of 12 interventions significantly improved

75 dietary outcomes. However, a similar review, also focusing on web-based computer-tailored
76 interventions that combined outcomes for PA and diet, concluded that tailoring was more
77 effective for nutrition interventions compared to PA interventions.³⁴ Krebs' et al.³⁵ meta-
78 analysis found that effect sizes were indeed somewhat larger for dietary computer-tailored
79 interventions ($d = .22$) compared to tailored PA interventions ($d = .16$). Importantly,
80 however, this meta-analysis also demonstrated that effect sizes increased when the computer-
81 tailored interventions were dynamic (having multiple assessment and feedback cycles) and
82 did not decrease when PA and diet were targeted simultaneously. In relation to eHealth
83 interventions it is important to consider that small effect sizes do not necessarily mean small
84 public health impact, as these interventions have the potential to reach more people compared
85 to traditional face-to-face interventions.

86 Brouwer et al.³⁶ conducted a systematic review specifically examining which characteristics
87 are effective in increasing exposure to Internet-delivered interventions, as increased exposure
88 to intervention content has consistently demonstrated to increase intervention effectiveness.³⁷
89 They found that eHealth intervention components such as provision of peer support,
90 **counsellor** support, e-mail/phone contact and website updates were significantly associated
91 with increased exposure. Webb et al.³⁸ focussed on the influence of using health behavior
92 theory in internet-based interventions and found that more extensive use of theory was
93 associated with increases in effect size; particularly, interventions that used the Theory of
94 Planned Behavior tended to have substantial effects ($d = .36$). Additionally, interventions that
95 incorporated more behavior change techniques also tended to have larger effects. Despite the
96 frequent use of behavior change theory in academic-led eHealth interventions, Vandelanotte
97 et al.³⁹ audited freely available PA websites and found they tend to lack the fundamental
98 components associated with behavior change. However, the increasing presence of social
99 media applications in most websites was encouraging.

100 The use of online social networks (e.g. *Facebook*, *Twitter*, or purpose-designed health online
101 social networking sites) to improve health behaviors was addressed in a systematic review by
102 Maher et al.²⁵ They reported generally small effect sizes, as well as difficulties with
103 intervention engagement and retention, despite some of the interventions being delivered on
104 existing online social network platforms with proven engagement and retention. The authors
105 observed that most interventions to date had not incorporated characteristics of popular social
106 networking (such as convenience of communication, enjoyment, and emphasising
107 interactions with existing friends).

108 In summary, there is a considerable body of scientific literature regarding eHealth behavior
109 change interventions. To date, evidence suggests such interventions can lead to positive,
110 short-term changes in behavior, that tailoring is a useful intervention element, and that
111 theoretical underpinning is important. However, further work examining how to maintain
112 behavior change into the longer term, identifying which intervention elements are effective,
113 and responding to new intervention opportunities as technology advances, is required.

114

115 **Status of m-Health in Behavioral Research**

116 High penetration of mobile devices and the use of new and powerful smartphone apps
117 provide opportunities to expand the reach of diet and PA behavioral mHealth interventions.⁴⁰
118 Mobile phones, personal digital assistants (PDAs) and body sensing systems have been used
119 to assess PA, sedentary behavior and dietary patterns, as well as to deliver feedback,
120 information, and support to participants of behavioral interventions.⁴¹⁻⁴³ A review of dietary
121 assessment methods deployed on mobile platforms found that the feasibility and validity of
122 mobile phones to assess dietary intake were not superior to but equivalent to, traditional
123 interviewer- or self-administered paper/pencil methods.⁴⁴ Notably, participants' self-reported
124 satisfaction and preferences for mobile phone methods were higher than conventional

125 methods. A review of PA assessment methods using smartphones found a wide variety of
126 assessment tools either using smartphone apps (i.e., using tri-axial acceleration data from the
127 phone's native sensor) or on-body sensing systems (i.e., external accelerometer devices) that
128 were positioned on different body parts (e.g., hip or waist). Algorithms were used to
129 recognize a range of activities (e.g. walking, running) and postures (e.g. standing, sitting).
130 Overall, the 10 included studies reported moderate to high validity with measurement
131 accuracy ranging from 52 to 100%.²³

132 In terms of efficacy of mobile technologies in promoting healthy diet and PA, a 2012 meta-
133 analysis suggested interventions using personal digital assistants (PDA) and mobile phone
134 text messages (SMS) were moderately effective in increasing PA behavior (the *Hedges' g*
135 effect size was 0.54).⁴² This finding was echoed in later reviews that focused on interventions
136 utilizing SMS, PDA, interactive voice response systems, smartphone apps and wearable
137 devices (e.g. Fitbit) to promote PA.^{23,43,45-49} Similarly, Lyzwinski found a pooled medium
138 effect size for weight loss interventions using mobile phones,⁵⁰ PDA's and MP3 players
139 compared to varying controls ($d = 0.43$). Further, most of the included studies reported
140 positive changes in terms of body mass index (BMI), waist circumference, percentage body
141 fat, and dietary behaviors. These findings are in accordance with a meta-analysis on weight
142 management interventions delivered via SMS.⁵¹ While Lyzwinski's weight loss study
143 suggests that mHealth applications have been effective in improving dietary behaviours to
144 date there is no equivalent systematic review/meta-analytic study of the effectiveness of
145 mHealth interventions on dietary behavior. However, in the first instance there remains an
146 urgent need for more robust and large-scale efficacy trials in both diet and PA applications of
147 mHealth.^{23,52}

148 Content analyses of mobile apps⁵³⁻⁵⁷ have been conducted to identify apps using evidence-
149 based behavior change techniques,⁵⁸⁻⁶⁰ as well as diet and PA recommendations.⁶¹ These

150 investigations collectively indicate that health and fitness apps available on iTunes and
151 Google Play utilized few or no behavior change techniques, and infrequently incorporated
152 evidence-based recommendations. For example, Conroy et al.⁶² analyzed the online
153 descriptions of popular health and fitness apps and reported that most apps targeting PA are
154 using behavioral strategies that can be categorized into improving motivation and providing
155 behavioral education, while action planning as a successful strategy was rarely used. Further,
156 it was unclear how the respective behavior change techniques were implemented and
157 therefore no conclusion could be drawn whether they are as effective as face-to-face
158 interventions, or whether a parsimonious set of “effective” techniques outperforms apps that
159 include less effective techniques.⁵⁶ Most commercially available apps are not developed in
160 partnership with behavioral experts, thus, this might explain why evidence-informed content
161 and engagement techniques are notably scarce.^{54,55,61} The inclusion of such experts in the
162 development process may increase the likelihood of success.⁵⁷

163

164 **e- & mHealth in Underserved Populations and the Developing World**

165 With the use of new technologies, formerly isolated populations are now reachable. This
166 presents an opportunity to conduct health interventions in traditionally underserved
167 groups,^{62,63} particularly for those whose demographic, geographic or economic characteristics
168 negatively affect health care access and delivery,⁶⁴ such as older adults, people with low
169 socioeconomic status, ethnic minorities, gay-lesbian-bisexual-transgender people, people
170 with disabilities and those living in low to middle-income countries.⁶⁵ However, only a
171 limited amount of research has been conducted in relation to e- & mHealth in these
172 populations.

173 With regard to e- & mHealth research in ethnic minorities, most studies are small feasibility
174 trials, conducted in the United States, limiting the generalizability of the study results. Two

175 small studies in African Americans used SMS to encourage weight-loss and increase overall
176 PA, respectively. In both studies SMS was effective for weight loss over six months⁶⁶ and
177 increasing PA levels⁶³ respectively, illustrating the potential of this type of intervention.
178 Similarly, the use of PDAs has been effective to improve dietary intake in economically
179 disadvantaged girls from an ethnic minority in the United States.⁶⁷ Finally, in a systematic
180 review of eHealth weight management interventions in overweight and obese ethnic
181 minorities in the United States,⁶⁸ four of six studies reported that significantly greater weight
182 loss occurred in the eHealth conditions compared to control conditions. The authors,
183 however, highlighted that further research is needed because eHealth interventions were not
184 compared with non-eHealth approaches, and the extent to which weight loss was achieved in
185 these studies was not considered clinically meaningful.

186 e- & mHealth research in older adults is scarce with only one review available focusing on
187 non-face-to-face PA interventions in older adults.⁶⁹ Only four out of the 16 included studies
188 used e- & mHealth in some form, however three of these showed a significant positive impact
189 on PA with medium to large effect sizes. Technology use in older adults is growing rapidly
190 (e.g. about half of Americans over 65 years of age regularly used e-mail or internet), this
191 highlights the potential for future e- & mHealth research.⁷⁰ Recruiting people with disabilities
192 in e- & mHealth trials seems particularly challenging, and only one paper could be identified
193 that described an 8-week internet-based intervention to increase PA in adolescents with
194 cerebral palsy.⁷¹ After the intervention, a significant increase in walking was observed in the
195 intervention group, however the intervention effects disappeared after 20 weeks.

196 Globally, low- to middle income countries are in high need of sustainable and cost-effective
197 behavioral diet and PA interventions due to the steep increase of non-communicable
198 diseases.⁷¹ The use of mHealth may be more promising than the use of eHealth in developing
199 countries due to the rapid growth of mobile phone ownership, in contrast to the number of

200 people having access to or ownership of computers with an Internet connection.^{18,52,73} One
201 systematic review has targeted mHealth interventions in low- to middle income countries.
202 The authors included 76 studies, 20 of which focused on health education and behavioral
203 change.⁶² However, most of these studies focused on health behaviors related to infectious
204 diseases, with only two SMS-based studies (one in South-Africa and one in India) focused on
205 type 2 diabetes prevention and reported on diet and PA outcomes.^{74,75} The South-African
206 study (N = 22 females) was not able to significantly improve step counts, healthy eating and
207 BMI, however participants were regularly texting their peer support buddies.⁷⁴ The Indian
208 study (N = 537 males) showed significant improvements in the diet of intervention group
209 participants, but not in PA.⁷⁵

210 It is clear that there are great opportunities to advance the science in this area. It is important
211 to point out that not all groups are able to take advantage of e- & mHealth services, not only
212 because of a lack of access to computers, mobile devices and the Internet (i.e., the “digital
213 divide”), but also because individual, social and cultural barriers relating to internet self-
214 efficacy, health literacy, and cultural/linguistic appropriateness.⁷⁶ Despite the increasing
215 popularity of the internet, there is overwhelming evidence of inequalities across the
216 dimensions of access to and use of communication media, the processing of health
217 information, and the effect on health behaviors.^{77,78} This suggests that access alone is not
218 enough, and that how and where information is presented, organised and disseminated is
219 equally important.⁷⁶ Currently, limited information exists on how to best operationalize
220 intervention content and strategies to maximise use among underserved populations.

221

222 **The Use Of Theory in e- & mHealth Interventions to Enhance User Engagement**

223 In the context of e- & mHealth interventions, ‘engaging’ interventions are those that entice
224 users to be involved with the intervention platform. As such, engagement is often assessed in

225 terms of intervention usage (e.g., number of logins, number of modules completed, pages
226 viewed). There is consensus among researchers that the application of theory to the
227 development and evaluation of health behavior change interventions significantly improves
228 behavioral outcomes.⁷⁹ Theories help pinpoint *what* factors need to be considered when
229 designing interventions; provide insight into *how* to target these factors; and provide insights
230 into *why* an intervention works.^{79,80} To date, the majority of discussions and research
231 involving the application of theory to the development and evaluation of health behavior
232 change interventions has focused on theories concerned with psycho-social and
233 environmental determinants of health behavior.⁷⁹⁻⁸³ Overall, while these theories provide
234 guidance in the development of intervention content, they provide little insight into how to
235 design engaging interventions that effectively prompt recommended patterns of intervention
236 usage.⁸⁴ Consequently, e- & mHealth interventions are often developed without explicitly
237 giving consideration to attributes influencing attitudes, online behavior and health behavior
238 change. This may partially explain the modest effect-sizes reported in e- & mHealth
239 interventions and why issues associated with user engagement (e.g., low use of intervention
240 features, few logins, non-usage attrition) are consistently reported.^{19,84} Notably, in a recent
241 review of the eHealth literature (involving over 80 studies), only 50% of participants on
242 average were found to engage with the intervention platform as intended by intervention
243 developers.⁸⁵

244 Findings from systematic reviews and meta-analyses support the notion that intervention
245 characteristics associated with user engagement (e.g., tailoring intervention content to match
246 individual characteristics, website interactivity, credibility, number of updates and reminders)
247 mediate intervention efficacy and should be considered when designing interventions.^{19,36,38,85}

248 Further, research stemming from multiple disciplines, including social and health
249 psychology, information science, and marketing suggest that factors relating to the individual

250 (e.g., demographics), the individual's environment (including the online environment), and
251 the intervention itself (e.g., aesthetics, prompts, reminders) are likely to influence how users
252 engage with the intervention and how persuasive it is.^{84,86-91} Further research is needed to
253 determine which factors within these domains are most changeable and result in the largest
254 effects when targeted. In line with best practices, these factors should be considered within a
255 conceptual framework that is both evidence-based and guided by theory. Several existing
256 models may be useful for this purpose, including The Elaboration Likelihood Model of
257 Persuasion,^{86,88} O'Brien and Tom's conceptual model of user engagement with technology,⁸⁷
258 Short and colleagues' model of user engagement in online interventions,⁹⁰ and the Persuasive
259 Systems Design Model,⁹² as applied by Kelders and colleagues.⁸⁴ These models can be
260 integrated with traditional behavior change theories to form an integrated approach in order
261 to address both sets of determinants – that is, those that predict behavior (e.g., self-efficacy),
262 and those that influence how engaging the intervention is (e.g., use of prompts, reminders,
263 tunneling, social networking features, tailoring).

264 While some progress in this areas has been made,⁸⁴ more research is required in order to
265 develop a more comprehensive understanding of how e- & mHealth interventions work, and
266 how to make them more effective. Particularly, experimental studies examining the impact of
267 specific intervention features on user engagement are an essential next step for theory
268 development and evaluation and thus for building 'a science of user engagement.'⁹¹

269

270 **Methodological Issues in e- & mHealth Research**

271 A large number of randomized controlled trials (RCTs) of e- & mHealth interventions have
272 been undertaken in the past 10-15 years, and their reporting typically shares common
273 weaknesses. Publications commonly describe the scientific procedure at length, but only
274 provide brief details of the intervention itself. The intervention is typically described by

275 naming a guiding behavior change theory (if one has been used) and briefly listing a range of
276 characteristics, such as duration and key aspects of content (educational materials, goal-
277 setting, coaching etc.). Eysenbach⁹³ highlighted the need for detailed intervention description
278 in his development of the eHealth CONSORT guidelines; these reporting guidelines have
279 subsequently been adopted by the Journal of Medical Internet Research, but not by other
280 leading scholarly journals in the field. Similarly, other fields, such as online marketing, are
281 highly mindful of the importance of an e- or m-resource's look, brand and language-style, in
282 how materials are received and used,⁹⁴ yet such elements are rarely described in scientific e-
283 & mHealth publications. This is remarkable, given that, by convention, scientific studies
284 should be described in adequate detail to allow reproduction.^{93,95}

285 Maher et al.²⁵ conducted a systematic review of online social networking behavior change
286 interventions and reported that out of the 10 included studies, only two of the interventions
287 could be publically accessed via the Internet (the rest had either been removed or were locked
288 away behind secure screens so that only research participants with log in details could gain
289 access). In other fields, such as commercial product research and development, viewing,
290 dissecting and learning from others' products is a vital part of developing new products;⁹⁶ as
291 such, the inability to view others' e- & mHealth interventions is likely to be severely
292 restricting the development of innovative and improved online health behavior change
293 resources. Online forums and resource sharing websites such Open Science Framework⁹⁷ are
294 beginning to address this deficit, offering researchers a public forum through which they can
295 share their resources, and thus allow other researchers to find, use and cite them. Widespread
296 use of such resources will avoid researchers reinventing something that already exists and
297 assist the field to develop more rapidly.

298 To date, most empirical studies in the field of e- & mHealth (and particularly those published
299 in highly regarded journals) have taken the form of RCTs. Such evidence has been critical for

300 bringing the field to where it is today, by drawing attention and credibility to the vast
301 potential of e- & mHealth, and providing a body of evidence regarding efficacy. However,
302 RCTs are insufficient to answer several important questions, such as how to disseminate an
303 effective e- or mHealth resource, or assessing whether an e- or mHealth intervention with
304 proven efficacy in a RCT, continues to be effective in a “real-world” setting.⁹⁸ One successful
305 example of a “real-world” (sometimes termed “ecological” or “pragmatic”) study is Cobb and
306 Poirier’s⁹⁷ evaluation of a commercial eHealth intervention, “Daily Challenge”. Participants
307 were recruited entirely via *Facebook* advertising, minimal exclusion criteria were applied,
308 and participants were free to use the intervention as they chose. The study recruited 1503
309 participants in just 49 days, shedding light on dissemination strategies, as well as leading to
310 timely production of study outcomes and intervention iterations. Despite such benefits, in our
311 experience, “real-world” study designs are not favored by funders nor publishers compared
312 with randomized controlled designs. Accepting and appreciating the value of ecologically-
313 valid research designs will require a paradigm shift from peer-reviewers, including in many
314 cases, those from within the e- & mHealth field itself.⁹⁹

315 While there have been significant technological advances in the way dietary data are
316 collected and processed,¹⁰⁰ these advances have allowed researchers to trade one set of issues
317 for another. Limitations of traditional self-report methods of dietary intake include social
318 desirability of response, reporting biases, participant burden, and the dual requirements of
319 literacy and motivation. However, technology-based approaches to data capture (e.g., food
320 photography, computer-assisted recall) create new challenges (e.g., the need for a specific
321 make/model of a device, consistent and speedy Internet connectivity), without reducing the
322 limitations of the traditional approaches. Thus far, new methods have not demonstrated to be
323 superior over traditional “paper/pencil” approaches.^{44,100} Therefore, there is an ongoing need
324 for significant methodological e- & mHealth based advances in dietary assessment.

325

326 **RECOMMENDATIONS FOR FUTURE BEHAVIORAL E- & MHEALTH**
327 **RESEARCH**

328 Based on the literature presented in the previous sections, the following recommendations
329 have been formulated:

330 - *Enhance interactivity*: Studies have demonstrated repeatedly that the most interactive
331 interventions lead to higher usage and engagement, which then subsequently lead to greater
332 and longer lasting intervention effects.^{19,20,22,34} The use of social media and online social
333 networks is especially promising within this context,²⁵ and may help to reach underserved
334 groups.⁷⁶

335 - *Examine the effectiveness of specific intervention components in isolation*: Typically,
336 interventions implement a plethora of intervention components (e.g., goal setting, computer-
337 tailoring, social networking) simultaneously, making it impossible to attribute outcomes to
338 specific intervention components. It is important to understand which specific elements of the
339 interventions led to positive behavior change in order to further improve overall intervention
340 effectiveness.^{20,21,30} This may be achieved by applying smart study designs that, for example,
341 have multiple intervention arms in which different combinations of intervention components
342 are examined.⁹¹

343 - *Increase the level of detail regarding the intervention description in study reporting*: Whilst
344 most quality journals have already adopted CONSORT reporting guidelines, we advocate that
345 further emphasis should be placed on the requirement for authors to provide detailed
346 descriptions of their e- & mHealth interventions. This is important to inform future research
347 efforts, particularly given that many e- & mHealth resources created for research purposes are
348 not publically accessible.

349 - *Consider the determinants of engagement and persuasion:* While most interventions will
350 apply health behavior change theory, few systematically apply theories from communication
351 and marketing science in order to improve user engagement and persuasion with the
352 intervention. It is not only important to examine which intervention components are effective,
353 but it is also important to consider a theoretical framework that specifically addresses how
354 intervention content should be communicated and presented in an online environment. This is
355 needed to increase the ‘stickiness’ of an intervention and participants want to come back time
356 and time again.

357 - *Examine long-term maintenance of behavior change:* While short-term efficacy of e- &
358 mHealth interventions has repeatedly been demonstrated, few e- & mHealth studies have
359 examined long-term maintenance of behavioral outcomes more than six months after the end
360 of the intervention.¹⁹ Evidence of long-term behavior change is needed if this field is to move
361 forwards.^{20,21,69} This is related to the need to improve sustained engagement with e- &
362 mHealth interventions, as higher levels of usage have shown to be related to greater
363 behavioral change.

364 - *Improve external validity:* A review by Blackman and colleagues on the internal and
365 external validity of mHealth PA interventions found that only half of the included studies
366 reported on intervention reach.⁴⁶ These findings are mirrored in the dietary literature.¹⁰¹
367 Using the CONSORT-EHEALTH checklist⁹² to improve on how intervention trials are
368 reported in the literature can be a useful and practical means of enhancing our understanding
369 of the generalizability of e- & mHealth outcomes. Often too little information is available to
370 allow reproducing the study. Tight journal word limits are often the cause, however more
371 journals now publish full-length protocol papers, which may help to circumvent this problem.
372 Moreover, researchers can provide access to their e- & mHealth resources so that they are

373 accessible for other researchers and practitioners. This ‘open access’ model will enhance the
374 dissemination of effective interventions.

375 - *Apply alternative research designs:* Evaluating intervention effectiveness under real life
376 conditions will be essential to advance the field vertically. Alternative research designs (e.g.,
377 n-of-1, pre-post, interrupted time-series, quasi experimental studies) should be considered.⁴⁰

378 - *Research translation:* To truly test the potential of e- & mHealth interventions large-scale
379 implementation studies are needed, whereby the aim is not only to improve behavior, but also
380 to reach as many people as possible. Applying mass-media broadcasting techniques, as well
381 as social and viral marketing strategies, will play an important role in achieving widespread
382 adoption of new interventions.¹⁰²

383 - *Focus on underserved populations:* A limited amount of e- & mHealth research has
384 specifically targeted underserved populations. It is important to note that some underserved
385 populations may actually be easier to reach using technology-based approaches, for example,
386 people with physical incapacities that limit their access to traditional face-to-face
387 interventions. In the past, access issues may have reduced the usefulness of e- & mHealth
388 interventions for populations with low social capital, such as ethnic minorities, people from
389 low socioeconomic status backgrounds, and those with literacy issues. However, as Internet
390 access and mobile device ownership further increase, the feasibility of technology based
391 interventions for these populations will also be enhanced.⁷³

392 In conclusion, while our report demonstrates that a substantial amount of progress has been
393 made in the field of behavioral e- & mHealth research, large gaps remain that need to be
394 addressed. Many issues relate to how research has been conducted in this area (e.g., poor
395 reporting), while others are specific to e- & mHealth applications (e.g., lack of knowledge of
396 effectiveness of specific e- & mHealth intervention components).

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