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Measuring Psychiatric Symptoms Remotely: a Systematic Review of Remote Measurement-Based Care

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Abstract

Purpose of Review This article systematically reviews studies examining remote measurement-based care (RMBC), defined as using technology to measure patients' psychiatric symptoms outside the context of a clinical encounter.

Recent Findings Thirty-six studies were identified that measured patients' psychiatric symptoms remotely and provided feedback to treatment providers. The majority were single group designs. There was evidence supporting the short-term feasibility and acceptability of RMBC, although long-term sustainability was less clear. Thirteen randomized controlled trials were identified. RMBC was typically implemented as part of a multicomponent intervention (e.g., internet-based cognitive behavioral therapy with feedback to provider). Three studies experimentally isolated the clinical effects of RMBC, with two reporting no statistically significant differences between the RMBC and control conditions and one reporting greater symptom improvement associated with RMBC.

Summary RMBC appears feasible and acceptable and may be a promising intervention for improving mental health care, but additional experimental studies are needed.

Keywords Measurement-based care · Technology · Mobile health · mHealth · Routine outcome monitoring

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Introduction

Measurement-based care (MBC) involves the regular and systematic administration of symptom rating scales, with results used to drive individualized clinical decision-making [1]. There has been increasing interest in the application of MBC to mental health care, with efforts to integrate MBC into clinical practice evident in several large-scale healthcare organizations (e.g., Department of Veterans Affairs, Kaiser Permanente [1]). MBC has been proposed as one method for detecting non-response to treatment and tailoring treatment to the needs of individual patients [2]. Randomized controlled trials (RCTs) testing MBC in the form of frequent and timely feedback of patients' symptoms to psychiatrists and psychologists have been shown to improve outcomes [3–5]. MBC that communicates symptom scores to providers in a structured way during the clinical encounter appears particularly promising [6]. In addition to improving patient outcomes, other justifications proposed for implementing MBC include increased ability to demonstrate effectiveness to payers [7], supporting clinicians' skill development [8], and allowing program evaluation [1]. Although not currently mandated, routine

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symptom monitoring has been recommended as a method for quality assurance [7].

Although an evidence-based practice, MBC has had a limited impact on population health because it has traditionally been implemented only in the context of a clinical encounter. Symptoms are typically not assessed for patients who drop out of treatment or fail to appear for scheduled appointments, perhaps because they feel the treatment is not helping. Moreover, scheduling and attending appointments does not necessarily correlate well with clinical need. Individuals in need of services can face a multitude of barriers to care such as lack of insurance, high copayments, long travel times, long appointment wait times, inconvenient appointment times, stigma, privacy concerns, hopelessness, and perceived ineffectiveness of treatment, to name a few [9]. As a result, healthcare systems allocate clinical resources to those patients who are able to overcome barriers to care rather than those who are most symptomatic. Innovations in MBC are needed to enable healthcare systems (especially Accountable Care Organizations) to manage the mental health of an enrolled population, including those who do not present for care. Specifically, systems are needed to remotely monitor the symptom severity of patients in between clinical encounters in order to conduct outreach to patients most in need. Remote MBC could potentially allow healthcare systems to more efficiently and equitably allocate scarce clinical resources to patients based on need rather than the ability to present for care.

Technological advancements have made it possible to extend the reach of MBC into non-clinical settings. Ecological momentary assessment (EMA) research provides evidence that remote assessment may minimize recall bias, memory inaccuracies, demand characteristics, and threats to ecological validity [10]. In fact, there may be transient symptom exacerbations (e.g., increased suicidality, persecutory ideation [11]) that are most accurately assessed *in situ*. Symptoms can be assessed remotely in various ways, for example, through self-report scales delivered via text messages and mobile phone or web-based applications. These technologies also have the ability to cue patients for EMA data collection [12]. Additionally, most modern mobile phones allow passive or personal sensing through embedded sensors capable of detecting of a variety of parameters (e.g., locations, movement, light, sound [13]) that can serve as a non-self-report marker for psychiatric symptoms and allow more frequent assessment of potentially rapidly changing symptoms (e.g., psychotic episodes [14]). These mHealth technologies can facilitate ongoing asynchronous communication of symptom data to providers. On a continuum of e-mental health services, ranging in intensity from an informational website (level 1) to synchronous provider encounters conducted via interactive video (level 10), RMBC would be classified as level 8, which includes mHealth apps, sensors, and other technologies capable of gathering data that can be communicated to providers [12].

We define remote measurement-based care (RMBC) as the asynchronous assessment of symptoms outside the context of a clinical encounter and use of this information to drive encounter scheduling and clinical decision making. Like traditional clinic-based MBC, RMBC helps providers detect non-response and facilitate changes to the treatment plan [1]. For patients falling through the cracks and missing appointments, RMBC also may help healthcare systems identify those who need to be more engaged in care. Thus, RMBC may help healthcare systems' better match the frequency and/or intensity of clinical encounters with the clinical needs of each patient.

The current review aimed to systematically evaluate the existing literature on RMBC. In order to allow a variety of RMBC approaches to be considered (e.g., self-report questionnaires, passive sensing), we operationalize RMBC to be the assessment of psychiatric symptoms outside of the context of the clinical encounter that are asynchronously transmitted to a clinician in a way that can be used to inform clinical decision making. To date, a variety of terms have been used to refer to symptom monitoring technologies that would fall within RMBC (e.g., symptom tracking, mobile health assessment), and these technologies have been implemented as standalone interventions [15] or, more often, as part of a more comprehensive mobile health intervention [16]. This systematic review was designed to highlight what research has been done in this area and identify gaps for future research. Due to the heterogeneity of study designs and interventions in which RMBC is implemented, a formal meta-analysis was not possible. Nonetheless, we aim to provide a preliminary narrative evaluation of the strength of the evidence supporting RMBC.

Method

Study Selection

The PRISMA guidelines for systematic reviews were followed (see Supplemental Materials). We included studies that tracked patients' psychiatric symptoms remotely (i.e., not immediately before, after, or during a clinical encounter) and communicated this information to providers. Samples had to include individuals experiencing psychiatric symptoms, defined as a diagnosed psychiatric condition, elevations in psychiatric symptoms (e.g., positive screen), or receiving treatment in a psychiatric treatment setting (e.g., substance use disorder clinic). To allow evaluation of a wider variety of studies, a formal psychiatric diagnosis was not required. Samples of individuals with physical health conditions were excluded, unless the individuals also had elevated psychiatric

symptoms (e.g., depression and diabetes [17]). No restriction was placed on sample age or study design (i.e., both single group designs and RCTs were acceptable). Studies had to report some quantitative data, reflecting adherence (e.g., percentage using the feedback system), feasibility (e.g., did the technology function successfully), acceptability (e.g., did patients and/or providers find the technology useful), or clinical effectiveness (e.g., changes in symptoms). No restrictions were placed on publication status (i.e., peer-reviewed or not), language, or year of publication (based on our expectation that a limited number of studies would meet our inclusion if the search was restricted to only recent years). The final search was conducted on February 14, 2018.

Data Sources and Searches

Studies were identified through searching PubMed using search terms and MeSH headings related to technology (e.g., cellphone, e-mental health) and psychiatric conditions (e.g., mental disorders, depression). Search terms were identified through consultation with a medical librarian (see Supplemental Materials). Additional studies were identified through hand searching in the process of reviewing bibliographies of the primary sample of studies. Title and abstracts were first reviewed for inclusion by individual study team members, with studies of uncertain eligibility reviewed by the first and senior author.

Study Feature Extraction

A variety of study features were extracted relating to the study population (sample size, diagnosis category, demographics, setting), communication (frequency, mode), intervention components, and study design (see Table 1 and Supplemental Materials). Studies were categorized based on whether a study's design isolated RMBC by examining the addition of RMBC to treatment-as-usual (TAU) [18, 19] or by comparing an active control condition (e.g., in person psychotherapy) to another condition that differed only in the addition of RMBC (i.e., in person psychotherapy augmented with RMBC [20••]). We defined RMBC as instances in which information flowed primarily from the patient to the provider, rather than substantial content (e.g., CBT-based treatment suggestions [21•]) flowing back to the patient. Adherence, feasibility, and acceptability as well as clinical effectiveness were also extracted. Clinical effectiveness outcomes were defined as intervention effects on psychiatric symptoms of the disorder or disorders under study (i.e., targeted symptoms). When available, standardized effect sizes (e.g., Cohen's *d*, odds ratio, hazard ratio) and *p* values from tests of interest were coded (see Supplemental Materials). A clinical effectiveness summary was made indicating evidence for the effectiveness of the intervention (RMBC alone or a multicomponent intervention including RMBC). The following codes were used: "positive" (evidence of clinical effectiveness), "no significant difference" (no intervention effect or no differences between groups), "negative" (evidence of worse outcomes associated with RMBC or multicomponent intervention including RMBC). Effects on other outcomes (e.g., non-targeted symptoms, medication adherence) were also coded. We coded whether a study reported an intent-to-treat (ITT) analysis. All study features were first extracted by the first author, with coding reviewed by an additional author. Discrepancies were resolved through discussion with the senior author.

Results

A total of 4062 titles and abstracts were reviewed (Fig. 1). Potential studies were excluded for not including a treatment ($k = 2103$), not tracking psychiatric symptoms ($k = 984$), not providing feedback to a provider ($k = 873$), not providing quantitative data ($k = 30$), not including individuals experiencing psychiatric symptoms ($k = 28$), or providing data redundant with included studies ($k = 2$). The final sample included 42 studies representing 36 unique samples.

Information coded from the included studies is reported in Table 1 and Supplemental Materials. Across the 36 unique samples, the average sample was 40.04 years old ($SD = 14.97$, range = 11.33 to 77.60), 61.34% female, and 32.95% racial/ethnic minority participants. A variety of metrics were reported related to educational attainment, with percentage of participants who completed "some college" being reported most commonly. Across the 13 studies reporting this, 54.30% of participants had completed some college. The most common categories of psychiatric symptoms experienced by individuals in the included studies were related to depression ($k = 12$), psychotic disorders ($k = 6$), and substance use ($k = 5$). Studies were conducted in a variety of clinical settings, most commonly primary care clinics ($k = 7$) or clinics established primarily for research purposes ($k = 7$). Interventions lasted on average 4.70 months ($SD = 3.82$), with follow-up evaluation assessments on average occurring at 6.35 months ($SD = 4.16$). The average total sample size was 127.47 ($SD = 184.88$). The average sample size in the treatment group was 85.19 ($SD = 111.66$) and in the control group (or groups, for the two studies that included multiple control groups) 42.28 ($SD = 93.14$).

A variety of technologies were used to measure symptoms remotely, including smartphone app ($k = 16$), text messages ($k = 11$), website ($k = 9$), telephone call ($k = 3$), passive sensing ($k = 3$), email ($k = 2$), electronic medical record ($k = 1$), home telehealth monitor ($k = 1$), and CO2 sensor ($k = 1$) (several studies included more than one assessment mode). Approximately half of studies measured symptoms daily ($k = 17$), with the next larger proportion measuring symptoms weekly ($k = 10$). Assessed symptoms were designed to trigger

Table 1 Summary of included studies

Study	*N*	Psych disorder	Setting	Treatment	Control	RMBC platform	Study design	RMBC isolated	Response rate (%)	ITT	Clinical effectiveness/ efficacy
Aguilera 2017 [21•]	Tx $n = 45$; cont $n = 40$	Depression	Not reported	In-person psychotherapy	In-person psychotherapy	Text messages	Non-RCT	No	NA	Yes	No significant difference
Aharonovich 2017 [20••]	Tx $n = 80$; cont $n = 160$	Substance use	Primary care	In-person psychotherapy	In-person psychotherapy, psychoeducation	Telephone call	RCT	Yes	Daily = 64.1%	No	No significant difference
Aikens 2014 [43]	Tx $n = 135$; cont $n = 86$	Depression	Primary care	TAU	TAU with automated feedback	Telephone call	Non-RCT	No	Weekly = 72%	Not specified	No significant difference
Bauer 2012 [44]	Tx $n = 82$; cont $n = 83$	Bulimia	Research clinic	Remote therapist support	No intervention	Text messages	RCT	No	NA	Yes	Positive
Bauer 2018 [23•]	Tx $n = 17$; cont $n = NA$	Depression or anxiety	Primary care	Collaborative care	NA	Smartphone app	SG feasibility	No	Weekly = 88%	NA	NA
Ben-Zeev 2014 [28]	Tx $n = 17$; cont $n = NA$	Psychotic disorder, substance use	Research clinic and psychiatric rehabilitation agency	Remote therapist support	NA	Text messages	SG feasibility	No	Daily = 87%	NA	NA
Ben-Zeev 2016 [24•]	Tx $n = 342$; cont $n = NA$	Psychotic disorder	Community mental health center	Self-management intervention	NA	Text messages	SG feasibility	No	Weekly = 82%	NA	NA
Burns 2011 [25]	Tx $n = 8$; cont $n = NA$	Depression	Research clinic	Self-administered psychotherapy	NA	Smartphone app and website	SG pre--post	No	NA	Yes	Positive
Chen 2017 [18]	Tx $n = 9$; cont $n = NA$	Depression or autism spectrum disorder	Not reported	TAU	NA	Text messages	SG feasibility	Yes	Daily = 72%; weekly = 100%	NA	NA
Depp 2010 [45]	Tx $n = 11$; cont $n = NA$	Psychotic disorder	Not reported	Automated support	NA	Text messages	SG feasibility	No	NA	NA	NA
Forchuk 2015 [33]	Tx $n = 400$; cont $n = NA$	Mood or psychotic disorder	Community mental health center	TAU	NA	Website and smartphone app	SG feasibility	Yes	NA	NA	NA
Gustafson 2014 [16], Glass 2017 [46], McTavish 2012 [47]	Tx $n = 170$; cont $n = 179$	Substance use	Residential substance use treatment center	Self-administered psychoeducation with remote therapist support	TAU	Smartphone app	RCT	No	NA	Yes	Positive
Hantsoo 2018 [36•]		Depression	Prenatal clinic	TAU	TAU	Smartphone app	RCT	Yes	Daily = 75.9%	No	Positive

Table 1 (continued)

Study	*N*	Psych disorder	Setting	Treatment	Control	RMBC platform	Study design	RMBC isolated	Response rate (%)	ITT	Clinical effectiveness/ efficacy
	Tx $n = 48$; cont $n = 24$										
Haug 2015 [30]	Tx $n = 25$; cont $n = 25$	Substance use	Outpatient specialty mental health	Remote therapist support	TAU	Text messages	RCT	No	Daily = 88.1%	No	No significant difference
Ivanova 2016 [48]	Tx $n = 50$; cont $n = 102$	Anxiety	Research clinic	Self-administered psychoeducation with remote therapist support	Self-administered psychoeducation	Website and smartphone app	RCT	No	NA	Yes	No significant difference
Kumar 2018 [27]	Tx $n = 61$; cont $n = NA$	Psychotic disorder	Outpatient specialty mental health	TAU	NA	Smartphone app	SG pre--post	Yes	Daily = 41%; weekly = 39%	NA	NA
Lazarou 2016 [49]	Tx $n = 4$; cont $n = NA$	Dementia	Alzheimer day treatment center	In-person psychotherapy	NA	Tablet app	SG pre--post	No	NA	NA	Positive
Mares 2016 [50•]	Tx $n = 77$; cont $n = NA$	Substance use	Primary care	Self-guided intervention	NA	Smartphone app	SG feasibility	No	Weekly = 80%	NA	NA
Mavandadi 2015 [37]	Tx $n = 50$-9; cont $n = 509$	Depression or anxiety	Primary care and specialty care	Collaborative care management and behavioral health provider support	RMBC alone	Telephone call	RCT	No	NA	Yes	Positive
Meglic 2010 [41]	Tx $n = 21$; cont $n = 25$	Depression	Primary care	Collaborative care	TAU	Web- or smartphone--based	RCT	No	NA	No	Positive
Miklowitz 2012 [51]	Tx $n = 19$; cont $n = NA$	Bipolar disorder	Outpatient specialty mental health	In-person psychotherapy	NA	Text messages or email	SG pre--post	No	Daily = 81%	Not specified	Not reported
Mohr 2010 [52]	Tx $n = 21$; cont $n = NA$	Depression	Research clinic	Self-administered psychotherapy with therapist support	NA	Web-based	SG pre--post	No	Weekly = 91%	Yes	Positive
Mohr 2015 [34]	Tx $n = 8$; cont $n = NA$	Depression	Internal medicine clinic	Self-administered psychoeducation	NA	Smartphone app	SG pre--post	No	NA	Not specified	Positive
Newby 2017 [17]	Tx $n = 42$; cont $n = 49$	Depression	Research clinic	Self-administered psychotherapy with therapist support	TAU	Web-based	RCT	No	NA	Yes	Positive
Niendam 2018 [31]	Tx $n = 76$; cont $n = NA$	Psychotic disorder	Outpatient specialty mental health	TAU	NA	Smartphone app	SG feasibility	Yes	Daily = 69%; weekly = 77.3%	NA	NA
Pramana 2014 [35]	Tx $n = 9$; cont $n = NA$	Anxiety	Not reported	In-person and self-administered psychotherapy	NA	Smartphone app	SG feasibility	No	NA	NA	NA
			Primary care	TAU		Smartphone app	RCT	Yes	Weekly = 72.25%	Yes	

Table 1 (continued)

Study	*N*	Psych disorder	Setting	Treatment	Control	RMBC platform	Study design	RMBC isolated	Response rate (%)	ITT	Clinical effectiveness/ efficacy
Reid 2011 [38], 2012 [53], 2013 [39]	Tx $n = 69$; cont $n = 49$	Various mental health concerns			TAU with activity monitoring						No significant difference
Robertson 2006 [26]	Tx $n = 14$-4; cont $n = NA$	Depression	Various	Self-administered psychotherapy and psychoeducation	NA	Web-based	SG pre--post	No	NA	Not speci-fied	Positive
Sheeran 2011 [29]	Tx $n = 48$; cont $n = NA$	Depression	Homecare agencies	Collaborative care	NA	Home telehealth monitor	SG pre--post	No	NA	Not speci-fied	Positive
Simon 2011 [19]	Tx $n = 10$-6; cont $n = 102$	Depression	Primary care	TAU	TAU	Secure messaging	RCT	Yes	Monthly = 82%	Yes	Positive
Simon 2017 [54]	Tx $n = 79$; cont $n = NA$	Bipolar disorder	Research clinic	TAU	NA	Text messages or email	SG pre--post	Yes	Weekly = 82%	NA	NA
Smith 2012 [55]	Tx $n = 27$; cont $n = NA$	PTSD	Residential PTSD and TBI treatment center	Minimal therapist support	NA	Text messages	SG pre--post	No	Monthly = 92.67%	NA	NA
Španiel 2008 [15], 2008 [56]	Tx $n = 73$; cont $n = NA$	Psychotic disorder	Outpatient specialty mental health	TAU	TAU	Text messages	SG pre--post	Yes	NA	Not speci-fied	Positive
Tolin 2017 [32]	Tx $n = 69$; cont $n = NA$	Panic disorder	Research clinic	Biofeedback	NA	Smartphone app with CO2 sensor	SG pre--post	No	Daily = 84.1%	Yes	Positive
Volker 2015 [40], 2017 [57]	Tx $n = 13$-1; cont $n = 89$	Depression, anxiety, or somatization	Outpatient occupational health clinic	Self-administered psychotherapy and psychoeducation	TAU	Web-based	RCT	No	NA	Yes	Positive/no significant difference
Watts 2013 [22]	Tx $n = 35$; cont $n = NA$	Depression	Not reported	Self-guided intervention	NA	Web- or smartphone--based	RCT	No	NA	Not speci-fied	Positive

N/n sample size, *RMBC* remote measurement-based care, *RMBC isolated* study design examined the effects of RMBC alone and not combined with other treatment components beyond treatment-as-usual, *Response rate %* of RMBC assessments completed, *ITT* intent-to-treat, *Tx* treatment group, *Cont* control group, *RCT* randomized controlled trial, *No significant difference* no statistically significant difference between groups or within RMBC group over time (for single group designs) on psychiatric symptoms, *Positive* improvements on psychiatric symptoms in the RMBC group relative to the control group or within RMBC group over time, *Negative* increase of psychiatric symptoms in the RMBC group relative to the control group or within RMBC group over time, *NA* not applicable/not reported, *SG* single group, *TAU* treatment-as-usual, *PTSD* posttraumatic stress disorder, *TBI* traumatic brain injury

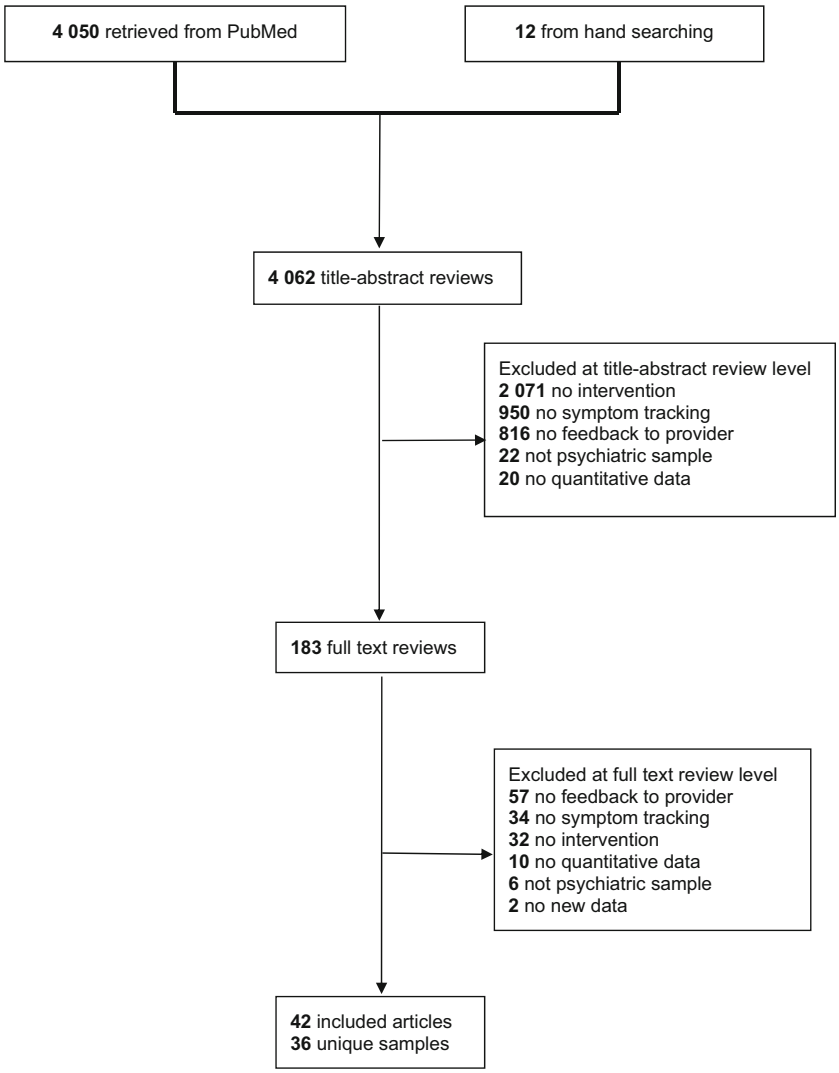

Fig. 1 PRISMA flow diagram

provider outreach to patients (e.g., alert provider to contact patient if symptoms worsen beyond a pre-specified threshold [15]) in approximately half of the studies ($k = 17$). A minority of studies isolated RMBC ($k = 10$), which we defined as including a treatment arm exclusively involving the remote assessment of symptoms with communication of these results to a treating provider, with very limited additional intervention beyond TAU provided. RMBC was most often examined as part of a multicomponent intervention including additional treatment ingredients such as various forms of TAU ($k = 10$), self-guided interventions (e.g., smartphone app with CBT content [22]), or in-person psychotherapy [20••].

The vast majority of studies were single group designs ($k = 21$), either assessing clinical outcomes ($k = 12$) or only feasibility and acceptability outcomes ($k = 9$). Two studies were non-randomized clinical trials and 13 were RCTs. The majority of studies reported data related to feasibility and acceptability ($k = 32$), with 24 studies reporting data related to clinical effectiveness. Only three studies were identified that used a randomized controlled design, experimentally isolated RMBC, and reported data on clinical effectiveness.

Feasibility and Acceptability

A variety of metrics of feasibility and acceptability were reported across 32 studies. A commonly reported metric of RMBC adherence/acceptability was participants' response rates to symptom monitoring. Average response rates were similar for daily (73.58%) and weekly (79.23%) assessment, and somewhat higher for assessments made monthly or less frequently (87.34%, although based on $k = 2$). Several studies reported declining response rates over time [23•–26]. The lowest response rate for both daily (41%) and weekly (39%) assessments was Kumar et al. [27]. As the authors discuss, response rates may have been impacted by staff turnover at the clinic and technical difficulties with the mobile health platform.

Several studies reported additional measures of feasibility and acceptability, although variations in assessment methodology across studies made aggregation impossible. In general, satisfaction with RMBC, either as a stand-alone assessment or part of a multicomponent intervention, was moderately high (e.g., 77% [23•], 87% [28]; 83% [29]; 75% would participate again [30]; 83% would be open to using as a part of treatment [31]). When reported, the majority of participants said they would recommend the RMBC intervention (again either as a stand-alone assessment or part of a multicomponent intervention) to a friend (e.g., 100% [28]; 61% [27]; 88% [32]; 64% in [22]). Ease of use ratings were similarly positive [29, 33–35]. Technical difficulties associated with the RMBC platform were reported by a minority of participants in some studies (15–23% [27]), although not all platforms had difficulties [30].

Clinical Effectiveness

Data pertaining to clinical effectiveness were reported in 24 studies, half of which reported ITT analyses ($k = 12$). Nine studies used single group designs, with 8 out of 9 reporting positive within-subject effects of the intervention. However, all but one of these studies included RMBC as part of a multicomponent intervention, prohibiting the possibility of isolating the clinical benefits of RMBC. Two studies used non-randomized clinical trial designs. Both reported equivalent between-group effects in the RMBC and comparison condition, with neither trial incorporating a control group that differed from the intervention group only in its omission of RMBC, thus not experimentally isolating RMBC. Among the 13 RCTs, seven reported larger effects in the RMBC condition than the control condition. The remainder either reported no statistically significant differences between the RMBC control conditions or did not include comparisons between the RMBC and control conditions [36•].

The largest RCT compared RMBC combined with collaborative care ($n = 509$) to RMBC alone ($n = 509$) in a sample of participants with depression and/or anxiety symptoms [37]. RMBC involved telephone monitoring of symptoms. While patients in both groups improved significantly over time, effects were larger in the RMBC combined with collaborative care condition than in the RMBC alone condition (effect sizes at 6-month follow-up = 0.24 and 0.28, for depression and anxiety symptoms, respectively).

RCTs that isolated the effects of RMBC provide the most direct evidence related to the effectiveness of RMBC in the treatment of psychiatric conditions. Three trials met these criteria. Two of these studies found no differences between RMBC and the comparison condition. Aharonovich et al. [20••] compared an in-person implementation of motivational interviewing augmented with symptom monitoring via automated telephone calls ($n = 80$) to motivational interviewing without monitoring calls ($n = 77$) within a sample of individuals with four or more days of non-injection drug use in the past 30 days. Both groups reduced substance use over the course of the intervention and the between-group risk ratios (RR) did not differ between the RMBC and non-RMBC condition [RRs = 1.02 to 1.60 favoring the motivational interviewing only condition, for number of days and quantity of use, at all time points (end of intervention to 12-month follow-up)]. Reid et al. [38] compared primary care TAU augmented with symptom and activity tracking via a smartphone app ($n = 69$) with primary care TAU and activity tracking only in a sample of youth (age 14 to 24) with a variety of mental health concerns. As in Aharonovich et al. [20••], both groups decreased on psychiatric symptoms (ds = 0.53, 0.46, for depression and anxiety symptoms, respectively), with no statistically significant differences in outcomes between the RMBC and non-RMBC conditions (ds = 0.07 to 0.09 favoring the RMBC condition, for depression and anxiety respectively).

One relatively large trial reported larger effects in the RMBC condition relative to non-RMBC TAU. Simon et al. [19] examined the effect of primary care TAU augmented with monthly RMBC through secure messaging within the medical record monitored by a nurse care manager ($n = 106$) compared to primary care TAU ($n = 102$) in a sample of participants diagnosed with depression. Using an ITT analysis at 5-month follow-up, participants in the RMBC condition reported lower depressive severity compared with the non-RMBC condition ($d = 0.29$) and were more likely to show a 50% or more reduction in depressive symptoms (odds ratio = 1.80).

Other Outcomes

A variety of non-clinical outcomes were reported across studies. Several studies reported increased treatment attendance, treatment seeking, and referrals associated with RMBC [16, 19, 21•], although other studies did not find effects on these outcomes [19, 36•, 39, 40]. Several studies reported increased medication adherence associated with RMBC [19, 41] as well as improvement on non-targeted psychological outcomes (e.g., well-being [17]). Given the study designs employed, these effects generally cannot be definitively attributed to RMBC.

Limited information was reported regarding changes in providers' knowledge or behavior in reaction to RMBC information from patients (with one exception [39]). Likewise, none of the studies examined whether patients with symptoms that were not improving had more frequent/intensive treatment (e.g., changes to the treatment plan, consultations, referrals) or whether patients responding well to treatment had the frequency/intensity of treatment decreased in order to expand their providers' capacity to treat patients with greater need.

Discussion

The current systematic review sought to summarize research on remote measurement-based care (RMBC), characterized by the assessment of patients' psychiatric symptoms outside of the clinical encounter paired with asynchronous communication of symptom information to providers. The 41 studies representing 36 unique samples reviewed provide a depiction of current knowledge on RMBC, highlighting several known features of RMBC and important gaps in the literature.

What We Know About RMBC

Feasibility and Acceptability Studies used a wide variety of metrics for assessing and reporting feasibility and acceptability, making firm conclusions difficult. Among the studies that reported percentage of messages returned, adherence/acceptability appeared promising (response rates 73.58 to 87.34%). Several studies reported decreased responsiveness over time [23•, 24•], which may raise questions regarding the feasibility of long-term, routine RMBC in ongoing treatment settings. It also may be that acceptability varies, depending on a variety of factors, including whether RMBC is part of an automated assessment system or is initiated by or communicated directly with a provider or care manager known to the patient [19].

From a technological standpoint, it appears that a variety of methods are feasible to implement RMBC, including text messages, smartphone apps, websites, and secure messaging within medical records. Few technical difficulties were reported. Three studies used passive sensing technologies that may provide templates for assessment methods that reduce patient burden. Of course, establishing the validity of passive sensing data as a marker for psychiatric symptoms is an area of active research [14, 42].

Clinical Effectiveness Multicomponent interventions using RMBC, including remotely delivered interventions, appear generally effective at reducing psychiatric symptoms. Due to the limited number of RCTs experimentally isolating the effects of RMBC, the clinical effectiveness of RMBC specifically is less clear. However, the positive clinical effects observed in the largest trial isolating the effects of RMBC are encouraging (Simon, 2011). Another large trial found that RMBC alone is clinically effective, although not as effective as RMBC combined with collaborative care [37].

What We Do Not Know About RMBC

Despite some promising evidence in support of RMBC (at least when coupled with other intervention components, e.g., CBT [17]), the existing literature leaves many questions unanswered. Most fundamentally, few studies were conducted in a way that the specific, isolated effect of RMBC could be determined. While our sample included 13 RCTs overall (the strongest design for demonstrating casual influence), most of these studies implemented RMBC as part of a more comprehensive treatment package. In these instances, the presence of positive RCT results leaves open the question of RMBC's additive (or subtractive) effects. Only three trials reported between-group comparisons and isolated RMBC in a RCT, with two small trials reporting no differences between RMBC and the non-RMBC comparison and one larger trial reporting benefits associated with the RMBC arm. The one trial that found benefits associated with RMBC included symptom monitoring in the context of primary care TAU for depression and involved a care manager emailing patients encouraging them to complete assessments. We construed this care manager as a part of RMBC because their only role was to monitor treatment response. Future research may be necessary to examine whether having human support involved in RMBC is essential for effectiveness.

In addition, the included studies provided relatively little insight into how or if providers were using remotely assessed patient symptom data. Technology-augmented interventions have the capacity to generate massive amounts of user data (e.g., through passive sensing [13]) and risk overloading providers with information. Important clinical signals can thereby get lost in a sea of incoming information. These issues could be addressed by the development of systems that are capable of processing RMBC data that do not rely on human effort (e.g., nurse care managers processing PHQ9 data [19]). Such systems could involve easily interpreted data representations, through visualizations of change over time or other user-centered technologies.

Future Research Directions

These open questions suggest several potentially fruitful avenues for future research. First, randomized controlled effectiveness trials comparing RMBC to TAU are needed for a range of populations and treatment settings in order to estimate the isolated effect of RMBC on provider behavior and patient clinical outcomes. To assess whether RMBC has the potential to improve population health, clustered randomized trials are also needed to determine if RMBC is able to safely reduce the frequency/intensity of services for less symptomatic patients in order to free up provider capacity to reach more symptomatic patients. For trials focused on improving population health, RMBC may need to be paired with engagement interventions to help symptomatic patients facing multiple barriers present for care. Future research could also assess whether RMBC is more effective or more acceptable in certain patient populations (e.g., younger individuals for whom technology may be more familiar or integrated into daily routines).

Given declining response rates over time noted in several of the included studies, future RMBC may rely more heavily on passive sensing technologies [13, 42]. While in its infancy, passive sensing has the potential to collect valuable patient symptom data with minimal patient burden. These data could then be paired with technologies capable of translating sensor data into clinically actionable feedback to providers.

Limitations

The primary limitation of the current study relates to the literature search. Given the wide variety of studies that could be considered RMBC, we relied on broad search terms. It is possible that some potentially eligible studies were missed in this way. Likewise, due to the heterogeneity of outcomes and study designs, we were not able to conduct a meta-analysis.

Conclusions

Technological advances in recent decades have increased the viability of assessing patients' psychiatric symptoms remotely. This practice has the potential to increase providers' awareness of their patients' response to treatment and to inform clinical decision-making. While it appears that monitoring patients' symptoms remotely is generally feasible and acceptable, the specific impact of RMBC on clinical and health service utilization outcomes is largely unknown. Additional research is needed to determine whether RMBC, like encounter-based MBC, can improve the quality and efficiency of mental health treatment.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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- •• Of major importance

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