mHealth Apps Using Behavior Change Techniques to Self-report Data: Systematic Review

Maria Aguiar1,2, BSc; Maria Trujillo2, PhD; Deisy Chaves2,3, PhD; Roberto Álvarez1,4, BSc; Gorka Epelde1,4, PhD

1Vicomtech Foundation, Basque Research and Technology Alliance, Donostia-San Sebastián, Spain
2Multimedia and Computer Vision Group, Universidad del Valle, Cali, Colombia
3Department of Electrical, Systems and Automation, Universidad de León, León, Spain
4Biodonostia Health Research Institute, eHealth Group, Donostia-San Sebastián, Spain

Corresponding Author:
Maria Aguiar, BSc
Vicomtech Foundation
Basque Research and Technology Alliance
Paseo Mikeletegi 57
Donostia-San Sebastián, 20009
Spain
Phone: 34 943 30 92 30
Email: maria.aguiar@correounivalle.edu.co

Abstract

Background: The popularization of mobile health (mHealth) apps for public health or medical care purposes has transformed human life substantially, improving lifestyle behaviors and chronic condition management.

Objective: This review aimed to identify behavior change techniques (BCTs) commonly used in mHealth, assess their effectiveness based on the evidence reported in interventions and reviews to highlight the most appropriate techniques to design an optimal strategy to improve adherence to data reporting, and provide recommendations for future interventions and research.

Methods: We performed a systematic review of studies published between 2010 and 2021 in relevant scientific databases to identify and analyze mHealth interventions using BCTs that evaluated their effectiveness in terms of user adherence. Search terms included a mix of general (eg, data, information, and adherence), computer science (eg, mHealth and BCTs), and medicine (eg, personalized medicine) terms.

Results: This systematic review included 24 studies and revealed that the most frequently used BCTs in the studies were feedback and monitoring (n=20), goals and planning (n=14), associations (n=14), shaping knowledge (n=12), and personalization (n=7). However, we found mixed effectiveness of the techniques in mHealth outcomes, having more effective than ineffective outcomes in the evaluation of apps implementing techniques from the feedback and monitoring, goals and planning, associations, and personalization categories, but we could not infer causality with the results and suggest that there is still a need to improve the use of these and many common BCTs for better outcomes.

Conclusions: Personalization, associations, and goals and planning techniques were the most used BCTs in effective trials regarding adherence to mHealth apps. However, they are not necessarily the most effective since there are studies that use these techniques and do not report significant results in the proposed objectives; there is a notable overlap of BCTs within implemented app components, suggesting a need to better understand best practices for applying (a combination of) such techniques and to obtain details on the specific BCTs used in mHealth interventions. Future research should focus on studies with longer follow-up periods to determine the effectiveness of mHealth interventions on behavior change to overcome the limited evidence in the current literature, which has mostly small-sized and single-arm experiments with a short follow-up period.

(JMIR Mhealth Uhealth 2022;10(9):e33247) doi: 10.2196/33247

KEYWORDS
mobile health; mHealth; behavior change techniques; adherence; app; mobile health interventions; behavior
Introduction

Overview

In modern society, the rushed lifestyle and excessive adulteration in food products have caused health-related disorders, making them an inevitable part of modern life [1]. This is associated with the development of noncommunicable diseases, which are related to 16 million premature deaths per year worldwide. The treatment of these lifestyle-related disorders demands long-term clinical help and can last a lifetime [2].

Besides, smartphones have become an essential tool in our daily lives, impacting 7.2 billion users worldwide with more than 70% of them in low- and middle-income countries [3]. Smartphone sensor technology has significantly improved and become more stable for collecting real-time data, which can be saved and processed for multiple analyses, making it possible to monitor our health through mobile health (mHealth) apps [4,5].

Recently, the popularization of mHealth apps for public health or medical care purposes have transformed human life substantially. Strategies such as reminders, counselling, reinforcement, or education have been used to improve people’s adherence to the app, thus improving lifestyle behaviors [6] and chronic condition management (CCM). These strategies are known as behavior change techniques (BCTs).

There is a need to improve the adherence to one’s well-being, regular health monitoring, and expert involvement [7]. The World Health Organization (WHO) estimated that in high-income countries the average adherence rate is 50% in patients with chronic medical illness [8], with even lower rates in low-income countries. It considers the extent to which a person’s behavior—taking medication, following a diet, or making lifestyle changes—corresponds to recommendations agreed upon with a health professional directly or through a mobile app. Nonadherence leads to considerable morbidity, mortality, and avoidable health care costs [9], and it may be caused by people’s intentional or unintentional behaviors. Intentional nonadherence refers to deciding not to report data based on the person’s perceptions such as incomplete disease-related knowledge. In contrast, unintentional nonadherence means that the person intends to report data but fails because of forgetfulness or carelessness. Awareness and proper screening of these intentional and unintentional determinants for the target population are necessary to design and develop tailored solutions to ensure a methodology that improves adherence to data reporting.

mHealth has the potential to improve lifestyle and CCM, and can be rapidly adopted on a large scale and at low cost [10], but inconsistent findings have been reported on its effectiveness. Table 1 summarizes the systematic reviews conducted in the literature on the effectiveness of mHealth interventions with BCTs in distinct contexts and populations. Although the reviews include mHealth studies for a specific population, activity, or disease, most of these studies evaluated the effectiveness in terms of the results obtained for the intervention’s objective. Because of this, it is difficult to discern whether the intervention was ineffective due to a lack of adherence by participants or the combination of 35 BCTs being inadequate for the problem addressed. Therefore, the motivation of this systematic review is to identify current studies that have specifically reported their results in terms of adherence to extract the most used BCTs among the effective studies. This will help to design an adherence-focused strategy combining these BCTs.
Background

*mHealth* is a term used for mobile apps and other wearable devices that collect and monitor medical information from users [22]. Data collected from their routine leads to the accumulation of data depending on the number of users and how often they report data manually (eg, questionnaires) and through their wearable sensors. Therefore, the use of big data analytics on *mHealth* may be promising to provide medical information, improve people’s well-being in nonclinical and clinical settings [23], and improve access to quality care and timely monitoring at an affordable cost with enriched outcomes. Within *mHealth* apps, BCT refers to an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behavior (eg, feedback, self-monitoring, and reinforcement) [24]. BCTs are coded using an established taxonomy of 93 techniques provided in “A Taxonomy of Behaviour Change Techniques Used in Interventions” [25]—for which a standardization has been proposed—and were initially grouped into 16 categories [26,27]. Besides, Dugas et al [27] extended the taxonomy of BCTs in 2020 with 2 additional categories, personalization and gamification, comprising 9 BCTs. Figure 1 shows the final taxonomy with 18 categories that will be used in this study.

Adherence is defined by the WHO [8] as “the extent to which a person’s behaviour – taking medication, following a diet, and/or executing lifestyle changes – corresponds with agreed recommendations from a health care provider.” Moreover, from a technical point of view, adherence is defined as the developer’s expectations, referring to the degree to which the user’s activity within the app matches the pattern of activity that was intended by the developers, differing from the definition of usage that refers to the level of activity within an app. For example, a user who completes 5 modules in a program will obtain 100% usage on the modules’ metric of usage. However, if these modules were supposed to be completed weekly and the user only completed 3 of these on time, the user achieved 60% on the modules’ adherence metric. On the other hand, if these modules are completed 3 of these on time, the user achieved 100% adherence. If people do not report data as often as expected or stop using the app, the quantity and homogeneity of data to be processed will be reduced, producing lower quality outcomes. We will consider both definitions when reviewing the efficacy of the studies.

### Table 1. Systematic reviews were examined, describing the number of studies included and their research objective.

| Authors | Studies, n | Objective |
|---------|------------|-----------|
| Schorr et al [11] | 26 | Identify studies using mHealth for secondary CVD prevention that focus on lifestyle behavior change and medication adherence |
| Akinosun et al [12] | 25 | Identify and measure the effectiveness of digital technology interventions (eg, mobile phones, the internet, software applications, or wearables) in randomized controlled trials and determine which behavior change constructs are effective at achieving risk factor modification in patients with CVD |
| Godinho et al [13] | 29 | Examine the implementation and evaluation of mHealth to support the integration of people-centered health services in the World Health Organization Western Pacific Region |
| Monteiro-Guerra et al [14] | 17 | Study real-time PA coaching mobile apps with personalization mechanisms |
| Wang et al [15] | 17 | Evaluate the effectiveness of mHealth interventions for the treatment and management of diabetes and obesity reported in reviews and meta-analyses to provide recommendations for future interventions and research |
| Thomas Craig et al [16] | 30 | Identify context-aware digital behavior change interventions that provide individualized interventions to improve health |
| Bearne et al [17] | 4 | Identify apps that facilitate PA for adults with rheumatoid arthritis and compare the quality and content of these apps to incorporate relevant BCTs against recommendations for cardiorespiratory, resistance, flexibility, neuromotor PA, and exercise |
| Kalke et al [18] | 30 | Identify breast cancer apps that support behavior change and assess the extent to which these apps address cancer care content |
| Tighe et al [19] | 7 | Identify digital platformlike interventions and examine their potential for supporting self-management of noncommunicable diseases and health behavior change |
| Armitage et al [20] | 9 | Estimate the efficacy of app-based interventions designed to support medication adherence and investigate which BCTs used by these apps are associated with efficacy |
| Pfaeffli Dale et al [21] | 7 | Determine the effectiveness of mHealth interventions on behavioral lifestyle changes and medication adherence for CVD self-management |

---

**a**mHealth: mobile health.  
**b**CVD: cardiovascular disease.  
**c**PA: physical activity.  
**d**BCT: behavior change technique.
Methods

Research Questions
The objective of our systematic review is to identify and analyze relevant studies on BCTs used in mHealth interventions, focusing on the effectiveness of the BCTs on use and paying special attention to improve adherence to data reporting. Hence, the research questions (RQs) that have guided this review are:

- RQ1: What BCTs are most commonly used in the context of mHealth apps? How can these techniques be classified?
- RQ2: What is the performance of these techniques concerning end-user adherence?
- RQ3: Are BCTs (personalization, feedback, and monitoring strategies) useful for improving adherence to data reporting in mHealth apps?

Search Strategy
This systematic review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement [28]. Details of the search strategy are given below.

Eligibility Criteria
Eligible studies were peer-reviewed articles published in English from January 1, 2010, to December 2021. With the growth of technology used for mHealth, the selected time allowed us to assess studies using the most relevant technologies. Participants in the studies were patients of any age, both healthy and with any type of chronic disease. Moreover, studies with interventions using health practices supported by any type of mobile device were eligible for inclusion. Besides, interventions could include multiple delivery methods and nondigital elements. The result assessed was adherence focusing on any outcome (e.g., physical activity, medication adherence, and data reporting) measured by any metric during any follow-up period.

Selection of Sources
The scientific databases selected for the review were Scopus, PubMed, Web of Science, and IEEE Xplore. The combination of these databases provides comprehensive coverage of publications in the context of medical informatics, high relevance, and a complete advanced search. Search strings and search methods were consistent across all databases.

Search Terms
A preliminary literature review resulted in the first search equation, which aimed to find the different applications of mHealth in personalized medicine. This allowed us to identify relevant keywords and search terms to refine the search equation in each iteration by focusing on relevant topics such as adherence and data reporting but without limiting it to the field of personalized medicine. Finally, behavior change was found to be a popular aspect of improving adherence and hence the effectiveness of studies. We only included the term “behaviour change” because it is not limited to techniques, as there are different theories and models that contain them. As a result, four search iterations were performed. Those iterations are shown in Table 2.
Table 2. Search equations, data source, and total records per query.

| Search equation and source | Total records, n |
|---------------------------|-----------------|
| 1 (“mHealth” AND “personalised medicine”) |
| Scopus                    | 124             |
| PubMed                    | 19              |
| Web of Science            | 4               |
| IEEE Xplore               | 15              |
| 2 (“mobile health” OR “mHealth”) AND “adherence” AND “personalised medicine”) |
| Scopus                    | 23              |
| PubMed                    | 2               |
| Web of Science            | 0               |
| IEEE Xplore               | 5               |
| 3 (“mHealth” AND (“data” OR “information”) AND “registration” AND “adherence”) |
| Scopus                    | 52              |
| PubMed                    | 152             |
| Web of Science            | 35              |
| IEEE Xplore               | 1               |
| 4 (“mobile health” OR “mHealth”) AND “adherence” AND “behaviour change”) |
| Scopus                    | 156             |
| PubMed                    | 120             |
| Web of Science            | 23              |
| IEEE Xplore               | 9               |

Inclusion/Exclusion Criteria

After the initial gathering and screening of studies, articles were selected based on predefined eligibility criteria.

**Inclusion Criteria**

The included studies meet the criteria of being an mHealth intervention. In addition, they fulfill at least one of the following conditions:

- The study implements at least one BCT.
- The study compares several BCTs.
- The study evaluates the BCTs using at least one adherence metric.

**Exclusion Criteria**

The excluded studies meet at least one of the following conditions that aim to discard irrelevant studies for this systematic review:

- The study does not address the use of BCTs in the context of mHealth or vice versa.
- The study does not present at least one of its results in terms of adherence.
- The study was not published in between the years 2010-2021.
- The study does not belong to one of these categories: journal paper, conference paper, or review.
- The study was not peer reviewed.
- The study is not written in English or Spanish.

Data Extraction and Coding of BCTs

PRISMA [28] guidelines were used for data extraction. We gathered information about the study background (year, authors, etc), eligibility criteria (population), the number of participants, intervention description, technology, and results.

The behavioral strategy used in each study was identified and coded using the taxonomy of 18 categories introduced in the Background section to answer RQ1. To perform correct identification and coding, free taxonomy training was received using materials available online [29]. Results using any adherence assessment metric were extracted to solve RQ2. Finally, to answer RQ3, a more in-depth analysis was performed in the Discussion section about what was found to answer the previous RQs.

Results

This section presents the results obtained from the methodology described in the Methods. First, an overview of the selected studies and their main characteristics is presented, and then an analysis of these studies is performed.

Search Results and Study Selection

The search results and study selection are summarized in the PRISMA flowchart in Figure 2. A total of 368 studies were obtained from the search engines. Subsequently, 88 duplicate studies obtained from the combination of the databases’ results were excluded using the Mendeley tool. In the screening step,
we had 269 studies, of which 171 were excluded for not meeting the inclusion criteria after abstract review. In the eligibility step, we had 98 studies, of which 74 were excluded for not meeting the inclusion criteria after full-text review. Finally, 13 studies were included; however, the snowball strategy was applied to the systematic reviews listed in Table 1, resulting in 11 additional studies. These studies were not found in our initial search because they did not use the term adherence in their title, abstract, or keywords.

Figure 2. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart.

Outcome and Characteristics
We summarized the selected 24 studies [30-53] to understand which technologies and BCTs were most frequently used in mHealth research. Data extracted from each study following the methodology defined in the Data Extraction and Coding of BCTs section are presented in Table S1 in Multimedia Appendix 1 [30-53]. The first column refers to the study identifier, the next two columns specify the sample, and the remaining four columns correspond to the duration, description, technology, and evaluation of the intervention.

We observed in the reviewed papers that the most targeted behavior was medication adherence—present in 67% (n=16) of the studies—which is important in preventing rehospitalization, morbidity, mortality, and increased health care costs [54]. We also found that the most frequent population was patients diagnosed with chronic conditions, participating in 83% (n=20) of the studies, and the most popular form of technology in the studies was the use of apps, present in 71% (n=17) of the studies, with wearable support becoming popular. Still, 29% (n=7) of the studies examined the effects of SMS text message–based interventions, indicating that simpler health interventions delivered by text remain popular. With respect to the techniques, the most frequently used BCTs in the studies were feedback and monitoring (n=20, 83%), goals and planning (n=14, 58%), associations (n=14, 58%), and shaping knowledge (n=12, 50%). On the other hand, personalization (n=7, 29%) was approached in a simple way, considering their capabilities, including tailoring to demographic information, health status (eg, alcoholic or nonalcoholic), and time of notifications. On average, 4 BCTs are included in each mHealth intervention; a minimum of 1 and maximum of 8 techniques were used per study. This is shown in Table S2 in Multimedia Appendix 2 [30-53] where the BCTs used by each study are presented.

Regarding adherence evaluation metrics, it is worth mentioning that different methods are used for this measurement, from daily use of the mobile app to the Morisky Medication Adherence Scale. To analyze these studies homogeneously, a cutoff point for effectiveness in terms of adherence rate was considered. High adherence was defined by an adherence rate ≥80% and nonadherent as an adherence rate <80%. This cut point is conventional in the adherence literature [55,56] and is considered crucial for the effectiveness of long-term therapy [57]; however, it is interesting to note that many studies used
the arbitrary threshold of 80% [58], indicating that the optimal cut point for adherence ranged from 58% to 85%.

Moreover, after the BCTs used in each study were identified, we classified the studies into effective and ineffective using the cut point of 80% to gain further insight about why some interventions yielded significant improvements. As a result, Table 3 shows the number of times each BCT was used in both effective and ineffective studies.

This comparison revealed that, among the top five most used BCTs in the studies, feedback and monitoring (60%-40%) along with associations (57%-43%) have been used homogeneously in effective and ineffective studies, goals and planning (79%-21%) and personalization (71%-29%) have improved the effectiveness of the interventions since they have a higher presence in effective than in ineffective studies, and shaping knowledge (42%-58%) had a lower presence in effective than ineffective studies.

It was observed that 2 of the main BCTs (goals and planning, and associations) used on effective interventions were present in 100% of the adherence-oriented studies for mobile apps and in none of the ineffective studies [30,40,42,52]. Meanwhile, shaping knowledge was present in 100% of the ineffective studies for medication adherence and in none of the effective ones [31,33,35,37,44,47]. This is a good starting point for the design of a general BCT strategy.

Table 3. Behavior change techniques used in effective and ineffective studies (N=24).

| Behavior change technique       | Effective studies (≥80% adherence rate), n (%) | Ineffective studies (<80% adherence rate), n (%) |
|--------------------------------|-----------------------------------------------|-----------------------------------------------|
| Feedback and monitoring        | 12 (50)                                       | 8 (33)                                        |
| Goals and planning             | 11 (46)                                       | 3 (13)                                        |
| Associations                   | 8 (33)                                        | 6 (25)                                        |
| Shaping knowledge              | 5 (21)                                        | 7 (29)                                        |
| Personalization                | 5 (21)                                        | 2 (8)                                         |
| Regulation                     | 4 (17)                                        | 3 (13)                                        |
| Reward and threat              | 4 (17)                                        | 1 (4)                                         |
| Social support                 | 4 (17)                                        | 1 (4)                                         |
| Comparison of behavior         | 2 (8)                                         | 3 (13)                                        |
| Natural consequences           | 3 (13)                                        | 0 (0)                                         |
| Repetition and substitution     | 2 (8)                                         | 0 (0)                                         |
| Antecedents                    | 1 (4)                                         | 1 (4)                                         |
| Comparison of outcomes         | 0 (0)                                         | 1 (4)                                         |

Discussion

Principal Findings

We answered three RQs (defined in the Methods section) related to BCTs used in mHealth interventions. To answer RQ1, the taxonomy of BCTs, proposed by Michie et al [24] and which has been updated over the years [27], was identified. Based on this, the BCTs used in the selected studies were extracted and coded to the 18 categories to improve the understanding and meaning of the comparisons. We found that the most frequently used BCTs in mHealth interventions were feedback and monitoring, goals and planning, associations, shaping knowledge, and personalization. Similar BCTs were also found to be common in reviews of mHealth interventions targeting physical activity and sedentary behaviors, lifestyle, and medication adherence for CCM [59,60].

For RQ2, the categories of BCTs with the highest presence in effective studies were goals and planning, associations, feedback and monitoring, and personalization (as described in the Results section). However, in line with other reviews that found mixed effectiveness in mHealth outcomes [15,27], they suggested that the need remains to improve the use of these and many common BCTs for better outcomes. Possible reasons for the mixed effects of BCTs include the need for details on the specific BCTs that are used in the studies since current mHealth interventions often lump together a multitude of BCTs, making it difficult to discern the characteristics that lead to a study being effective or not and for more specific mHealth intervention content for different population subgroups (eg, those with specific mental health disorders such as anxiety) who may react differently compared to those with healthy mental health in an intervention setting, such as patients with coronary heart disease. This was reflected in the finding that some BCTs did not have the same effects for all groups, with those with higher levels of depression or anxiety deriving less benefit from some BCTs.

Regarding RQ3, considering the responses for RQ1 and RQ2, it was observed that, although some studies in the mHealth context have evaluated user adherence as a complementary outcome resulting from their implementation of BCTs, none of the reviewed studies applied BCTs for adherence to data reporting or use of the mHealth app; the studies generally aimed to improve outcomes for activity in chronically ill or healthy people. However, designing an approach that combines the BCTs most effective for adherence (feedback and monitoring, goals and planning, associations, and personalization),
previously identified in RQ2, could be helpful to improve data reporting in mHealth apps.

**Limitations**

Several limitations were found that are important to highlight. This review focused on mHealth interventions that include BCTs and how they affect user adherence. As a result, we found a lack of heterogeneity in the sample of results, evidencing that most of these interventions do not focus on improving user adherence to data reporting or to the app but rather on achieving an improvement in the objective of the study, whether it is an improvement in lifestyle behaviors or CCM.

In addition, designing mHealth apps is relatively new, and there is little agreement regarding best practices. Researchers are still trying to understand how and why BCTs lead to positive health outcomes when delivered through apps. There is growing evidence to support the effectiveness of mHealth interventions on health outcomes. Even though the evidence is growing, it is still relatively weak. This may be in part due to the difficulty of designing and conducting rigorous studies on mHealth interventions, even more in the context of the COVID-19 pandemic.

Additionally, the BCT taxonomy approach used to summarize the characteristics of interventions still has some limitations, despite the inclusion of the extension proposed by Dugas et al [27]. This taxonomy allows for the coding of different BCTs but does not assess the intensity or dosage of interventions. Nevertheless, the taxonomy works perfectly well as an excellent starting point and a standard to systematically describe an mHealth intervention.

Finally, we found that most studies are small single-arm studies with short follow-up periods. Future research should focus on studies with longer follow-up periods to determine the effectiveness of mHealth interventions on behavior change.

**Conclusions**

mHealth interventions to improve lifestyle behaviors and CCM have become popular in recent years, improving along with different technologies. Although SMS text message–based mHealth interventions remained popular for their proven high results in terms of effectiveness, this review suggests that mHealth is progressively moving toward the implementation of mobile apps and wearable interventions, replacing SMS text messaging with notifications. This review also revealed that mHealth is being applied to address a diversity of lifestyle behaviors and health outcomes, showing its applicability to a variety of health care contexts, with one of its focuses being medication adherence. On the other hand, we found that the most frequently used BCTs in mHealth interventions were feedback and monitoring, goals and planning, associations, shaping knowledge, and personalization. However, this does not necessarily imply that they are the most effective, so we conducted further analysis that found that frequently used BCTs in ineffective studies are often well supported in the health behavior change literature [61,62], suggesting a need to better understand best practices for applying such techniques and to obtain details on the specific BCTs used in mHealth interventions.

Congruent with other reviews that found heterogeneous effectiveness of mHealth, the results also suggested that there remains a need to optimize the use of BCTs or find a better combination for better outcomes, it is intended that this review could help identify the most appropriate techniques to improve adherence to data reporting and thus design an optimal strategy while taking into account the differences among population subgroups, pointing to the need to go beyond the idea that “one-size-fits-all.” As a small step forward, more sophisticated technologies such as wearable activity trackers and wireless sensors have been included in mHealth interventions.

**Acknowledgments**

This research was developed within the BG19 (2019-2020/Grant number KK-2019/00032) and the BG21 (2021-2022/Grant number KK-2021/00005) research projects funded by the Department of Economic Development and Infrastructure of the Basque Government under the Elkartek program.

**Conflicts of Interest**

None declared.

**Multimedia Appendix 1**

Mobile health studies describing the sample criteria (population), the sample size (N), the study duration (duration), the technology used (tech), and results.

[DOC File, 38 KB - Multimedia Appendix 1]

**Multimedia Appendix 2**

Behavior change techniques in mobile health studies.

[DOC File, 34 KB - Multimedia Appendix 2]

**References**
1. Saxena M, Saxena A. Evolution of mHealth eco-system: a step towards personalized medicine. In: Khanna A, Gupta D, Bhattacharyya S, Snasel V, Platos J, Hassanien AE, editors. International Conference on Innovative Computing and Communications Proceedings of ICICC 2019, Volume 1. Singapore: Springer; 2020:351-379.

2. Lapão LV. The future of healthcare: the impact of digitalization on healthcare services performance. In: Neto AP, Flynn MB, editors. The Internet and Health in Brazil: Challenges and Trends. Cham: Springer; 2019:435-449.

3. Paglia Longa A, Mastropietro A, Scalco E, Rizzo G. The mHealth. In: Andreoni G, Perego P, Frumento E, editors. m_Health Current and Future Applications. Cham: Springer; 2019:5-17.

4. Weiler A. mHealth and big data will bring meaning and value to patient-reported outcomes. Mhealth 2016;2:2. [doi: 10.3978/j.issn.2306-9740.2016.01.02] [Medline: 28293580]

5. Kubben P. Mobile apps. In: Kubben P, Dumontier M, Dekker A, editors. Fundamentals of Clinical Data Science. Cham: Springer; 2019:171-179.

6. Hsieh W, Su Y, Han H, Huang M. A novel mHealth approach for a patient-centered medication and health management system in Taiwan: pilot study. JMIR Mhealth Uhealth 2018 Jul 03;6(7):e154 [FREE Full text] [doi: 10.2196/mhealth.9987] [Medline: 29970356]

7. Donkin L, Hickie IB, Christensen H, Naismith SL, Neal B, Cockayne NL, et al. Rethinking the dose-response relationship between usage and outcome in an online intervention for depression: randomized controlled trial. J Med Internet Res 2013 Oct 17;15(10):e231 [FREE Full text] [doi: 10.2196/mir.2771] [Medline: 24135213]

8. Sabate E. Adherence to long-term therapies: evidence for action. World Health Organization. 2003 May 28. URL: https://apps.who.int/iris/handle/10665/42682?locale-attr=es& [accessed 2022-09-01]

9. McDonald HP, Garg AX, Haynes RB. Interventions to enhance patient adherence to medication prescriptions: scientific review. JAMA 2002 Dec 11:1188(22):2868-2879. [doi: 10.1001/jama.288.22.2868] [Medline: 12472329]

10. Marco-rólo MS, Oliveira IAQ, D’Agostino M, Ribeiro AL, Alkmin MBM, Novillo-Ortiz D. The impact of mHealth interventions: systematic review of systematic reviews. JMIR Mhealth Uhealth 2018 Jan 17;6(1):e23 [FREE Full text] [doi: 10.2196/mhealth.8873] [Medline: 29343463]

11. Schorr EN, Gepner AD, Dolansky MA, Forman DE, Park LG, Petersen KS, Thrombosis and Vascular Biology; and Council on Lifestyle and Cardiometabolic Health. Harnessing mobile health technology for secondary cardiovascular disease prevention in older adults: a scientific statement from the American Heart Association. Circ Cardiovasc Qual Outcomes 2021 May;14(5):e001003 [FREE Full text] [doi: 10.1161/HCQ.0000000000000103] [Medline: 33793309]

12. Akinosun AS, Polson R, Diaz-Skeete Y, De Kock JH, Carragher L, Leslie S, et al. Digital technology interventions for risk factor modification in patients with cardiovascular disease: systematic review and meta-analysis. JMIR Mhealth Uhealth 2021 Mar 03;9(3):e21061 [FREE Full text] [doi: 10.2196/21061] [Medline: 33656444]

13. Godinho MA, Jonnagaddala J, Gudi N, Islam R, Narasimhan P, Liaw S. mHealth for integrated people-centred health services in the Western Pacific: a systematic review. Int J Med Inform 2020 Oct;142:104259. [doi: 10.1016/j.ijmedinf.2020.104259] [Medline: 32858339]

14. Monteiro-Guerra FM, Rivera-Romero O, Fernandez-Luque L, Caulfield B. Personalization in real-time physical activity coaching using mobile applications: a scoping review. IEEE J Biomed Health Inform 2020 Jun;24(6):1738-1751. [doi: 10.1109/jbhi.2019.2947243] [Medline: 33085767]

15. Wang Y, Min J, Khiur J, Xue H, Xie B, A Kaminsky L, et al. Effectiveness of mobile health interventions on diabetes and obesity treatment and management: systematic review of systematic reviews. JMI R Mhealth Uhealth 2020 Apr 28;8(4):e15400 [FREE Full text] [doi: 10.2196/15400] [Medline: 32343253]

16. Thomas Craig KJ, Morgan LC, Chen C, Michie S, Fusco N, Snowden JL, et al. Systematic review of context-aware digital behavior change interventions to improve health. Transl Behav Med 2021 May 25;11(5):1037-1048 [FREE Full text] [doi: 10.1093/tbm/ibaa099] [Medline: 33085767]

17. Beanne LM, Sekhon M, Grainger R, La A, Shamali M, Amirova A, et al. Smartphone apps targeting physical activity in people with rheumatoid arthritis: a qualitative appraisal and content analysis. JMIR Mhealth Uhealth 2020 Jul 21;8(7):e18495 [FREE Full text] [doi: 10.2196/18495] [Medline: 32206727]

18. Kalki K, Ginosarr T, Bentley JM, Carver H, Shah SFA, Kinney AY. Use of evidence-based best practices and behavior change techniques in breast cancer apps: systematic analysis. JMIR Mhealth Uhealth 2020 Jan 24;8(1):e14082 [FREE Full text] [doi: 10.2196/14082] [Medline: 32102084]

19. Tighe SA, Ball K, Kensing F, Kayser L, Rawstorn JC, Maddison R. Toward a digital platform for the self-management of noncommunicable disease: systematic review of platform-like interventions. J Med Internet Res 2020 Oct 28;22(10):e16774 [FREE Full text] [doi: 10.2196/16774] [Medline: 33112239]

20. Armitage LC, Kassavou A, Sutton S. Do mobile device apps designed to support medication adherence demonstrate efficacy? A systematic review of randomised controlled trials, with meta-analysis. BMJ Open 2020 Jan 30;10(1):e032045 [FREE Full text] [doi: 10.1136/bmjopen-2019-032045] [Medline: 32005778]

21. Pfaffeli Dale L, Dobson R, Whittaker R, Maddison R. The effectiveness of mobile-health behaviour change interventions for cardiovascular disease self-management: A systematic review. Eur J Prev Cardiol 2016 May;23(8):801-817. [doi: 10.1177/2047487316513462] [Medline: 26490093]
22. Perego P. Device for mHealth. In: Andreoni G, Perego P, Frumento E, editors. m_Health Current and Future Applications. Cham: Springer; 2019:87-99.
23. van den Berg A, Mummery CL, Passier R, van der Meer AD. Personalised organs-on-chips: functional testing for precision medicine. Lab Chip 2019 Jan 15;19(2):198-205 [FREE Full text] [doi: 10.1039/c8lc00872b] [Medline: 30506070]
24. Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Ann Behav Med 2013 Aug;46(1):81-95. [doi: 10.1007/s12160-013-9486-6] [Medline: 23512568]
25. Abraham C, Michie S. A taxonomy of behavior change techniques used in interventions. Health Psychol 2008 May;27(3):379-387. [doi: 10.1037/0278-6133.27.3.379] [Medline: 18624603]
26. BCT Taxonomy (v1): 93 hierarchically-clustered techniques. Digitalwellbeing.org. URL: https://digitalwellbeing.org/wp-content/uploads/2016/11/BCTTv1_PDF_version.pdf [accessed 2021-08-05]
27. Dugas M, Gao GG, Agarwal R. Unpacking mHealth interventions: a systematic review of behavior change techniques used in randomized controlled trials assessing mHealth effectiveness. Digit Health 2020;6:2055207620905411 [FREE Full text] [doi: 10.1177/2055207620905411] [Medline: 32128233]
28. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JPA, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. PLoS Med 2009 Jul 21;6(7):e1000100 [FREE Full text] [doi: 10.1371/journal.pmed.1000100] [Medline: 19621070]
29. BCT Taxonomy. URL: http://www.bct-taxonomy.com/ [accessed 2021-08-05]
30. Klasnja P, Rosenberg DE, Zhou J, Anau A, Gupta A, Arterburn DE. A quality-improvement optimization pilot of BariFit, a mobile health intervention to promote physical activity after bariatric surgery. Transl Behav Med 2021 Mar 16;11(2):530-539. [doi: 10.1093/tnb/iba040] [Medline: 32421187]
31. Jahan Y, Rahman MM, Faruque ASG, Chisti MJ, Kazawa K, Matsuyama R, et al. Awareness development and usage of mobile health technology among individuals with hypertension in a rural community of Bangladesh: randomized controlled trial. J Med Internet Res 2020 Dec 07;22(12):e19137 [FREE Full text] [doi: 10.2196/19137] [Medline: 33284129]
32. Eaton C, Comer M, Pruette C, Psoter K, Riekert K. Text messaging adherence intervention for adolescents and young adults with chronic kidney disease: pilot randomized controlled trial and stakeholder interviews. J Med Internet Res 2020 Aug 14;22(8):e19861 [FREE Full text] [doi: 10.2196/19861] [Medline: 32795983]
33. Mata J, Pecorelli N, Kaneva P, Moldoveanu D, Gosselin-Tardiff A, Alhashemi M, et al. A mobile device application (app) to improve adherence to an enhanced recovery program for colorectal surgery: a randomized controlled trial. Surg Endosc 2020 Feb;34(2):742-751. [doi: 10.1007/s00464-019-06823-w] [Medline: 31087175]
34. Janevic MR, Shute V, Murphy SL, Piette JD. Acceptability and effects of commercially available activity trackers for chronic pain management among older African American adults. Pain Med 2020 Feb 01;21(2):e68-e78 [FREE Full text] [doi: 10.1093/pm/pnz215] [Medline: 31509196]
35. Fico G, Martinez-Millana A, Leutertz J, Fioravanti A, Beltrán-Jaunsar ME, Traver V, et al. User centered design to improve information exchange in diabetes care through eHealth : results from a small scale exploratory study. J Med Syst 2019 Nov;44(1):2. [doi: 10.1007/s10916-019-1472-5] [Medline: 32174069]
36. Chandler J, Suck L, Kellam K, Feder L, Nemeth L, Treiber F. Impact of a culturally tailored mHealth medication regimen self-management program upon blood pressure among hypertensive Hispanic adults. Int J Environ Res Public Health 2019 Apr 06;16(12):1226 [FREE Full text] [doi: 10.3390/ijerph16071226] [Medline: 30959858]
37. Coorey G, Peiris D, Usherwood T, Neubeck L, Mulley J, Redfern J. Persuasive design features within a consumer-focused eHealth intervention integrated with the electronic health record: a mixed methods study of effectiveness and acceptability. PLoS One 2019;14(6):e0218447 [FREE Full text] [doi: 10.1371/journal.pone.0218447] [Medline: 31220127]
38. Hovland-Tänneryd A, Melin M, Hägglund E, Hagerman I, Persson HE. From randomised controlled trial to real world implementation of a novel home-based heart failure tool: pooled and comparative analyses of two clinical controlled trials. Open Heart 2019;6(1):e000954 [FREE Full text] [doi: 10.1136/openhrt-2018-000954] [Medline: 32179992]
39. Morawski K, Ghazinouri R, Krumme A, Lauflenger JC, Lu Z, Durfee E, et al. Association of a smartphone application with medication adherence and blood pressure control: the MedISAFE-BP Randomized Clinical Trial. JAMA Intern Med 2018 Jun 01;178(6):802-809 [doi: 10.1001/jamainternmed.2018.0447] [Medline: 29710289]
40. Svendsen MT, Andersen F, Andersen KH, Pottegård A, Johannessen H, Möller S, et al. A smartphone application supporting patients with psoriasis improves treatment adherence to topical treatment: a randomized controlled trial. Br J Dermatol 2018 Nov;179(5):1062-1071. [doi: 10.1111/bjd.16667] [Medline: 29654699]
41. Labovitz DL, Shafner L, Reyes Gil M, Virmani D, Hanina A. Using artificial intelligence to reduce the risk of nonadherence in patients on anticoagulation therapy. Stroke 2017 May;48(5):1416-1419 [FREE Full text] [doi: 10.1161/STROKEAHA.116.016281] [Medline: 28386037]
42. Lakshminarayana R, Wang D, Burn D, Chaudhuri KR, Galtrey C, Guzman NV, et al. Using a smartphone-based self-management platform to support medication adherence and clinical consultation in Parkinson's disease. NPJ Parkinsons Dis 2017;3:2. [doi: 10.1038/s41531-016-0003-z] [Medline: 28649602]
43. Mertens A, Brandl C, Miron-Shatz T, Schlick C, Neumann T, Kribben A, et al. A mobile application improves therapy-adherence rates in elderly patients undergoing rehabilitation: a crossover design study comparing documentation
via iPad with paper-based control. Medicine (Baltimore) 2016 Sep;95(36):e4446. [doi: 10.1097/MD.0000000000004446] [Medline: 27603339]

44. Recio-Rodriguez JJ, Agudo-Conde C, Martin-Cantera C, González-Viejo MN, Fernandez-Alonso MDC, Arietaleinzbeaskoa MS, EVIDENT Investigators. Short-term effectiveness of a mobile phone app for increasing physical activity and adherence to the Mediterranean diet in primary care: a randomized controlled trial (EVIDENT II Study). J Med Internet Res 2016 Dec 19;18(12):e331 [FREE Full text] [doi: 10.2196/jmir.6814] [Medline: 27993759]

45. Pfaffelli Dale L, Whittaker R, Jiang Y, Stewart R, Rolleston A, Maddison R. Text message and internet support for coronary heart disease self-management: results from the Text4Heart randomized controlled trial. J Med Internet Res 2015 Oct 21;17(10):e237 [FREE Full text] [doi: 10.2196/jmir.4944] [Medline: 26490012]

46. Ammenwerth E, Woess S, Baumgartner C, Fetz B, van der Heidt A, Kastner P, et al. Evaluation of an integrated telemonitoring surveillance system in patients with coronary heart disease. Methods Inf Med 2015;54(5):388-397. [doi: 10.3414/ME15-02-0002] [Medline: 26395147]

47. Safran Naimark J, Madar Z, Shahar DR. The impact of a web-based app (eBalance) in promoting healthy lifestyles: randomized controlled trial. J Med Internet Res 2015 Mar 02;17(3):e56 [FREE Full text] [doi: 10.2196/jmir.3682] [Medline: 25732936]

48. Hammonds T, Rickert K, Goldstein C, Gathright E, Gilmore S, Derflinger B, et al. Adherence to antidepressant medications: a randomized controlled trial of medication reminding in college students. J Am Coll Health 2015;63(3):204-208. [doi: 10.1080/07448481.2014.975716] [Medline: 25338175]

49. Goldstein CM, Gathright EC, Dolansky MA, Gunstad J, Sterns A, Redle JD, et al. Randomized controlled feasibility trial of two telemedicine medication reminder systems for older adults with heart failure. J Telemed Telecare 2014 Sep;20(6):293-299 [FREE Full text] [doi: 10.1177/1357633X14541039] [Medline: 24958355]

50. Santo K, Singleton A, Rogers K, Thiagalingam A, Chalmers J, Chow CK, et al. Medication reminder applications to improve adherence in coronary heart disease: a randomized clinical trial. Heart 2019 Feb;105(4):323-329. [doi: 10.1136/heartjnl-2018-313479] [Medline: 30150326]

51. Varnfield M, Karunanithi M, Lee C, Honeyman E, Arnold D, Ding H, et al. Smartphone-based home care model improved use of cardiac rehabilitation in postmyocardial infarction patients: results from a randomised controlled trial. Heart 2014 Nov;100(22):1770-1779 [FREE Full text] [doi: 10.1136/heartjnl-2014-305783] [Medline: 24973083]

52. Hartman SJ, Nelson SH, Weiner LS. Patterns of Fitbit use and activity levels throughout a physical activity intervention: exploratory analysis from a randomized controlled trial. JMIR Mhealth Uhealth 2018 Feb 05;6(2):e29 [FREE Full text] [doi: 10.2196/mhealth.8503] [Medline: 29402761]

53. Párraga-Martínez I, Rabanales-Sotos J, Lago-Deibe F, Téllez-Lapeira JM, Escobar-Rabádan F, Villena-Ferrer A, et al. Effectiveness of a combined strategy to improve therapeutic compliance and degree of control among patients with hypercholesterolaemia: a randomised clinical trial. BMC Cardiovasc Disord 2015 Jan 19;15:8 [FREE Full text] [doi: 10.1186/1471-2261-15-8] [Medline: 25599690]

54. Gandapur Y, Kianoush S, Kelli HM, Misra S, Bhalu MJ, et al. The role of mHealth for improving medication adherence in patients with cardiovascular disease: a systematic review. Eur Heart J Qual Care Clin Outcomes 2016 Oct;2(4):237-244 [FREE Full text] [doi: 10.1093/ehjqcco/qcw018] [Medline: 29474713]

55. Wei L, Wang J, Thompson P, Wong S, Struthers AD, MacDonald TM. Adherence to statin treatment and readmission of patients after myocardial infarction: a six year follow up study. Heart 2002 Sep;88(3):229-233 [FREE Full text] [doi: 10.1136/heartjnl-2018-313479] [Medline: 21281120]

56. Chapman RH, Benner JS, Petrilla AA, Tierce JC, Collins SR, Battlemen DS, et al. Predictors of adherence with antihypertensive and lipid-lowering therapy. Arch Intern Med 2005 May 23;165(10):1147-1152. [doi: 10.1001/archinte.165.10.1147] [Medline: 15911728]

57. Bansilal S, Castellano JM, Garrido E, Wei HG, Freeman A, Spettel C, et al. Assessing the impact of medication adherence on long-term cardiovascular outcomes. J Am Coll Cardiol 2016 Aug 23;68(8):789-801 [FREE Full text] [doi: 10.1016/j.jacc.2016.06.005] [Medline: 27539170]

58. Karve S, Cleves MA, Helm M, Hudson TJ, West DS, Martin BC. Good and poor adherence: optimal cut-point for optional measures using administrative claims data. Curr Med Res Opin 2009 Sep;25(9):2303-2310. [doi: 10.1185/03007990903126833] [Medline: 19635045]

59. Direito A, Carraça E, Rawstorn J, Whittaker R, Maddison R. mHealth technologies to influence physical activity and sedentary behaviors: behavior change techniques, systematic review and meta-analysis of randomized controlled trials. Ann Behav Med 2017 Apr;51(2):226-239. [doi: 10.1007/s12160-016-9846-0] [Medline: 27757789]

60. Morrissey EC, Corbett TK, Walsh JC, Molloy GJ. Behavior change techniques in apps for medication adherence: a content analysis. Am J Prev Med 2016 May;50(5):e143-e146. [doi: 10.1016/j.amepre.2015.09.034] [Medline: 26597504]

61. Burke LE, Wang J, Sevick MA. Self-monitoring in weight loss: a systematic review of the literature. J Am Diet Assoc 2011 Jan;111(1):92-102 [FREE Full text] [doi: 10.1016/j.jada.2010.10.008] [Medline: 21185970]

62. Michie S, Abraham C, Whittington C, McAteer J, Gupta S. Effective techniques in healthy eating and physical activity interventions: a meta-regression. Health Psychol 2009 Nov;28(6):690-701. [doi: 10.1037/a0016136] [Medline: 19916637]
Abbreviations

BCT: behavior change technique
CCM: chronic condition management
mHealth: mobile health
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RQ: research question
WHO: World Health Organization