User Engagement with mHealth Interventions to Promote Treatment Adherence and Self-Management in People with Chronic Health Conditions: A Systematic Review

Cyd Eaton, Natalie Vallejo, Xiomara McDonald, Jasmine Wu, Rosa Rodríguez, Nishanth Muthusamy, Nestoras Mathioudakis, Kristin Riekert

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Abstract

Background: There are numerous mobile health (mHealth) interventions aimed at promoting treatment adherence and self-management in people with health conditions, yet very little is known about the nature of user engagement, or interaction, with these technologies. Further, although research findings suggest positive correlations between user engagement and adherence/self-management, mHealth tools are frequently abandoned. To optimize engagement with these mHealth interventions, it is imperative to comprehensively and systematically evaluate how mHealth user engagement is defined and measured in the recent scientific literature.

Objective: (1) To characterize user engagement with mHealth treatment adherence and self-management promotion interventions for adults and youths with health conditions using a registered systematic literature review and (2) to generate user engagement-focused research recommendations.

Methods: Scientific database (e.g., PubMed) search results (2016-2021) were screened for final inclusion. Data were extracted in a standardized form on Covidence (blinded double coding). The initial search returned 3,885 unique references, of which 3,593 were excluded, and 292 were included for full data extraction.

Results: Most mHealth interventions were evaluated in non-randomized studies (n=159, 54%), involved people with diabetes (n=51, 18%), targeted medication adherence (n=98, 34%), and were comprised of apps (n=220, 75%). Over 60 unique terms were used to define user engagement; “use” (n=102, 35%) and “engagement” (n=94, 32%) were most common. 11 distinct user engagement measurement approaches were identified; the most common were objective user login data from an app or web portal (e.g., number of logins; n=160, 55%), manual user data entry in app/website-based self-monitoring diaries (n=77, 26%), and responding to text notifications (n=49, 17%). User engagement generally decreased across time (n=76/99, 77%). Engagement levels varied based on measurement method with user login data and module completion more commonly characterized as low; response to text notifications, interacting via chats, phone calls, or social media posts, wearing an electronic monitoring device, and using a non-wearable electronic monitoring device tended to be characterized as high. Participants were given recommendations for how much to engage with the mHealth intervention (technology dosages) in only 41% (n=119) of studies. Researchers set minimum levels of engagement to be considered adequately engaged with the mHealth intervention (minimum user engagement research benchmarks) in only 28% (n=81) of studies. Though only assessed in one-third of studies, higher engagement was associated with higher adherence/self-management (n=62/103, 60%). User engagement was a research end point in only 19% (n=56) of studies.

Conclusions: This systematic review revealed critical gaps in how user engagement is evaluated in the mHealth adherence/self-management intervention literature. Specific recommendations are outlined in response to our findings with the goal of improving research rigor in this area to ultimately promote the sustainability and scalability of these much-needed interventions.
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Abstract

Background: There are numerous mobile health (mHealth) interventions for treatment adherence and self-management, yet little is known about user engagement, or interaction, with these technologies.

Objective: This systematic review aimed to answer these questions: 1) How is user engagement defined and measured in studies of mHealth interventions to promote adherence to prescribed medical/health regimens or self-management among people living with a health condition?, 2) To what degree are patients engaging with these mHealth interventions?, 3) What is the association between user engagement with mHealth interventions and adherence or self-management outcomes?, and 4) How often is user engagement a research end-point?

Methods: Scientific database (Ovid MEDLINE, Embase, Web of Science, PsycINFO, CINAHL) search results (2016-2021) were screened for inclusion (peer-reviewed English-language manuscript; participants followed a medical/health regimen for a chronic physical or mental health condition; mHealth intervention was accessible on a mobile device, at least partially automated, and used by participants and/or caregivers at home; primary intervention target was treatment adherence or self-management; user engagement with the intervention was a measured study outcome) and exclusion (meta-analysis, systematic review, published abstract, dissertation, published protocol, usability testing or intervention development only) criteria. Data were extracted in a standardized electronic form. No risk of bias assessment was conducted as this review aimed to characterize user engagement measurement rather than certainty in primary study results. Results were synthesized descriptively and thematically.

Results: 292 studies were included for data extraction. The median number of participants per study was 77 (IQR=34-164). Most mHealth interventions were evaluated in non-randomized studies (n=157/292, 54%), involved people with diabetes (n=51/292, 18%), targeted medication adherence (n=98/292, 34%), and were comprised of apps (n=220/292, 75%). The principal findings were: (1) Over 60 unique terms were used to define user engagement; “use” (n=102/292, 35%) and “engagement” (n=94/292, 32%) were most common; (2) 11 distinct user engagement measurement approaches were identified; objective user login data from an app or web portal (n=160/292, 55%) was the most common; (3) though inconsistently evaluated, most studies reported >1 level of engagement due to using multiple measurement methods or analyses (99/195, 51%), decreased engagement across time (n=76/99, 77%), and results and conclusions suggesting that higher engagement was associated with positive adherence/self-management (n=60/103, 58%); and (4) user engagement was a research end point in only 19% (n=56/292) of studies.

Conclusions: Results revealed major limitations in the literature reviewed including significant variability in how user engagement is defined, a tendency to rely on user login data over other measurements, and critical gaps in how user engagement is evaluated (infrequently evaluated over time or in relation to adherence/self-management outcome, rarely a research endpoint). Recommendations are outlined in response to our findings with the goal of improving research rigor in this area.

Review registration: PROSPERO CRD42022289693

Keywords: mHealth, digital health, treatment adherence, self-management, user engagement, chronic health conditions

User Engagement with mHealth Interventions to Promote Treatment Adherence and Self-Management in People with Chronic Health Conditions: A Systematic Review

As smartphones have become integral parts of modern daily life [1,2], mobile health (mHealth) interventions for treatment adherence and self-management promotion have rapidly developed. These interventions often use existing smartphone features, such as sending text notifications as cues to take prescribed medications [3]; others may integrate external technologies, such as a Bluetooth-enabled glucometer linked to a smartphone app to track blood glucose levels over time with the goal of supporting diabetes management [4]. In general, more frequent engagement, or interaction, with mHealth tools is expected to result in improved treatment adherence or self-management [5]. However, mHealth tools are frequently abandoned by users. Among mobile phone users in the United States, over half reportedly downloaded an mHealth app but nearly half also stopped using the app due to high data entry burden, low interest, and costs [6].

There is a disconnect between research findings supporting positive correlations between engagement and adherence or self-management and user tendencies to stop using mHealth tools. This discrepancy may reflect an argument put forth by Arigo and colleagues' that the mHealth field "lacks a science of engagement" [7]. Specifically, there is (1) a lack of consensus in how mHealth user engagement is measured, defined, and reported, (2) no consensus on the optimal level of mHealth user engagement to facilitate meaningful behavior change, and (3) infrequent consideration of user engagement as a research endpoint. Not treating user engagement as a research endpoint suggests this domain is poorly defined and haphazardly evaluated, particularly in terms of how user engagement might evolve over the course of intervention or relate to behavioral and health outcomes. While the tendency for mHealth use to decline over time suggests that users will not experience maximum benefit from accessing these tools, poor measurement of user

engagement has presented a challenge to researchers' abilities to characterize exactly how and why engagement may decrease and how these decreases may affect intervention outcomes. These critical gaps in the science of user engagement significantly limit the utility, effectiveness, uptake, and scalability of mHealth interventions for adherence and self-management promotion.

Recent systematic reviews have examined aspects of user engagement with mHealth interventions for specific diagnoses, including hypertension [8], physical activity [9,10], depressive symptoms [11,12], and mental health conditions [13]. The applicability of these reviews to adherence and self-management mHealth interventions is significantly limited by the small number of studies included and lack of unified focus on adherence and self-management behaviors. These prior reviews have been further limited by using a very broad definition of "engagement" to include usability, feasibility, user satisfaction, and acceptability [13], limiting the review to studies in which only post-assessment retention data were obtained [11] (excludes interventions earlier in the design phase), and focusing on design features associated with user engagement rather than the evaluation of user engagement itself [10]. Another review identified a range of valid and reliable measurement approaches for evaluating user engagement with mHealth interventions for behavior change but used a snowballing method to identify sources rather than a rigorous systematic review of the literature [14]. To encourage continued use of and optimal engagement with mHealth interventions to facilitate adherence and self-management behavior change, it is imperative to comprehensively and systematically evaluate the recent scientific landscape of mHealth user engagement with a clear focus on adherence and self-management behavior.

In response to gaps identified in the current scientific literature [7], our registered systematic review aimed to (1) characterize user engagement with mHealth treatment

adherence/self-management promotion interventions for adults and youths with health conditions and (2) generate user engagement-focused research recommendations. “User engagement” with mHealth tools can be conceptualized as both behavioral (extent of use) and experiential (the subjective experience of interacting with the technology) [15]. To enhance the practical application of our review findings, we focus on the behavioral aspects of user engagement to evaluate the degree of use and interaction with the mHealth tool(s) [7] among users with chronic health conditions. Users’ behavioral interaction with mHealth tools, features, and associated behavior change components is known as “Little e” engagement. In theory, increased “Little e” engagement is expected to contribute to increased engagement in the desired health behavior, known as “Big E” [16]. Thus, better precision in how behavioral, or “Little e” engagement, is empirically evaluated could help to facilitate greater changes in “Big E” outcomes, thus improving the overall efficacy of mHealth interventions for adherence and self-management. A systematic review approach was selected due to expected heterogeneity in both measurement of user engagement and adherence and self-management outcomes, which precludes the use of a meta-analysis [17–19]. We specifically aimed to answer the following research questions: 1) How is "user engagement" defined and measured in studies of mHealth interventions to promote adherence to prescribed medical/health regimens or self-management among people living with a health condition?, 2) To what degree are patients engaging with these mHealth interventions?, 3) What is the association between user engagement with mHealth interventions and adherence or self-management outcomes?, and 4) How often is user engagement a research end-point? An exploratory question was, are there differences in user engagement measurement approach and level in studies providing monetary compensation compared to not providing monetary compensation?

Methods

This systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO CRD42022289693) and prepared in accordance with Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. The review team prepared and followed a standard Manual of Procedures designed for this systematic review. Institutional review board approval was not required.

Information Sources and Search Strategy

The search strategy (see Multimedia Appendix 1) was developed by the first and last authors (CKE, KAR) in collaboration with an Informationist at Johns Hopkins Libraries, implemented in Ovid MEDLINE, Embase, Web of Science, PsycINFO, and CINAHL, and restricted to manuscripts published from 2016 through 2021. All citations returned from the search were imported into our Covidence [20] database for screening and data extraction.

Eligibility Criteria

Inclusion criteria were: 1) peer-reviewed manuscripts reporting on original qualitative or quantitative investigations published in the English language between 2016-2021; 2) participants followed a medical/health regimen or engaged in adherence or self-management activities for a chronic physical or mental health condition, 3) mHealth intervention was used by these participants and/or their caregivers in a home setting, was at least partially automated (could not only include manual two-way text messaging or video web conferencing), and was accessible on a mobile device (smartphone or tablet, including internet browser-based programs), 4) primary intervention target was treatment adherence (e.g., taking medicine, exercise, diet) or self-management of the health condition, often measured by a health outcome associated with treatment adherence behavior (e.g., hemoglobin A1c test, viral load, body mass index), and 5) user engagement (use, interaction) with the mHealth intervention was a measured study outcome, either by objective (e.g., app-recorded login data) or subjective (e.g., user self-report, qualitative

interviews) metrics. We excluded meta-analyses, systematic reviews, published abstracts, dissertations, and published protocols, as well as studies reporting on usability testing or intervention development only.

Selection Process

Citations were uploaded into Covidence, duplicate citations were removed, and title and abstract screening was conducted followed by full text review. At each level of review, two separate review team members evaluated each article against inclusion and exclusion criteria (discrepancies resolved by CKE and NM). Any study meeting inclusion criteria after full text review progressed to the Data Extraction phase (detailed below).

Data Extraction

Data extraction was performed by two separate review team members independently of each other using a standard data extraction form developed by the study team (discrepancies resolved by CKE and NM). For each study, reviewers recorded quantitative and qualitative data relevant to study design (e.g., randomized controlled trial, case control) and methodology (e.g., monetary compensation for participation), demographic characteristics of participants, mHealth intervention targets and characteristics, measurement of user engagement including whether it was a research endpoint (a key outcome being measured and potentially impacted by going through the intervention), and terminology (words) used to describe the behavioral aspects of “user engagement” (researcher-evaluated user interactions with the mHealth technology).

Study results were summarized as follows:

- *Level of engagement with the intervention* was categorized as High, Medium, Low, >1 levels reported due to using multiple measurement and/or analytic approaches, or Not characterized. Categorizations were assigned based on the language used by the authors to characterize users’ level of engagement with the mHealth intervention

(e.g., the authors described user engagement with the mHealth intervention as “high”).

- *Change in level of engagement* was categorized as Increased, No change, Decreased, >1 directions reported due to using multiple measurement and/or analytic approaches, or Not assessed. For studies that assessed change in engagement over time, categorizations were assigned based on the data presented by the authors (e.g., the authors presented data showing that the user engagement measurement decreased over time).
- *Association with treatment adherence/self-management study outcome(s)* was categorized as Higher engagement, positive treatment adherence/self-management outcome(s), Moderate engagement, positive treatment adherence/self-management outcome(s), Lower engagement, positive treatment adherence/self-management outcome(s), No association, >1 associations reported due to using multiple measurement and/or analytic approaches, or Not assessed. For studies that assessed this association, categorizations were assigned based on how the authors reported and framed the study results and conclusions (e.g., the authors’ reporting and framing of study results and conclusions suggested that higher engagement with the mHealth intervention was associated with positive study outcomes, such as higher treatment adherence or improved self-management outcome(s)).
- *Technology dosage* was categorized as Yes, given (the researchers told participants how often and/or in what way(s) they should use the mHealth intervention components, such as complete one module per week, log medication administration in the app every day) or No, not given.
- *Minimum engagement research benchmark* was categorized as Yes, selected (the researchers reported in their manuscript that a minimum cutoff for technology

engagement was set as an empirical outcome to denote adequate participant engagement; for example, to be adequately engaged, a participant needed to use the Bluetooth-enabled glucometer at least once a day during the study period) or No, not selected.

The decision was made by the authors to not conduct a formal risk of bias assessment given that the primary aim of this review was to characterize the evaluation and measurement of user engagement rather than certainty in the primary study results. Therefore, it was deemed inappropriate to evaluate the studies using standard risk of bias assessment tools.

Synthesis Methods

Statistical analyses were conducted in IBM SPSS Statistics (Version 28) [21]. Data extractions were summarized using frequencies and percentages. Methods of measuring user engagement with the mHealth intervention were thematically grouped into discrete measurement categories. Subgroup sensitivity analyses were conducted to examine studies involving pediatric samples (Pediatric: ages 0-18 years old or up to 25 years of age if the sample was characterized as “pediatric” by the authors) from those involving adults only (Adult: >18 years old). In these age-based subgroup analyses, five studies were excluded due to including both pediatric and adult participants and one study was excluded due to not reporting participant ages. Given that this investigation was designed as a systematic review, no effect measures or meta-regressions were used. No missing summary statistics or data conversions were used.

Results

Search Results and Screening Process

Figure 1 presents the PRISMA diagram of the screening process. The initial search returned 3,955 citations and 70 duplicates were removed. During title and abstract

screening, 3,885 studies were screened and 2,736 studies were excluded. During full-text screening, 1,149 studies were evaluated and 857 studies were excluded. The primary reasons for exclusion were: ineligible manuscript type (e.g., published abstract; 330/857, 39%), user engagement with the mHealth intervention was not measured (206/857, 24%), and ineligible participant population (111/857, 13%). The final review included 292 studies (see Multimedia Appendix 2 for all included studies and characteristics and Multimedia Appendix 3 for the full citations).

Basic Study and mHealth Intervention Characteristics

The majority of studies were conducted in the United States and used a randomized controlled trial design (n=135/292, 46%). The median number of participants was 77 (IQR=34-164). Nearly half were considered feasibility studies (n=135/292, 46%). The median number of days for study length was 90 (IQR=60-180). Diabetes (n=51/292, 18%) and mental health conditions (n=35/292, 12%) were the most common diagnoses. Study characteristics were similar between adult and pediatric studies with the exception of health conditions, reflecting expected age-based differences in diagnoses more common among adults versus children (e.g., type 2 diabetes and substance use were more commonly studied in adult samples than pediatric). See Supplemental Table 1 for details.

Supplemental Table 2 contains specific details on the mHealth interventions' adherence/self-management targets, intervention components, and intended users. The most frequently targeted adherence/self-management concern was taking medication (n=98/292, 34%), followed by exercise (n=93/292, 32%) and diet (n=73/292, 25%). Nearly all of the mHealth interventions were used by the patient (n=291/292, >99%) but some included healthcare providers (n=58/292, 20%) or caregivers (n=20/292, 7%). The majority of mHealth interventions were comprised of a mobile app (n=220/292, 75%), text messaging (n=74/292, 25%), websites or web portals not within a mobile app (n=48/292,

16%), and non-wearable monitoring devices (n=47/292, 16%). Interventions that did not include a mobile app were primarily comprised of text messaging, a wearable device, a non-wearable device, video web conferencing or telephone, or a website or web portal not within a mobile app. Nearly three-quarters (n=216/292, 74%) prompted users to engage with the mHealth intervention. Less than half of the studies (n=124/292, 43%) provided monetary compensation for participation. Only 11% (n=31/292) allowed users to continue using the mHealth intervention after the formal study period. Intervention characteristics were generally similar between adult and pediatric studies with the exception of intervention target behavior, reflecting expected age-based differences in health concerns more common among adults versus children (e.g., exercise, mental health management, and drug and/or alcohol use/abuse were more commonly targeted in adult samples than pediatric).

How is user engagement defined and measured?

Definition. Terminology defining user engagement varied widely (see Supplemental Table 3). There were 33 unique terms used to define engagement in at least two studies. 11% (n=31/292) of the overall review contained other terms appearing in only one study. “Use” (n=102/292, 35%) and “engagement” (n=94/292, 32%) were the most common terms. Although most terms were synonymous with “use,” “engagement,” or “interaction” with the technology (reflecting our a priori definition of behavioral user engagement and our search strategy), other studies notably used disparate terms, including “acceptability” (n=26/292, 9%), “fidelity” (n=5/292, 2%), “satisfaction” (n=6/292, 2%), and “perception” (n=6/292, 2%).

Measurement. Across all studies, 11 distinct user engagement measurement approaches emerged, comprising both objective (n=9/11) and subjective (n=2/11) methods. User engagement was most frequently evaluated via objective user login data from the app or web portal (e.g., number of logins; 160/292, 55%), followed by manually entering data in

an app (77/292, 26%), qualitative interview (54/292, 19%), and responding to text notifications (49/292, 17%). There were “Other objective measures” that did not fall into any of the 11 main categories (15/292, 5%; e.g., notification reading rate, downloading podcasts). These results were similar between adult and pediatric studies. See Table 1 and Supplemental Table 4 for details.

Table 1. How is User Engagement Measured?

Measurement methods	Example	N (%) (N=292)
Objective measures		
User login data retrieved from app or website	• Number of logins to app/website • Length of time spent in app/website • Frequency of accessing specific features within the app/website	160 (55)
Manual user data entry in app/website-based self-monitoring diaries	• User manually enters data in the app, such as blood glucose level, date and time when medicine was taken, or blood pressure values	77 (26)
Response to text messages or push notifications	• User types and sends a response to a text message asking if they took their medicine that day	49 (17)
Number or proportion of intervention program modules completed within app/website	• User completes 3 out of 6 possible modules on pain management skills	48 (16)
Interacting via chats, phone calls, or social media posts	• Number of times user sends a chat message to care team through app	33 (11)
Wearing an electronic monitoring device	• Length of time the user wore a Fitbit to track daily step count	26 (9)
Using a non-wearable electronic monitoring device	• Medication adherence is monitored with an electronic pill bottle that tracks when the bottle is opened and closed to administer medicine	26 (9)
Submitting videos via app	• Medication adherence is measured with a mobile directly observed therapy app	5 (2)
Other objective measures	• Examples: Notification message reading rate, downloading podcasts	13 (5)
Subjective Measures		
Qualitative interview	• User completes a qualitative interview about their experience using the mHealth app	54 (19)
Participant-reported survey	• User self-reports frequency of using the app	29 (10)

Note. *Percentages within headings do not add up to 100% because studies could fall into >1 category.

When examining engagement definitions by measurement approaches, “use” and “engagement” were most commonly used across objective measurement approaches. The exceptions were “wearing an electronic monitoring device” and “submitting videos via app” for which “adherence” was most commonly used. Qualitative interviews had the widest range of terminology used with “user experience” being most common (n=21/54, 39%). See Table 2 for details.

Table 2. Associations Between User Engagement Evaluation Method and Definitions

Evaluation method	**Terms used to define “user engagement”**
User login data retrieved from app or website (n=160)	Use (n=78, 49%) Engagement (n=62, 39%) Feasibility (n=27, 17%) Adherence (n=25, 16%)
Manual user data entry in app/website-based self-monitoring diaries (n=77)	Use (n=31, 40%) Engagement (n=24, 31%) Adherence (n=19, 25%) Feasibility (n=17, 22%) Compliance (n=10, 13%)
Response to text messages or push notifications (n=49)	Engagement (n=21, 43%) Response (n=19, 39%)
Number or proportion of intervention program modules completed within app/website (n=48)	Use (n=22, 46%) Engagement (n=12, 25%) Adherence (n=11, 23%)
Interacting via chats, phone calls, or social media posts (n=33)	Engagement (n=14, 42%) Use (n=13, 39%) Feasibility (n=5, 15%) Compliance (n=4, 12%)
Wearing an electronic monitoring device (n=26)	Adherence (n=11, 42%) Engagement (n=9, 35%) Feasibility (n=6, 23%)
Using a non-wearable electronic monitoring device (n=26)	Use (n=9, 25%) Adherence (n=8, 31%) Engagement (n=6, 23%)
Submitting videos via app (n=5)	Adherence (n=2, 40%) Use (n=2, 40%) Compliance (n=1, 20%) Engagement (n=1, 20%) Acceptability (n=1, 20%)
Other objective measures (n=13)	Engagement (n=7, 54%) Feasibility (n=2, 15%) Use (n=2, 15%) Response (n=2, 15%)
Qualitative interview (n=54)	User experience (n=21, 39%)

	Engagement (n=18, 33%) Use (n=17, 31%) Acceptability (n=13, 24%) Feasibility (n=8, 15%) Adherence (n=8, 15%)
Participant-reported survey (n=29)	Use (n=13, 45%) Feasibility (n=10, 24%) Engagement (n=6, 21%) Acceptability (n=6, 21%) Adherence (n=5, 17%)

Note. Percentages within headings do not add up to 100% because studies could fall into >1 category. We report terms used to describe user engagement in at least 10% of studies using a given evaluation method; this cutoff was selected to enhance interpretability due to the wide range of words used to describe user engagement (see Supplemental Table 3).

User login data was the most common measurement method across mHealth intervention components except for text messaging or push notifications and wearable device. When text messaging or push notifications was an intervention component, response to text messages or push notifications was most common (n=38/74, 51%). When wearable device was an intervention component, wearing an electronic monitoring device was the most common metric (n=26/39, 67%). See Supplemental Table 5 for details.

To what degree are participants engaging with these mobile health interventions?

Level of user engagement. Level of user engagement was characterized in two-thirds of reviewed studies, of which the majority reported >1 levels of engagement due to the use of multiple measurement methods or analyses (n=99/195, 51%). Only one-third of studies examined change in engagement over time; when it was examined, engagement tended to decrease (n=76/99, 77%). These results were similar between adult and pediatric studies (see Table 3 for details).

Table 3. Degree of Engagement and Association with Treatment Adherence/Self-Management

Characteristic	**All (N=292) N (%)**	**Adult (n=241) N (%)**	**Pediatric (n=45) N (%)**
Level of engagement			
High	63 (22)	55 (23)	7 (16)
Medium	6 (2)	4 (2)	2 (4)
Low	27 (9)	19 (8)	6 (13)

>1 levels reported	99 (34)	81 (33)	18 (40)
Not characterized	97 (33)	82 (34)	12 (27)
Change in level of engagement			
Increased	3 (1)	3 (1)	0
No change	15 (5)	13 (5)	1 (2)
Decreased	76 (26)	61 (25)	13 (29)
>1 directions reported	5 (2)	4 (2)	1 (2)
Not assessed	193 (66)	160 (66)	30 (67)
Association with adherence/self-management (SM) outcome(s)			
Higher engagement, positive adherence/SM outcome(s)	60 (21)	49 (20)	8 (18)
Moderate engagement, positive adherence/SM outcome(s)	1 (<1)	1 (<1)	0
Lower engagement, positive adherence/SM outcome(s)	1 (<1)	1 (<1)	0
No association	18 (6)	15 (6)	3 (7)
>1 associations reported	23 (8)	18 (7)	5 (11)
Not assessed	189 (65)	157 (65)	29 (64)

Note. Categories with ">1" findings reflect the use of multiple measurements and/or analyses, leading to multiple results in different directions (e.g., for Change Over Time, engagement is shown to increase and decrease depending on the measurement used).

Measurement approach by user engagement level. Compared to studies characterized as having high user engagement, studies with low user engagement tended to measure (≥10% difference) engagement with user login data (n=19/27, 70% vs n=36/63, 57%) and module completion (n=7/27, 26% vs n=9/63, 14%). Compared to studies characterized as having low user engagement, studies with high user engagement tended to measure engagement with response to text notifications (n=14/63, 22% vs n=1/27, 4%), interacting via chats, phone calls, or social media posts (n=13/63, 21% vs n=1/27, 4%), wearing an electronic monitoring device (n=6/63, 10% vs 0), using a non-wearable electronic monitoring device (n=7/63, 11% vs 0), and qualitative interview (n=12/63, 19% vs n=2/27, 7%). See Table 4 for details.

Table 4. Measurement Approach by User Engagement Level with Intervention

	Characterization of User Engagement Level With Intervention				
	Low n=27	**Medium n=6**	**High n=63**	**>1 n=99**	**Not characterized n=97**

Measurement	n (%)	n (%)	n (%)	n (%)	n (%)
User login data retrieved from app or website	19 (70)	5 (83)	36 (57)	57 (57)	43 (44)
Manual user data entry in app/ website-based self-monitoring diaries	8 (29)	2 (33)	15 (24)	29 (29)	23 (24)
Response to text messages or push notifications	1 (4)	0	14 (22)	14 (14)	20 (21)
Number or proportion of intervention program modules completed within app/website	7 (26)	2 (33)	9 (14)	16 (16)	14 (14)
Interacting via chats, phone calls, or social media posts	1 (4)	0	13 (21)	10 (10)	9 (33)
Wearing an electronic monitoring device	0	0	6 (10)	9 (9)	11 (11)
Using a non-wearable electronic monitoring device	0	0	7 (11)	11 (11)	8 (8)
Submitting videos via app	2 (7)	0	0	2 (20)	1 (20)
Other objective measures	2 (7)	0	3 (5)	5 (5)	3 (3)
Qualitative interview	2 (7)	1 (17)	12 (19)	16 (16)	23 (24)
Participant-reported survey	1 (4)	2 (33)	4 (6)	10 (10)	12 (12)

Note. Percentages within headings do not add up to 100% because studies could fall into >1 category.

Technology dosages and minimum engagement research benchmarks. Technology dosages denote when researchers provided participants with specific recommendations for mHealth intervention use (e.g., log into the app at least three times a week). Minimum engagement research benchmarks denoted when researchers set a minimum research cutoff for adequate participant engagement (e.g., a participant who responded to ≥75% of text messages during the study period was considered by the researchers to be adequately engaged with the mHealth intervention). A research benchmark could be set without giving a technology dosage and vice versa. Less than half the time were technology dosages given to participants by the researchers across all studies (n=119/292, 41%) and when examined by age group. Whether technology dosages were given or not, researchers characterized engagement level as “low” (n=14/27, 52% vs n=13/27, 48%) and “high” (n=29/63, 46% vs n=34/63, 54%) at relatively equal proportions (<10% difference; see Table 5 for details).

Less than one-third of the time was a minimum engagement research benchmark set as outcome criteria in all reviewed studies (n=81/292, 28%) and when examined by age group. When a minimum engagement research benchmark was set, researchers tended to characterize user engagement levels as low (n=11/27, 41%) rather than high (n=15/63, 24%). When no minimum engagement research benchmark was set, researchers tended to characterize user engagement as high (n=48/63, 76%) rather than low (n=16/27, 59%; see Table 5 for details).

Table 5. Study Characteristics and Engagement Level Based on Technology Dosage and Minimum Engagement Research Benchmark

Study Characteristic	**All (N=292) N (%)**	**Adult (n=241) N (%)**	**Pediatric (n=45) N (%)**
Technology dosage given to participants			
Yes	119 (41)	96 (40)	22 (49)
No	173 (59)	145 (60)	23 (51)
Minimum engagement research benchmark set			
Yes	81 (28)	71 (30)	10 (22)
No	211 (72)	170 (70)	35 (78)

Engagement Level	**Low n=27**	**Medium n=6**	**High n=63**	**>1 n=99**	**Not characterized n=97**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Dosage given to participants					
Yes	14 (52)	2 (33)	29 (46)	43 (43)	31 (32)
No	13 (48)	4 (67)	34 (54)	56 (57)	66 (68)
Minimum engagement research benchmark set					
Yes	11 (41)	2 (33)	15 (24)	38 (38)	15 (15)
No	16 (59)	4 (67)	48 (76)	61 (62)	82 (85)

Among studies that had a minimum engagement research benchmark (n=81/292), less than half gave a technology dosage to participants (n=35/81, 43%). Among studies that gave a technology dosage to participants (n=119), only 29% (n=35/119) also had a minimum engagement research benchmark.

35 studies gave both a technology dosage and set a minimum engagement research benchmark; these indices matched in 33/35 studies (94%). 29/35 studies characterized

engagement level (83%), of which the majority reported >1 levels of engagement due to the use of multiple measurement methods or analyses (n=13/29, 45%).

When a minimum engagement research benchmark was set or a recommended technology dosage was given, engagement tended to be measured with user login data (n=48/81, 59% and n=69/119, 58%), manual data entry (n=26/81, 32% and n=32/119, 27%), or module completion (n=16/81, 20% and n=21/119, 18%). See Table 6 for details.

Table 6. User Engagement Measurement Approach When Minimum Engagement Research Benchmarks or Technology Dosages Were Given

	User Engagement Level Set by Researchers	
	Minimum engagement research benchmark n=81	**Technology dosage recommended n=119**
Measurement	**n (%)**	**n (%)**
User login data retrieved from app or website	48 (59)	69 (58)
Manual user data entry in app/website-based self-monitoring diaries	26 (32)	32 (27)
Response to text messages or push notifications	9 (11)	15 (13)
Number or proportion of intervention program modules completed within app/website	16 (20)	21 (18)
Interacting via chats, phone calls, or social media posts	12 (15)	14 (12)
Wearing an electronic monitoring device	10 (12)	18 (15)
Using a non-wearable electronic monitoring device	10 (12)	14 (12)
Submitting videos via app	2 (2)	5 (4)
Other objective measures	4 (5)	7 (6)
Qualitative interview	9 (11)	16 (13)
Participant-reported survey	1 (1)	12 (10)

Note. Percentages within headings do not add up to 100% because studies could fall into >1 category.

What is the association between user engagement with mHealth interventions and adherence or self-management outcomes?

The association between engagement and treatment adherence/self-management outcome(s) was only assessed in one-third of studies, of which study authors tended to

report and frame results and conclusions to suggest that higher engagement was associated with positive adherence/self-management outcome(s) (n=60/103, 58%). These results were similar between adult and pediatric studies. See Table 3 for details.

How often is user engagement a research endpoint?

User engagement was a research endpoint in only 19% (n=56/292) of all reviewed studies, with similar results in adult (n=44/241, 18%) and pediatric (n=11/45, 24%) studies. Of these studies, the majority used non-randomized experimental designs (n=30/56, 53%) and just under half were feasibility studies (n=27/56, 48%). User engagement was typically defined as “engagement” (n=24/56, 43%), “adherence” (n=16/56, 29%), or “use” (n=16/56, 29%; see Supplemental Table 3) and was most frequently measured with user login data (n=31/56, 55%) or manual data entry (n=22/56, 39%; see Supplemental Table 6).

Exploratory analysis: What is the association between providing study participants with monetary compensation and user engagement level?

Whether study participants were provided monetary compensation for their participation or not/not reported, user engagement measurement methods were used at similar proportions (<10% difference). Similarly, user engagement levels were observed at similar proportions between studies providing monetary compensation versus no compensation/not reported. See Supplemental Table 7 for details.

There were 10 studies of mHealth interventions which included as an intervention component financial incentives for using the technology or meeting mHealth intervention goals. Of these, 7/10 reported user engagement level: 1/7 each were characterized as high, medium, or low and 4/7 reported >1 level due to multiple measurement and/or analytic approaches.

Discussion

Principal Findings

The principal findings relative to our specific research questions were:

1) *How is "user engagement" defined and measured in studies of mHealth interventions to promote adherence to prescribed medical/health regimens or self-management among people living with a health condition?* Words used to describe user engagement outcomes were wide ranging but the most commonly used terminologies were “use” and “engagement.” Across all studies reviewed, 11 distinct user engagement measurement approaches were identified, comprised of both objective and subjective methods. The most common methods were user login data from the app or web portal, manually entering data in an app, qualitative interview, and responding to text notification.

2) *To what degree are patients engaging with these mHealth interventions?* Level of user engagement was difficult to quantify as it was only characterized in two-thirds of reviewed studies and most reported >1 level of engagement due to using multiple measurement methods or analyses. Only one-third of studies evaluated change in engagement over time, which tended to decrease.

3) *What is the association between user engagement with mHealth interventions and adherence or self-management outcomes?* Only one-third of studies evaluated the association between engagement and treatment adherence/self-management. When evaluated, the study authors tended to report and frame results and conclusions to suggest that higher engagement was associated with positive adherence/self-management outcomes.

4) *How often is user engagement a research end-point?* User engagement was rarely a research endpoint (only 56 out of 292 studies).

5) *Exploratory question: Are there differences in user engagement measurement approach and level in studies providing monetary compensation compared to not providing monetary compensation?* No, whether study participants were provided monetary compensation for

their participant or not/not reported, user engagement methods were used at similar proportions and user engagement levels were observed at similar proportions.

Implications and Future Directions

Despite immense focus in both commercial and research sectors on using mHealth to support chronic illness treatment adherence and self-management [22–24], people do not remain engaged with mHealth interventions long-term [6]. Our systematic review also found user engagement tends to decline over time. Consistent with the “Little e, Big E” framework” [16], mHealth intervention success hinges on the expectation that people will interact with the technology and thereby experience intended behavior changes that will lead to better overall health. Most importantly, our systematic review revealed critical limitations with how user engagement is defined and evaluated, which significantly impedes our ability to (1) communicate about this topic, and (2) draw strong conclusions about how much user engagement is necessary to achieve desired behavior and health changes.

A principal finding of our review was that there is no agreed upon definition of mHealth user engagement, which is a direct barrier to interdisciplinary communication about this topic. We found over 60 terms used to define user engagement, even when limiting inclusion criteria to the behavioral evaluation of this concept [15]. While “use” and “engagement” were the most common terms, “adherence” also frequently appeared. “Adherence” as a term for mHealth user engagement can be problematic because it is closely tied to treatment adherence [25], a key target of many of the mHealth interventions included in this systematic review. In some cases in this review, “adherence” applied to engaging with the mHealth technology as intended, such as logging into an app [26] or responding to text messages [27] rather than following a prescribed treatment regimen. There are instances when engaging with the technology has a direct connection to treatment adherence (e.g., using a Bluetooth-enabled blood pressure cuff reflects

adherence to a key part of the hypertension management regimen as well as engaging with the mHealth technology [28,29]). However, such interchangeability and lack of consistency in terminology will continue to be a barrier to communicating within and outside the field and add to existing challenges with defining and evaluating this domain. The extremely wide range of words used to define user engagement likely reflects a major critique of mHealth research—that there lacks a science of engagement [7]. We encourage standardization in terminology used when the intention is to evaluate users' behavioral engagement with mHealth technology, rather than treatment regimen, with the most common terms found in this systematic review: "use" or "engagement." Integrating standard user engagement language in an internationally-adopted clinical terminology system, such as the Systematized Nomenclature of Medicine-Clinical Terms (SNOMED CT®), could help facilitate standardization efforts.

Another key finding was that user login data was the default mHealth user engagement outcome, except for wearing a device when the intervention involved a wearable device component and responding to text messages and notifications when the intervention involved texting and notifications. Reliance on user login data over the other 10 major measurement approaches likely reflects that these data can be relatively straightforward to extract from a web portal. A strength of user login data is that it may indicate more effortful and deliberate interactions with the technology (user likely needs sufficient motivation to open and navigate an app) compared to, for example, quickly responding to a text message or wearing a pedometer on the wrist. User login data may be a more accurate reflection of engagement behavior than self-report, which is potentially subject to social desirability and recall bias. The tendency for user login data to be characterized as "low" may reflect the higher user burden of logging into and interacting with an app, in addition to the overwhelming selection of this method for measuring user

engagement. Reliance on user login data may bias interpretations of user engagement to favor higher quantities of engagement at the expense of higher quality engagement (e.g., infrequent access of a particularly effective app feature that users perceive as interesting, helpful, or motivating may be higher quality engagement than frequent logins to the app homepage). Given the ubiquitous selection of user login data and heterogeneity of adherence and self-management outcomes in this systematic review, it is not possible to evaluate which user engagement metric is best. In general, investigators should select the user engagement metric reflecting essential interactions with the mHealth intervention's key technology needed to facilitate behavior and health change.

We found that the exact degree of user engagement with the interventions reviewed was difficult to estimate and that the association between user engagement and adherence/ self-management outcomes were rarely evaluated. Both findings may relate to an important secondary finding that researchers rarely set a priori benchmarks for how much user engagement is considered scientifically adequate (no minimum engagement research benchmark set). Concerningly, when *no* minimum research benchmark was set, researchers tended to characterize user engagement as high, suggesting over-optimism about study results in the absence of any hypothesized lower boundary for what constituted minimally acceptable mHealth use. Setting cut points for how much user engagement is hypothesized to be adequate would also help to guide how much and in what ways users should interact with the mHealth intervention components to experience meaningful improvements on target outcomes. Matching technology dosages to minimum engagement research benchmarks, when possible, could inform whether engagement recommendations were met and allow researchers to evaluate if exceeding expectations is associated with even greater improvement on behavior or health outcomes. Of note, studies with technology dosages or minimum engagement research benchmarks appeared to require

more of participants reflected by the more common use of user login data and manual data entry to evaluate user engagement. User engagement burden should be considered when setting mHealth engagement expectations.

Setting minimum engagement research benchmarks could also account for variability in user engagement level characterization depending on the metric selected and help to define what constitutes effective and meaningful engagement. Specifically, user login data-assessed engagement tended to be characterized low. In contrast, responding to text notifications or interacting via chats, phone calls, or social media posts, which may be more socially rewarding and less effortful to complete, tended to be characterized as high. A similarly high pattern of user engagement was observed in studies evaluating the use of wearable and non-wearable devices, which are often part of the users' regular self-management routines (e.g., Bluetooth-enabled pill bottle or glucometer) or passively worn (e.g., pedometer) and, thus, may be less burdensome to use. A higher text message response rate and comparatively lower app login rate may both be minimally acceptable, and potentially meaningful, levels of engagement to effectively facilitate behavior or health change, particularly considering the level of effort and motivation involved in each type of interaction. Given inconsistencies in how investigators characterize engagement levels, setting minimum engagement research benchmarks could inform whether user engagement is adequate across metrics and associated with key adherence and self-management outcomes. This approach could also improve precision in how engagement levels are characterized (i.e., what level of engagement is considered low versus high?). Such efforts at the study planning phase could reduce the tendency to characterize user engagement at multiple levels due to the use of multiple metrics and analyses. Rethinking engagement levels as "adequate," "acceptable," "effective," or "meaningful" versus "high" or "low" may better inform how much people should realistically use mHealth technology and

evaluate whether engagement level is associated with behavior and health change.

In the mHealth trials reviewed, an important secondary finding was that participants were rarely told how much they should aim to engage with the technology (no technology dosages). This is in contrast to drug trials in which participants are instructed to take a specific dosage of medication on a strict schedule and trials of in person behavior change interventions (traditional therapy) in which participants are given therapy regimens and expectations for participation (e.g., attend 12 therapy sessions, complete assigned homework each week of treatment) [11]. Although an early phase research goal may be to see how much people interact with the technology in the absence of recommendations, an important future goal is to understand how much engagement is needed to maximize behavior and health changes. Recommending in what ways and how much users should aim to engage with the technology is necessary to this end. Giving technology dosages would also allow for experimental evaluation of different levels of recommended technology use to see what recommendation helps users achieve the most positive behavior and health changes. Further, improvements in health and wellness can take time and mHealth users may not observe immediate benefits to using mHealth interventions, which could contribute to prematurely abandoning the tool. Providing users with clearer guidance on how much and what type of mHealth intervention usage is needed to begin effecting positive health and behavior changes could help encourage sustained use.

Another primary finding was that user engagement was infrequently a research endpoint. This is a problem because it is generally expected that users will need to interact with the mHealth technology to experience clinical benefit. Thus, user engagement behavior is a critical aspect of the mHealth intervention itself. Without designating user engagement as a research endpoint, mHealth intervention trials risk lacking the necessary empirical data and results to help end users understand how to optimally use the

technology to see maximal clinical benefit. Lacking these data and results may also be a barrier to informing how these digital tools can be incorporated into regular clinical practice and policy [30]. Thus, in addition to carefully measuring the treatment adherence, self-management behavior, and associated health outcomes directly targeted by the mHealth intervention, equal care should be given to evaluating user engagement, such as how user engagement with the technology may change over time and potentially influence outcomes. Shifting user engagement from “after thought” data to an actual research endpoint would likely improve the quality and rigor of mHealth research and help develop mHealth interventions that motivate users to interact with the technology [31], and, ideally, experience greater clinical benefit.

Our exploratory analysis of studies providing monetary compensation for study participation versus no monetary compensation/not reported showed that engagement level characterizations were similar between the groups. It is possible that the delivery of monetary compensation was primarily for completing study procedures (e.g., completing study surveys) rather than engaging with the mHealth intervention. In the 10 studies of interventions comprised of financial incentives for using the technology or meeting mHealth intervention goals, no clear pattern emerged for user engagement levels, though this likely reflects the small number of studies incorporating this mHealth component. User engagement evaluation methods were used at similar proportions between the groups, suggesting that monetary compensation was not associated with user engagement measurement selection. An important avenue for future mHealth engagement research is to improve understanding of how monetary compensation is associated with user engagement levels, particularly when compensation is directed towards mHealth intervention use.

Limitations

This systematic review is among the most comprehensive reviews on this topic but

had some limitations. First, due to heterogeneity in the study outcomes, we did not conduct a meta-analysis. Thus, this systematic review cannot conclude which user engagement outcome is associated with the most effective interventions. Second, even though we found that study authors tended to frame their results and conclusions to suggest that higher user engagement was associated with positive intervention outcomes, this finding should be considered preliminary and hypothesis-generating and does not prove that higher engagement leads to better adherence or self-management, particularly given that study authors may have a tendency to report favorable results and frame their findings in a positive light. However, this is an important area to examine in for future research to better understand the characteristics of users with higher mHealth engagement as it relates to adherence and self-management outcomes (for example, highly engaged users may represent a patient group with already high adherence and self-management). Third, we did not exclude studies on the basis of their attrition rate; a future direction for improving the science of engagement is to consider how dropout/withdrawal may influence the characterization of user engagement levels. Fourth, a traditional risk of bias assessment [32,33] was not conducted due to our interest in user engagement, rather than the primary study results targeting adherence and self-management. If user engagement becomes more commonly designated as a research endpoint, such evaluations of study quality specific to the evaluation of user engagement will be warranted. Fifth, we included a range of medical and mental health conditions but, due to small Ns, were unable to conduct subgroup analyses by diagnosis; as the literature on user engagement grows, it may be possible to explore such differences by diagnosis. Sixth, we focused on the behavioral evaluation of user engagement, though this domain likely involves more than behavior alone [15,34] and these other aspects of user engagement may be examined in a future systematic review. Seventh, our interest was in the measurement and evaluation of

mHealth user engagement, thus, we did not consider the numerous individual-level factors that could be related to user engagement. Eighth, though study location was not part of the inclusion criteria, over half of the reviewed studies were conducted in the United States, which may have influenced the types of interventions studies and approaches to evaluating user engagement. Ninth, we conducted our search in specific scientific databases and did not review grey literature or unpublished results; although our search resulted in 292 studies meeting our inclusion criteria, this systematic review may not be generalize to all mHealth interventions. Lastly, it is necessary to select a cutoff date when conducting a systematic review yet new studies are constantly being published. An updated review of the mHealth user engagement literature may be warranted in the future. As the science of mHealth user engagement improves, an important next step is evaluate how factors related to diversity, equity, and inclusion relate to user engagement to promote wider mHealth use and access.

Recommendations for Future Researchers:

Our systematic review on mHealth user engagement highlighted critical gaps in mHealth adherence and self-management literature as well as opportunities to improve research in this important area of digital health. mHealth researchers need to prioritize the evaluation of user engagement during study planning phases. Strengthening mHealth user engagement methodological rigor would likely lead to higher quality data and more impactful study results to guide practice and policy and, ultimately, encourage uptake of mHealth adherence/self-management promoting interventions. Further, improved user engagement evaluation may help researchers begin to identify effective strategies for supporting meaningful user engagement and sustained interest to help users fully experience the intended behavioral and health benefits of the mHealth intervention [16]. Such research is critical for building the evidence base that will help mHealth interventions

break into regular clinical care and practice guidelines.

The following recommendations for the study of mHealth user engagement are offered:

1. Use consistent terminology. Reflecting the most common trends in the literature reviewed, we recommend referring to the measurement of behavioral mHealth use, interaction, or engagement as “use” or “engagement.” Greater consistency in terminology could help improve rigor and consistency in the measurement itself and facilitate comparisons between studies and evaluation of user engagement in meta-analyses.
2. Select mHealth user engagement metrics that reflect interactions with the intervention’s key technology components hypothesized to facilitate behavior and health change.
3. Provide mHealth users with expectations for how much they should aim to interact with the technology (give technology dosages) when possible.
4. Set minimum engagement research benchmarks to scientifically denote the hypothesized level of user engagement for a participant to be considered adequately, acceptably, or meaningfully engaged in the intervention.
5. Characterize user engagement levels as adequate or acceptable with minimum engagement research benchmarks to help address issues with engagement being characterized as high or low depending on the metric selected and consider whether engagement is adequate, meaningful, or effective across metrics (e.g., a higher text message response rate and comparatively lower app login rate may both be acceptable and meaningful levels of engagement).
6. Designate mHealth user engagement as a research endpoint to help improve the quality and rigor of the mHealth research and the data collected from these studies.

Focusing research efforts on user engagement could lead to mHealth engagement recommendations that could ultimately lead to greater clinical improvement.

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Abbreviations: mHealth=mobile health, Preferred Reporting Items for Systematic reviews and Meta-Analyses=PRISMA, self-management=SM, interquartile range=IQR.

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References

1. Pew Research Center. Teens, Social Media & Technology 2018. Pew Research Center; 2018. Available from: https://www.pewresearch.org/internet/2018/05/31/teens-social-media-technology-2018/#vast-majority-of-teens-have-access-to-a-home-computer-or-smartphone

2. Pew Research Center. Mobile Fact Sheet. 2021. Available from: https://www.pewresearch.org/internet/fact-sheet/mobile/

3. 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;22(8). doi: 10.2196/19861

4. Osborn CY, Hirsch A, Sears LE, Heyman M, Raymond J, Huddleston B, Dachis J. One Drop App With an Activity Tracker for Adults With Type 1 Diabetes: Randomized Controlled Trial. JMIR MHealth UHealth 2020 Sep 17;8(9):e16745. doi: 10.2196/16745

5. Rowland SP, Fitzgerald JE, Holme T, Powell J, McGregor A. What is the clinical value of mHealth for patients? Npj Digit Med 2020 Jan 13;3(1):4. doi: 10.1038/s41746-019-0206-x

6. Krebs P, Duncan DT. Health App Use Among US Mobile Phone Owners: A National Survey. JMIR MHealth UHealth 2015 Nov 4;3(4):e101. doi: 10.2196/mhealth.4924

7. Arigo D, Jake-Schoffman DE, Wolin K, Beckjord E, Hekler EB, Pagoto SL. The history and future of digital health in the field of behavioral medicine. J Behav Med 2019 Feb;42(1):67–83. doi: 10.1007/s10865-018-9966-z

8. Cao W, Milks MW, Liu X, Gregory ME, Addison D, Zhang P, Li L. mHealth Interventions for Self-management of Hypertension: Framework and Systematic Review on Engagement, Interactivity, and Tailoring. JMIR MHealth UHealth 2022 Mar 2;10(3):e29415. doi: 10.2196/29415

9. Yang Y, Boulton E, Todd C. Measurement of Adherence to mHealth Physical Activity Interventions and Exploration of the Factors That Affect the Adherence: Scoping Review and Proposed Framework. J Med Internet Res 2022 Jun 8;24(6):e30817. doi: 10.2196/30817

10. Schwarz A, Winkens LHH, de Vet E, Ossendrijver D, Bouwsema K, Simons M. Design Features Associated With Engagement in Mobile Health Physical Activity Interventions Among Youth: Systematic Review of Qualitative and Quantitative Studies. JMIR MHealth UHealth 2023 Mar 6;11:e40898. doi: 10.2196/40898

11. Lipschitz JM, Van Boxtel R, Torous J, Firth J, Lebovitz JG, Burdick KE, Hogan TP. Digital Mental Health Interventions for Depression: Scoping Review of User Engagement. J Med Internet Res 2022 Oct 14;24(10):e39204. doi: 10.2196/39204

12. Molloy A, Anderson PL. Engagement with mobile health interventions for depression: A systematic review. Internet Interv 2021 Dec;26:100454. doi: 10.1016/j.invent.2021.100454

13. Ng MM, Firth J, Minen M, Torous J. User Engagement in Mental Health Apps: A Review of Measurement, Reporting, and Validity. Psychiatr Serv 2019 Jul;70(7):538–544. doi: 10.1176/appi.ps.201800519

14. Short CE, DeSmet A, Woods C, Williams SL, Maher C, Middelweerd A, Müller AM, Wark PA, Vandelanotte C, Poppe L, Hingle MD, Crutzen R. Measuring Engagement in eHealth and mHealth Behavior Change Interventions: Viewpoint of Methodologies. J Med Internet Res 2018 Nov 16;20(11):e292. doi: 10.2196/jmir.9397

15. Perski O, Blandford A, West R, Michie S. Conceptualising engagement with digital behaviour change interventions: a systematic review using principles from critical interpretive synthesis. Transl Behav Med 2017 Jun;7(2):254–267. doi: 10.1007/s13142-016-0453-1

16. Cole-Lewis H, Ezeanochie N, Turgiss J. Understanding Health Behavior Technology Engagement: Pathway to Measuring Digital Behavior Change Interventions. JMIR Form Res 2019 Oct 10;3(4):e14052. doi: 10.2196/14052

17. Nieuwlaat R, Wilczynski N, Navarro T, Hobson N, Jeffery R, Keepanasseril A, Agoritsas T, Mistry N, Iorio A, Jack S, Sivaramalingam B, Iserman E, Mustafa RA, Jedraszewski D, Cotoi C, Haynes RB. Interventions for enhancing medication adherence. Cochrane Consumers and Communication Group, editor. Cochrane Database Syst Rev 2014 Nov 20;2014(11). doi: 10.1002/14651858.CD000011.pub4

18. Mellon L, Doyle F, Hickey A, Ward KD, de Freitas DG, McCormick PA, O'Connell O, Conlon P. Interventions for increasing immunosuppressant medication adherence in solid organ transplant recipients. Cochrane Kidney and Transplant Group, editor. Cochrane Database Syst Rev 2022 Sep 12;2022(9). doi: 10.1002/14651858.CD012854.pub2

19. Al-aqeel S, Gershuni O, Al-sabhan J, Hiligsmann M. Strategies for improving adherence to antiepileptic drug treatment in people with epilepsy. Cochrane Epilepsy Group, editor. Cochrane Database Syst Rev 2020 Oct 22;2020(10). doi: 10.1002/14651858.CD008312.pub4

20. Covidence systematic review software. Melbourne, Australia: Veritas Health Innovation; Available from: www.covidence.org

21. IBM SPSS Statistics for Windows. Armonk, NY: IBM Corp; 2021.

22. Nguyen E, Bugno L, Kandah C, Plevinsky J, Poulopoulos N, Wojtowicz A, Schneider KL, Greenley RN. Is There a Good App for That? Evaluating m-Health Apps for Strategies That Promote Pediatric Medication Adherence. Telemed E-Health 2016 Nov;22(11):929–937. doi: 10.1089/tmj.2015.0211

23. Carmody JK, Denson LA, Hommel KA. Content and Usability Evaluation of Medication Adherence Mobile Applications for Use in Pediatrics. J Pediatr Psychol 2019 Apr 1;44(3):333–342. doi: 10.1093/jpepsy/jsy086

24. Hatem S, Long JC, Best S, Fehlberg Z, Nic Giolla Easpaig B, Braithwaite J. Mobile Apps for People With Rare Diseases: Review and Quality Assessment Using Mobile

App Rating Scale. J Med Internet Res 2022 Jul 26;24(7):e36691. doi: 10.2196/36691

25. World Health Organization. Adherence to long-term therapies : evidence for action. Geneva: World Health Organization; 2003; Available from: https://apps.who.int/iris/handle/10665/42682

26. Forbes G, Newton S, Cantalapiedra Calvete C, Birch J, Dodds J, Steed L, Rivas C, Khan K, Rohricht F, Taylor S, Kahan BC, Ball E. MEMPHIS: a smartphone app using psychological approaches for women with chronic pelvic pain presenting to gynaecology clinics: a randomised feasibility trial. BMJ Open 2020;10(3). doi: 10.1136/bmjopen-2019-030164

27. Rohricht F, Padmanabhan R, Binfield P, Mavji D, Barlow S. Simple Mobile technology health management tool for people with severe mental illness: a randomised controlled feasibility trial. BMC Psychiatry 2021;21(1). doi: 10.1186/s12888-021-03359-z

28. Gordon K, Dainty KN, Steele Gray C, DeLacy J, Shah A, Resnick M, Seto E. Experiences of Complex Patients With Telemonitoring in a Nurse-Led Model of Care: Multimethod Feasibility Study. JMIR Nurs 2020;3(1). doi: 10.2196/22118

29. Zha P, Qureshi R, Porter S, Chao YY, Pacquiao D, Chase S, O'Brien-Richardson P. Utilizing a Mobile Health Intervention to Manage Hypertension in an Underserved Community. West J Nurs Res 2020;42(3). doi: 10.1177/0193945919847937

30. McLeod C, Norman R, Litton E, Saville BR, Webb S, Snelling TL. Choosing primary endpoints for clinical trials of health care interventions. Contemp Clin Trials Commun 2019 Dec;16:100486. doi: 10.1016/j.conctc.2019.100486

31. Pagoto S, Waring ME. A Call for a Science of Engagement: Comment on Rus and Cameron. Ann Behav Med 2016 Oct;50(5):690–691. doi: 10.1007/s12160-016-9839-z

32. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, Cates CJ, Cheng H-Y, Corbett MS, Eldridge SM, Emberson JR, Hernán MA, Hopewell S, Hróbjartsson A, Junqueira DR, Jüni P, Kirkham JJ, Lasserson T, Li T, McAleenan A, Reeves BC, Shepperd S, Shrier I, Stewart LA, Tilling K, White IR, Whiting PF, Higgins JPT. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ 2019 Aug 28;l4898. doi: 10.1136/bmj.l4898

33. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, Henry D, Altman DG, Ansari MT, Boutron I, Carpenter JR, Chan A-W, Churchill R, Deeks JJ, Hróbjartsson A, Kirkham J, Jüni P, Loke YK, Pigott TD, Ramsay CR, Regidor D, Rothstein HR, Sandhu L, Santaguida PL, Schünemann HJ, Shea B, Shrier I, Tugwell P, Turner L, Valentine JC, Waddington H, Waters E, Wells GA, Whiting PF, Higgins JP. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ 2016 Oct 12;i4919. doi: 10.1136/bmj.i4919

34. Torous J, Michalak EE, O'Brien HL. Digital Health and Engagement—Looking Behind the Measures and Methods. JAMA Netw Open 2020 Jul 17;3(7):e2010918. doi: 10.1001/jamanetworkopen.2020.10918

Supplementary Files

Figures

PRISMA diagram.

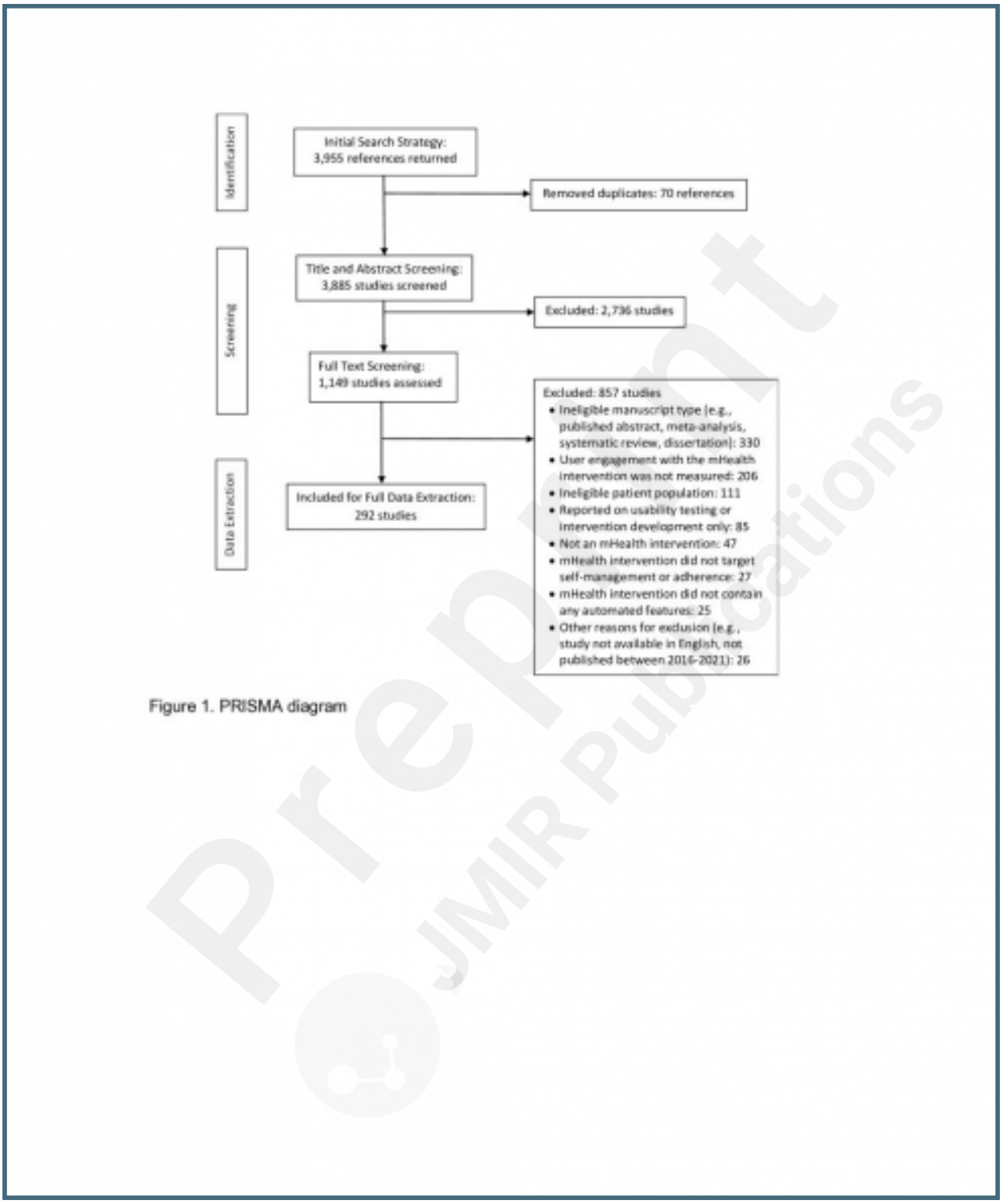

Figure 1. PRISMA diagram

Multimedia Appendixes

Search Strategy.
URL: http://asset.jmir.pub/assets/230313d2fb844476271b4d060c5a5454.pdf

Included Studies and Characteristics.
URL: http://asset.jmir.pub/assets/e1a3dbd9b2d87360f237167ad4b0c03b.xlsx

Full citations for included studies.
URL: http://asset.jmir.pub/assets/e8179bddd79021304495e7d5e0d2bb4e.docx

Supplemental Tables.
URL: http://asset.jmir.pub/assets/e8276348236960b870c509338dedf5d1.docx

CONSORT (or other) checklists

PRISMA Checklist for Systematic Reviews.
URL: http://asset.jmir.pub/assets/2cae13eb5a219174867e5c2442f24626.pdf