

Design Frameworks for Mobile Health Technology: A State-of-the-Art Review of Research From 2015-2021

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ABSTRACT

The World Health Organization envisions that mobile health (mHealth) technologies will revolutionize healthcare to help people around the world. This review examined recent literature to assess the state-of-the-art of mHealth technology design frameworks and guidelines. Through multiple rounds of searches and screenings, 12 eligible research publications were selected from MEDLINE and Web of Science for full analyses, including selected bibliometrics, categorical meta-trend analyses, and inductive content analysis. This review reveals the current state of mHealth research, highlights impactful design frameworks and guidelines, generates the current action cycle for mHealth technology research, and discusses on practical implications as well as future directions for mHealth research and design.

KEYWORDS

Design Framework, mHealth, mHealth Design, Mobile Health Applications, Mobile Health Technology, Mobile Technology Design, Research Review, Technology Design

INTRODUCTION

The rapid advancements in mobile technologies are transforming the practice of healthcare. The World Health Organization (WHO) global survey suggests that mHealth may well change health services across the globe (Ginsburg, 2014; WHO, n.d.). In 2019, most of the Americans (96%) own a cellphone and 81% of Americans have a smart phone (Pew Research Center, 2019). In 2017, there were 3.7 billion mobile health application downloads by smartphone users worldwide (US Food and Drug Administration, 2019). Mobile health technology, or “mHealth” thus is recognized as one of the fastest growing fields, and calls for interdisciplinary approaches to support its research, development, and evaluation.

mHealth empowers users, including patients, health care professionals, care givers, family and friends and more, with fast and easy access to health information and ample resources. Wearable technologies, for example, allow users to monitor their health data and provide just-in-time suggestions or advice on healthy choices enables users to manage their health and wellness, facilitate just-in-time learning, and promote healthy living (FDA, 2019; Jameel et al., 2022). During the COVID-19

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pandemic, mHealth applications have played crucial roles to promote public health through timely services like information sharing, disease detection, early screening, monitoring, education and more (Alam et al., 2021; Asadzadeh, & Kalankesh, 2021; Alzahrani et al., 2022).

Despite its growing popularity and affordability, evidence-based research is rather limited on mHealth (Brown, Yen, Rojas & Schnall, 2013; Free et al. 2013). With the thrive of mHealth technologies, effective design is critical to promote customized learning for mobile users. But research indicates that more than 95% of mHealth apps have not been tested or studied scientifically (Brown, Yen, Rojas & Schnall, 2013), most have no indication of expert input from healthcare professionals (Charbonneau et al., 2020), and many trials and research do not provide evidences on the benefits of their mHealth interventions (Free et al. 2013). Researchers call for a comprehensive, interdisciplinary framework to guide mHealth research and practice (Rincon, Monteiro-Guerra, Rivera-Romero, Dorronzoro-Zubiete, Sanchez-Bocanegra, & Gabarron, 2017; Milne-Ives et al., 2020; Wilhide III et al., 2016).

Recent reviews have examined mHealth technologies for a particular user population (e.g., Alam et al., 2021; Jameel et al., 2022), or mHealth in response to global public health threats like the pandemic (Alam et al., 2021; Asadzadeh, & Kalankesh, 2021). But still, very little is known about the design frameworks for mobile health technology. For example, what design frameworks or principles guide the creation of mHealth technologies? More importantly, what can we learn from the existing research on mHealth technology design frameworks? After many rounds of searches with different search engines, we have not found any research reviews focusing on mHealth design frameworks. Thus, the objective of this review is to examine the most recent literature to assess the state-of-the-art of mHealth technology design frameworks and guidelines. State-of-the-art review has been used in many informative studies in healthcare to provide the current thinking and practices in the field, through critical analyses of the latest literature (Dey et al., 2019; de Chazal et al., 2018; Liu et al., 2017; Paglialonga et al., 2018). This multi-phased state-of-the-art review critically examined selected refereed mHealth technology publications, and explored the following questions:

1. What is the state of mHealth technology publications in 2015-2021?
2. What design frameworks guide the design or evaluation of mHealth technology, as reported in recent refereed publications?
3. What implications does recent research have on mHealth technology development?
4. What implications does recent research have on mHealth technology research?

METHODS

This review involved multiple phases to explore mHealth technology research, development and evaluation frameworks and guidelines. Phase 1 included multi-step search and screening efforts to locate eligible publications in the recent six years, using two source databases, MEDLINE and Web of Science. They were selected as the primary source databases because: (1) MEDLINE is a premier comprehensive database with over 25 millions of references in life sciences (US Department of Health and Human Services, n.d.); (2) Web of Science collects over one billion multidisciplinary references from high impact journals and conferences, including the Social Science Citation Index, Science Citation Index Expanded, Arts and Humanities Citation Index, and Emerging Sources Citation Index; and (3) both databases provide comprehensive, web-based, bibliographic citations and information. Key words such as “mobile health”, “mHealth”, “design framework” were used in various combinations in multiple search efforts. Only articles reporting the design and use of mobile health applications were selected for further analysis. Thus, theoretical or conceptual articles, literature review papers, scoping reviews, personal opinions, cases or reports of personal experiences, and studies that did not focus on the use of mHealth technologies were all excluded. Multiple rounds of searches in MEDLINE yielded 28 initially eligible results, and only ten of them met all of the inclusion criteria for further

analyses. Similar searches in Web of Science yielded eight articles, and only two met all criteria after excluding duplicates. So, in total, twelve articles were eligible for full analyses.

The researchers applied selected bibliometrics (Okubo, 1997), categorical meta-trend analyses (Hung & Zhang, 2012; Thelwall 2008) and inductive content analysis (e.g., Gao, Luo, & Zhang, 2012; Zhang & Wildemouth, 2009) to review all eligible articles, focusing on the following characteristic: participants, country of the study, goals of the mHealth intervention, research design, data collection methods, and any design frameworks or guidelines reported.

DISCUSSION

The State Of mHealth Research Publications

Publication Venue

mHealth research was published in diverse venues of varied fields, including medicine, medical informatics, behavioral sciences, and computer science, as summarized in Table 1.

Table 1. Selected Articles by Journal/Proceeding

Journal/Proceeding	<i>n</i>	Study
<i>BMC Medical Informatics and Decision Making</i>	1	Vossebeld, Puik, Jaspers, & Schuurmans (2019)
<i>Human-Computer Interaction</i>	1	Halttu & Oinas-Kukkonen (2017)
<i>International Journal of Behavioral Medicine</i>	1	Goldstein et al. (2017)
<i>JMIR Cancer</i>	1	Morse et al. (2021)
<i>JMIR Formative Research</i>	2	Bricker et al. (2020); Zucchelli et al. (2021)
<i>Journal of Pain and Symptom Management</i>	1	Portz et al. (2020)
<i>Journal of Telemedicine and Telecare</i>	1	Dhillon, Wunsche, & Lutteroth (2016)
<i>Translational Behavioral Medicine</i>	2	van Agteren, Lawn, Bonevski, & Smith (2018); Buman et al. (2016)
<i>PLOS ONE</i>	1	Farao et al. (2020)
<i>Proceedings of the 6th International Conference on Digital Health Conference</i>	1	Alkushayni & McRoy (2016)

Prolific Countries

Recent studies were conducted in eight countries, Australia, Finland, New Zealand, Netherlands, South Africa, United Kingdom, the United States, and Tanzania (see Table 2). USA is the most prolific with five of the twelve studies, and the other seven countries each had one in the past six years. It is noteworthy that there was only two were from the Global South, one from South Africa (Farao et al., 2020) and the other focused on a digital care system for Tanzanian cancer patients (Morse et al., 2021).

Participants

A variety of users or stakeholders participated in these studies, including patients, caregivers, healthcare professionals, seniors, university students, veterans, and other mHealth technology users (see Table 2). Overall, the sample sizes were small: five of the studies had twenty or less participants (Buman et al., 2016; Farao et al., 2020; Goldstein et al., 2017 ; van Agteren et al., 2018; Zucchelli

et al., 2021), three had more than 50 participants (Bricker et al., 2020; Portz et al., 2020; Halttu & Oinas-Kukkonen, 2017, one of which had more than 100 participants (n=147) (Halttu & Oinas-Kukkonen, 2017).

Table 2. A Summary of Countries and Participants of Studies

Country of Study	<i>n</i>	Study	Participants
Australia	1	van Agteren, Lawn, Bonevski, & Smith (2018)	Smokers and health professionals, 16 interviews and one focus group with 5 participants
Finland	1	**Halttu & Oinas-Kukkonen (2017)	147 university students and employees
New Zealand	1	*Dhillon, Wunsche, & Lutteroth (2016)	43 senior healthcare consumers
Netherlands	1	*Vossebeld, Puik, Jaspers, & Schuurmans (2019)	29 participants, including 16 nurses, six nurse managers, and seven other stakeholders
South Africa	1	Farao et al. (2020)	20 participants
United Kingdom	1	Zucchelli et al. (2021)	14 participants
USA	5	Buman et al. (2016)	17 US veterans
		*Bricker et al. (2020)	59 adult smokers
		*Alkhusayni & McRoy (2016)	27 English speaking caregivers
		Goldstein et al., (2017)	12 participants
		*Portz et al. (2020)	81 participants
Tanzania	1	*Morse et al. (2021)	21 informants and 10 patients & caregivers

*: with more than 20 participants

**: with more than 100 participants

Research Methods

mHealth studies applied various research designs and utilized different methods for data collections, including qualitative, quantitative and mixed methods (see Table 3).

Table 3. Data Collection Methods in mHealth Studies

Method	<i>n</i>	Study
Qualitative interviews	6	Bricker et al. (2020) ; Goldstein et al., (2017) ; Farao et al. (2020); Portz et al. (2020); Vossebeld, Puik, Jaspers, & Schuurmans (2019); Zucchelli et al. (2021)
Quantitative surveys	4	Bricker et al. (2020); Dhillon, Wunsche, & Lutteroth (2016); Halttu & Oinas-Kukkonen (2017); Morse et al., 2021
Observations	7	Buman et al. (2016); Farao et al. (2020); Goldstein et al., (2017); Morse et al. (2021); van Agteren, Lawn, Bonevski, & Smith (2018); Vossebeld, Puik, Jaspers, & Schuurmans (2019); Zucchelli et al. (2021)
Focus groups	3	Alkhusayni & McRoy (2016) ; Buman et al. (2016) ; Zucchelli et al. 2021
Pilot Randomized Trial	1	Bricker et al., 2020
Multiple methods	3	Bricker et al. (2020); Morse et al., 2021; Zucchelli et al. 2021

Design Frameworks and Guidelines

A few different frameworks were found in recent publications, as summarized in Table 4. For instance, in a study to identify key features and functionalities for a new mHealth technology for caregivers of elderly with multiple chronic conditions, Alkushayni and McRoy (2016) applied Self-determination Theory, Fogg's Functional Role Triad, and Persuasive Design Framework (Kelders, et al., 2012; Oinas-Kukkonen, & Harjumaa, 2009) in their inquiry. In another study on mHealth to help quit smoking (van Agteren, Lawn, Bonevski, & Smith, 2018), multiple frameworks were integrated to guide the design and evaluation efforts of the mHealth technology, including Intervention Mapping Framework (Bartholomew, Parcel, & Kok, 1998), Behavioral Change Taxonomy, Theoretical Domains Framework, and Persuasive Design Framework. Among the various frameworks, the Persuasive System Design Framework was applied in three studies (i.e., Halttu & Oinas-Kukkonen, 2017; Kelders, Kok, Ossebaard, & Van Gemert-Pijnen, 2012; Oinas-Kukkonen, & Harjumaa, 2009). In the latest studies, user-centered framework (Bricker et al., 2020; Farao et al., 2020), human-centered iterative design principles (Morse et al., 2021; Portz et al., 2020) and participatory design framework (Zucchelli et al., 2021) were applied.

Table 4. Frameworks Used in mHealth Studies

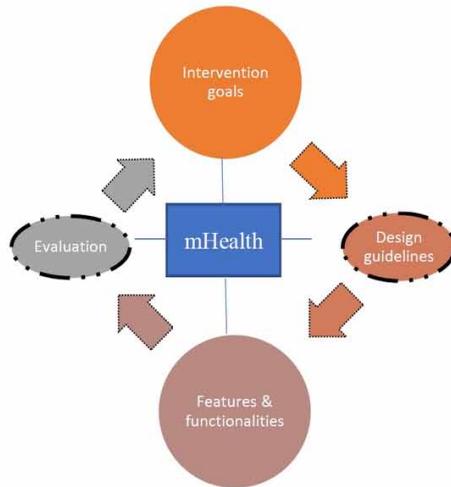
Frameworks & Guidelines	<i>n</i>	<i>Study</i>
Axiomatic design	1	Vosseveld, Puik, Jaspers, & Schuurmans (2019)
Behavioral change taxonomy	1	van Agteren, Lawn, Bonevski, & Smith (2018)
Community-embedded iterative design	1	Buman et al. (2016)
Fogg's functional role triad	1	Alkushayni & McRoy (2016)
Human-centered iterative design	2	Morse et al. (2021); Portz et al. (2020)
Intervention mapping framework	1	van Agteren, Lawn, Bonevski, & Smith (2018)
Just in time adaptive intervention	1	Goldstein et al. (2017)
Participatory design framework	1	Zucchelli et al. (2021)
Persuasive system design	3	<ul style="list-style-type: none"> • Alkushayni & McRoy (2016); • van Agteren, Lawn, Bonevski, & Smith (2018); • Halttu & Oinas-Kukkonen (2017)
Self-determination theory	1	Alkushayni & McRoy (2016)
Theoretical domains	1	van Agteren, Lawn, Bonevski, & Smith (2018)
User-centered framework	2	Bricker et al. (2020) ; Farao et al. (2020)
Information Systems Research framework	1	Farao et al. (2020)
design thinking	1	Farao et al. (2020)

DISCUSSIONS

mHealth Research & Development

This state-of-the-art review has found that mHealth research and development often involve the following cycle of actions: interventions goals, design guidelines, features and functionalities, and evaluation. As illustrated in Figure 1, design guidelines and evaluations are not always evident in mHealth research reports, and thus are noticeably smaller in size and with dotted lines to indicate the lack of such in many cases.

Figure 1. mHealth research and development action cycle



Intervention Goals

Intervention goals drive the design and development of mHealth technology. Such goals typically focus on behavioral changes at the individual level. Physical health related issues, such as diet and lifestyle behaviors have received a wealth of attention in recent research. For example, a few studies share a common goal to improve users' physical health (Buman et al., 2016; Farao et al., 2020; Goldstein et al., 2017; Halttu & Oinas-Kukkonen, 2017; Morse et al., 2021), to help quit smoking (Bricker et al. 2020; van Agteren, Lawn, Bonevski, & Smith, 2018), or to improve emotional health (Dhillon, Wunsche, & Lutteroth, 2016; Portz et al., 2020; Zucchelli et al., 2021). Other studies may focus on a particular user group, for example, senior patients (Dhillon et al., 2016) and their caregivers (Alkushayni & McRoy, 2016).

Intervention goals are essential to meet the varied user needs and preferences, as well as to address specific health issues or concerns. They are also vital for the decisions and design of mHealth features and functionalities. For example, Buman and colleagues (Buman et al., 2016) investigated the mHealth's effects on US veterans' behavioral changes and lifestyle management. To prevent metabolic health risks, the app monitored lifestyle behaviors, such as sleep, inactivity, and active behaviors in the 24-hour range. Similarly, researchers in Australia (van Agteren, Lawn, Bonevski & Smith, 2018) studied the mHealth application to help users quit smoking. To achieve the goal, the mHealth technology provided users with ample resources and support, including information, skills training, motivating content, self-regulatory functions, and network for social support. A study involving caregivers was to identify key functions and features of new mHealth technologies to better support caregivers of elderly patients with chronic conditions (Alkushayni & McRoy, 2016). A study in Netherlands (Vosseveld et al., 2019) showcased the use of a mobile input device for nurses to record their lab tasks with a goal to reduce their lab time and thus to increase nurses' productivity. Another study in New Zealand proposed a health care management system for senior healthcare consumers with the goal to empower them to become pro-active in managing their healthcare needs (Dhillon et al., 2016). Finish researchers (2017) reported a study on a mobile app that aimed to help users with diet management. The app monitored triggering events that caused diet lapses and generated personalized strategies to prevent such lapses. The persuasive systems (Halttu & Oinas-Kukkonen, 2017) were designed to improve physical health through mobile applications and self-tracking devices to achieve behavioral changes.

Design Guidelines

Following specific design guidelines, mHealth technology may integrate distinct features and functionalities to achieve the intervention goals and guide the evaluation efforts as well. For instance, a community-embedded iterative design framework was used to develop the smartphone application (Buman et al., 2016), based on input from various stakeholders in addition to its target users. The community-embedded iterative design process gathered design considerations based on input from various stakeholders, including behavioral experts, mHealth design experts, and veteran healthcare clinical teams, in addition to its target users, US veterans. Similarly, participatory design framework was employed to optimize the intervention's design with input from user representatives and psychological clinicians (Zucchelli et al., 2021). Another study used the intervention mapping framework (Bartholomew, Parcel, & Kok, 1998) to design and test the mHealth app for smokers (van Agteren, Lawn, Bonevski, & Smith, 2018).

Researchers also utilized human-centered iterative design to improve Symptom Control and Information Exchange via mHealth technology (Morse et al., 2021) and to enhance geriatric palliative care systems (Portz et al., 2020). Another study adapted the axiomatic design framework to assess the gap between the design parameters of a new system and the needs of its target users (Vosseveld, Puik, Jaspers, & Schuurmans, 2019). In a mobile app to help overweight patients to manage their diet habits (Goldstein et al., 2017), the just-in-time adaptive intervention framework (Nahum-Shani, Smith, Spring, Collins, Witkiewitz, Tewari, & Murphy, 2017) was applied to guide the design of the mHealth technology. Studies also relied on user-centered framework to design mHealth applications with various objectives, such as convincing cancer patients quit smoking or helping with tuberculosis skin test readings (Bricker et al., 2020; Farao et al., 2020). Some studies integrated multiple frameworks (Alkushayni & McRoy, 2016; Farao et al., 2020), such as the self-determination theory, Fogg's functional role triad, and persuasive system design, and synthesized them to design mHealth applications for caregivers (Alkushayni & McRoy, 2016). However, a critical review of 14 studies found that most mHealth research studies did not employ any theoretical frameworks (Cho et al., 2018). Only five out of the 14 studies applied a behavioral change theory to improve health, whereas the rest did not report any related theories in their design of the technology (Cho et al., 2018). The demands for appropriate frameworks and guidelines are ever increasing to guide mHealth interventions for desired health effects or behavioral changes.

Features & Functionalities

Driven by the intervention goals and shaped by selected design guidelines, mHealth technologies are developed with distinct features and functionalities, including resources and information, motivating content (van Agteren, et al., 2018), just-in-time intervention and support (Goldstein et al., 2017), personal rapport and self-reflections (van Agteren et al., 2018) and more. To improve user's physical health (Buman et al., 2016), for example, the mHealth app must have features to monitor user's behavior data such as sleep, inactivity, activities. Likewise, a mobile app to help quit smoking (van Agteren et al., 2018; Bricker et al. 2020) thus would feature related resources, self-regulatory functions, and networking opportunities for social and peer support. Similarly, to support caregivers the mHealth technology need functionalities like to-do lists, communications and care co-ordinations (Alkushayni & McRoy, 2016; Morse et al., 2021).

The evaluation of a mobile medical record app discovered that such mHealth applications ought to have features compatible to users' traditional, existing workflows (Vosseveld, Puik, Jaspers, & Schuurmans, 2019). Similarly, an mHealth technology to help manage dieting behaviors of overweight patients must have functionalities to identify lapses causing weight gain and lapses leading users to leave the diet, to provide personalized daily calorie targets, to generate tailored cues for lapse behaviors, and to encourage users without intimidation (Golstein et al., 2017). The study by Halttu and Oinas-Kukkonen (2017) confirmed that functions such as dialogue support, task support, and unobtrusiveness of the mobile health system were essential in persuasive design (Kelders, Kok, Ossebaard, & Van

Gemert-Pijnen, 2012). For a web and mobile app to support outpatient symptom assessment and care coordination and control, key features and functionalities would allow real-time symptom assessment and access to emergency phone contact with a care team member (Morse et al., 2021).

Evaluation

Evidence-based evaluations provide critical insights for mHealth research and development and inspire future studies and implementations. Evaluation data were often collected through multiple methods (see Table 3), such as interviews (e.g., Buman et al., 2016; Dhillon et al., 2016; Mores, et al., 2021; Vossebeld, et al., 2019), app usage data (e.g., Buman et al., 2016; Dhillon et al., 2016), survey questionnaires (e.g., Buman et al., 2016; Dhillon et al., 2016; Farao et al., 2020; Goldstein et al., 2017; Halttu & Oinas-Kukkonen, 2017), focus groups (e.g., Henry et al., 2019; Morse et al. ; Zucchelli et al. 2021) and observations (e.g., Farao et al., 2020; Morse et al., 2021; Vossebeld, et al., 2019; Zucchelli et al. 2021). Researchers (e.g., Morse et al., 2021; Portze et al., 2020; Singh et al., 2020) emphasize that user feedback is a key for usability evaluations of mHealth technologies, as the ease of use contributes positively to the overall adoption of mHealth interventions. Contextual factors are also imperative (Henry et al., 2019; Zucchelli et al., 2021).

Recommendations for mHealth Research

This review has found that only twelve mHealth studies had reportedly adapted some design frameworks or followed selected design guidelines in the mHealth intervention research cycle. Most of the studies had a small sample size. Thus, more large-scaled empirical studies with more participants and for a longer timeframe are necessary to advance evidence-based research on mHealth. Also, studies focusing on user acceptance of mHealth technologies may shed light on designs that could promote user adoption or sustain continuing usage of such technologies (Santos-Vijande et al., 2022).

As emerging technologies like artificial intelligence (Zhang & Aslan, 2021) or virtual reality (Zhang & Aslan, 2020) integrate with mobile technology, mHealth also needs to apply new methods and tools for research and evaluation, in addition to traditional randomized controlled trials (Pham, Miljer, & Cafazzo, 2016; Mookherji, Mehl, Kaonga, & Mechael, 2015).

RECOMMENDATIONS FOR MHEALTH DEVELOPMENT

Inclusive Design

mHealth must address user needs and preferences from multiple perspectives. For example, to improve an mHealth app for couples and women who are planning for pregnancy, it is important to address user diversity in terms of culture, socioeconomic status, and language (van Dijk et al., 2017). Similarly, in a study with over 300 cancer survivors (Senft et al., 2020), researchers find significant differences by race (i.e., white vs. African American) in perceived security and trustworthiness of eHealth as well as perceived ease of use. Thus, they recommend careful considerations to address diversity in eHealth interventions.

Personalization

Personalization is a major trend in healthcare, especially empowered by mHealth technologies (US Department of Health and Human Services, n.d.; US Food and Drug Administration, 2019; World Health Organization, n.d.). Through smartphones with sensors, healthcare professionals can collect data and monitor patients' behaviors in an ongoing manner, while patients, or other target users are in their own authentic environments and without interrupting their daily routines. mHealth technologies have great potential in changing user's health behaviors and managing their lifestyles (Meng et al., 2020); and thus, data-driven features and functionalities are the key to successful mHealth

interventions. With cloud services, mHealth can also empower users with networked peer and expert support (e.g., van Agteren et al., 2018).

Input from Multiple Stakeholders

As smartphones becoming a common tool for behavior changes through mHealth (e.g., Leichman et al., 2019), interdisciplinary research has also noted the lack of expert input in mHealth development (Charbonneau et al., 2020). For instance, a critical review of 123 mHealth apps for cancer care has revealed that only a few apps indicated some form of expert review or validation on the resources, information or other content within the mHealth app (Charbonneau et al., 2020).

Suggestions For Future Reviews

This state-of-the-art review is limited in its scope, because of the selection of source databases, search strategies, key words, and selection criteria. Other types of reviews, such as systematic or methodological reviews may examine related literature from different perspectives (Grant & Booth, 2009). Extending the search efforts to include other databases or applying different search engines may also alter the scope of future reviews. It is important to be familiar with different kinds of reviews to support future research endeavors appropriately (Sutton et al., 2019).

CONCLUSION

With worldwide rapid growth and increasing availability (Brown, Yen, Rojas, & Schnall, 2013; Pew Research Center, 2021; US Food and Drug Administration, 2019), mHealth technology has great potentials to achieve preventative (Prasad, 2019) and predicted healthcare (Sohi, 2019). The World Health Organization (WHO) shares a vision that mHealth will revolutionize healthcare and support users to protect their own wellbeing (WHO, n.d.). However, a recent critical review indicates mixed results regarding the benefits of mHealth, and it confirms that quality mHealth requires thoughtful design (Triantafyllidis et al., 2019). Similarly, a review of behavioral change techniques used in randomized controlled trials reveals that the effectiveness of mHealth is rather dubious and inconsistent (Dugas et al., 2020). Research also suggests that without applying theoretical frameworks in the design processes would result in inconsistent or ineffective mHealth interventions (Tamim & Grant, 2017). Thus, a rigorous, interdisciplinary and scientific approach is necessary to advance the research and development of mHealth (Kumar et al, 2013; Nilsen et al., 2012), while spearheading new methods in research and evaluations (Pham, Miljer, & Cafazzo, 2016; Mookherji, Mehl, Kaonga, & Mechael, 2015). Carefully selected design principles should be applied to guide the design, development, research and evaluation of mHealth, especially those based on inclusive, user-centered design frameworks.

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