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Digital health interventions to improve adherence to oral antipsychotics among patients with schizophrenia: a scoping review

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ABSTRACT

Objectives To assess the current evidence on the potential of digital health interventions (DHIs) to improve adherence to oral antipsychotics among patients with schizophrenia by assessing the methodologies, feasibility and effectiveness of DHIs as well as the perceptions of relevant stakeholders.

Design The scoping review was conducted based on the methodologies outlined by Levac *et al* and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews guidelines.

Data sources PubMed, Embase, Web of Science, Scopus, CINAHL, PsycINFO and the Cochrane Library were searched in August 2023 to identify relevant publications from the previous decade.

Eligibility criteria Studies published in English focused on improving medication adherence among adult patients with schizophrenia or schizoaffective disorder via DHIs were selected. Protocols, editorials, comments, perspectives, reviews, correspondence and conference abstracts were excluded.

Data extraction and synthesis The extracted data included general information about the study, framework, participants, features and strategies of DHIs, measurement tools for adherence used, and main findings.

Results In total, 64 studies were included in the qualitative synthesis. Features used in DHIs to improve medication adherence included phone calls, text messages, mobile apps, sensors, web-based platforms and electronic devices. Strategies included medication reminders and monitoring, providing medication-related information and suggestions, other illness management suggestions and individual support. Texting and mobile apps were commonly used as medication reminders and monitoring methods. Additionally, the use of sensors combined with other digital technologies has garnered significant attention. All the interventions were considered acceptable and feasible, and several were assessed in pilot trials. Preliminary findings suggest that DHIs could enhance medication adherence in patients with schizophrenia. However, further validation of their effectiveness is required.

Conclusion DHIs are a promising approach to enhancing medication adherence among patients with schizophrenia. Future interventions should be interactive, focusing on user preference, experience and privacy.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ We developed a comprehensive search strategy for seven electronic databases using a combination of Medical Subject Headings, Emtree, Index terms and keywords.

⇒ The Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews checklist was followed for results reporting.

⇒ The scoping review methodology allowed for assessing various articles and identifying opportunities and gaps in delivering digital health interventions for adherence enhancement in patients with schizophrenia.

⇒ We could have missed some data by not including results from the grey literature and non-English language studies.

INTRODUCTION

Schizophrenia is one of the most common severe mental diseases, with persistent clinical, cognitive and social deterioration, causing high social and economic costs.[1] A significant strategy for tackling this burden involves the universal coverage of cost-effective interventions for mental disorders.[2] Patients with schizophrenia typically need to take antipsychotics for a long time to help themselves manage symptoms and prevent self-harm, violence, relapse, hospitalisation and other negative consequences.[3–7] A previous investigation indicated that lack of adherence to antipsychotics was the strongest relapse predictor in patients with schizophrenia.[8]

Based on the meta-analysis, adherence to antipsychotics was only 71.1%, even when the most liberal adherence classification was employed as an indication. This was still below the 80% cut-off used to designate satisfactory adherence.[9] Additionally, medication adherence of patients with schizophrenia tended to deteriorate with time as the follow-up period after lengthening discharges.[10] Poor

medication adherence in patients with schizophrenia is a severe and widespread problem. However, it is challenging to address due to the complexity of the underlying factors, such as psychosocial, demographic and clinical aspects.[11] Various interventions have been used to improve medication adherence among schizophrenic patients, including cognitive–behavioural therapy (CBT), psychoeducation, motivational interviewing techniques and mixed interventions.[12] However, several interventions require specific therapist training or in-home visits. These interventions are logistically challenging and may not be affordable.

WHO published a report entitled 'Global strategy on digital health 2020–2025', which showed that digital technologies were essential to sustainable health systems and universal health coverage.[13] Digital health, or eHealth, uses information and communication technologies and networks to manage, deliver and optimise patient care and health services and assist patients.[14] Digital health interventions (DHIs) have been used with patients suffering from chronic diseases, such as hypertension, asthma and diabetes, to adhere to medications and have better health outcomes.[15–17] Numerous digital advancements provide a wide range of possibilities for psychiatry, from smartphones and virtual reality headsets to the underlying developments in data analytics and machine learning.[18] The COVID-19 pandemic accelerated the digital progress in mental health.

Researchers have investigated different digital approaches to support and monitor medication adherence among patients with schizophrenia. These included electronic medication monitoring devices, smartphone-based apps and digital ingestion tracking systems. The methods have been increasingly proposed and tested as potential clinical and economical solutions to encourage self-management, monitor relapse signs through self-reporting, and improve attendance rate for routine appointments and medication adherence.[19–22] Recent DHI advancements may offer viable methods to regulate medication adherence.

However, a thorough overview of DHIs to improve medication adherence in patients with schizophrenia is lacking. Rather than offering an in-depth review of digital technologies, previous studies primarily concentrated on applying a particular digital technology, such as mobile phones, to manage schizophrenia. A systematic review indicated telemedicine interventions may improve medication adherence in patients with depression, bipolar disorder or schizophrenia. Future studies should assess the feasibility of telemedicine interventions to improve medication adherence.[23] A systematic review from 2020 attempted to explore mobile technologies for the treatment and management of schizophrenia.[24] The authors observed that current mobile devices provided patients with more control over their ability to initiate, participate and engage in treatment. A study from 2021 evaluated treatment-related determinants and a range of strategies to enhance adherence among individuals with

schizophrenia.[25] The review provided a general introduction rather than discussing the specific characteristics and effectiveness of various digital technologies. The overall impact of interventions on medication adherence in individuals with schizophrenia or bipolar disorders was evaluated in a systematic review and meta-analysis from 2021.[12] Due to differences in the study methodology, the interventions, and the outcome measurements, no firm conclusions could be drawn regarding the most effective intervention to improve medication adherence in patients with schizophrenia.

A scoping review was conducted to assess the available research due to the availability of literature and heterogeneity of digital interventions with varying degrees of success. Scoping reviews provide a preliminary evaluation of the size and breadth of available literature on a topic and describe the nature of published studies, delivering an overview. Additionally, scoping reviews offer a foundation for more focused systematic reviews to develop specific research questions. Therefore, the purpose of this scoping review was to determine the future utility of DHIs in schizophrenia and to evaluate the different investigated options.

Objectives

To address the urgent issue of non-adherence to antipsychotic medication in schizophrenia, the scoping review aimed to explore the known information about DHIs for enhancing medication adherence in schizophrenia and determine the reported findings on the utility, acceptability, uptake, effectiveness and adoption of DHIs to improve antipsychotic medication adherence among patients with schizophrenia, and explore perceptions of patients with schizophrenia, their caregivers and healthcare professionals (HCPs) towards enhancing adherence to antipsychotics through DHIs.

METHODS

According to the methodology outlined by Levac *et al* and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews guidelines, a scoping review was conducted that included identifying the research question, relevant studies, study selection, data charting, collating and reporting the results.[26 27] This scoping review attempted to provide a thorough literature overview without focusing on a specific research subject.

Search terms

We searched PubMed, Embase, Web of Science, Scopus, CINAHL, PsycINFO and the Cochrane Library between 1 January 2010 and 31 August 2023. The search terms and strategies adapted for each database are reported in online supplemental file 1.

Inclusion criteria

Studies having participants older than 18 years and diagnosed with schizophrenia or schizoaffective disorder

through any criteria were included. DHIs included telemedicine, telehealth, mobile health or mHealth, health informatics and wearable devices. All the DHIs in clinical and community-dwelling settings that could improve antipsychotic treatment adherence among patients with schizophrenia were included. We also included studies on how patients, caregivers and HCPs felt about digital interventions. The publications written in English were only incorporated.

Exclusion criteria
Studies that were protocols, editorials, comments, perspectives, reviews, correspondence and conference abstracts were excluded.

Data extraction
Duplicates from the gathered items were eliminated using a reference manager (EndNote V.X9; Clarivate Analytics, Philadelphia, Pennsylvania). The titles and abstracts of the remaining articles were reviewed by two authors independently. A third author adjudicated discrepancies based on the eligibility criteria. The second round of screening was carried out after obtaining the full-text articles (two independent reviewers worked, and a third reviewer performed adjudication).

Data charting process and analysis
Data collation focused on the summary of information in included studies. A narrative synthesis was undertaken through established guidance. A standard data extraction form was created, and the information was charted as follows: article title, first author's name, year, country; study framework; study participants; features and strategies of DHIs; measurement tools of adherence used; and main findings. Two reviewers separately extracted the data, and discrepancies in the data extraction were settled through a consensus among the reviewing team.

Patient and public involvement
None.

RESULTS
In total, 2190 publications were identified. After the removal of duplications, 1281 publications were identified. After assessing titles and abstracts for relevance following the inclusion criteria, 274 articles were left for full-text screening. After a full-text assessment, 210 articles were eliminated, leaving 64 papers for use in this scoping study (figure 1).
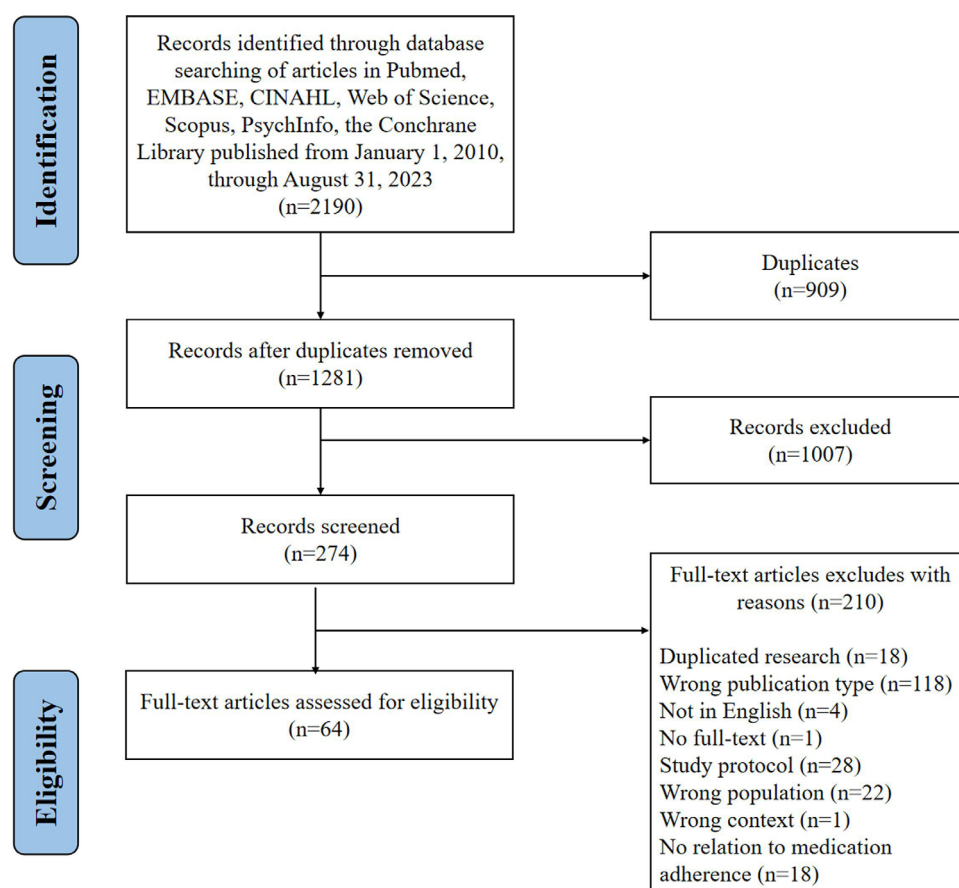

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews flow diagram for the literature search and selection process.

Characteristics of included articles

Of the included studies, 44 were interventional studies, comprising 22 randomised controlled trials (RCTs), 11 pilot studies and other interventional studies (online supplemental file 2). Twenty-three studies were from the USA, four were from China, three were from the UK and two were from Spain. Germany, Turkey, Switzerland, South Africa, Poland, Netherlands, France, Finland, Czech Republic, Canada, Australia and Oman had one study each. Twenty-two articles investigated the digital intervention perceptions of patients, their caregivers and clinicians.

Characteristics of study populations

Among the population of the included studies, the average participant age ranged from 28.8 to 53.7 years old. Most patients recruited were in symptomatic remission from community mental health team settings or discharged from psychiatric hospitals.[28–30] Acutely psychotic schizophrenic individuals, those requiring hospitalisation, or high-risk relapse status, defined by a recent hospitalisation in the past 2 years, were excluded.[31] Španiel et al[32] provided an information technology-aided program of relapse prevention for patients with schizophrenia who had an increased relapse risk, defined as having had at least one hospitalisation for psychosis in the past 3 years and at least two hospitalisations in total. Granholm et al[33] observed that non-completers of intervention possessed lower self-reported living skills, more severe negative symptoms and lower estimated premorbid verbal IQ than completers during their interactive text-messaging intervention. Few studies required patients to have smartphones and the ability to use apps on smartphones provided by researchers.[34 35] Some patients allocated to the intervention arm who did not own mobile phones were provided the same for the study.[36 37]

Strategies and features of intervention delivery

Various adherence-enhancing strategies were employed in the reviewed studies. Delivery of included interventions was through phone calls, text messages, mobile apps, sensors and electronic devices (figure 2). Most phone calls were made to individuals with schizophrenia to offer weekly individualised and targeted support.[29–31 38–41] HCPs-assisted outpatients with schizophrenia spectrum disorders (SSDs) through the problem-solving process of addressing adherence-related difficulties, including providing knowledge about medication, attending appointments and coping with symptoms. Moreover, Burda et al[42] conducted daily telephone interviews,
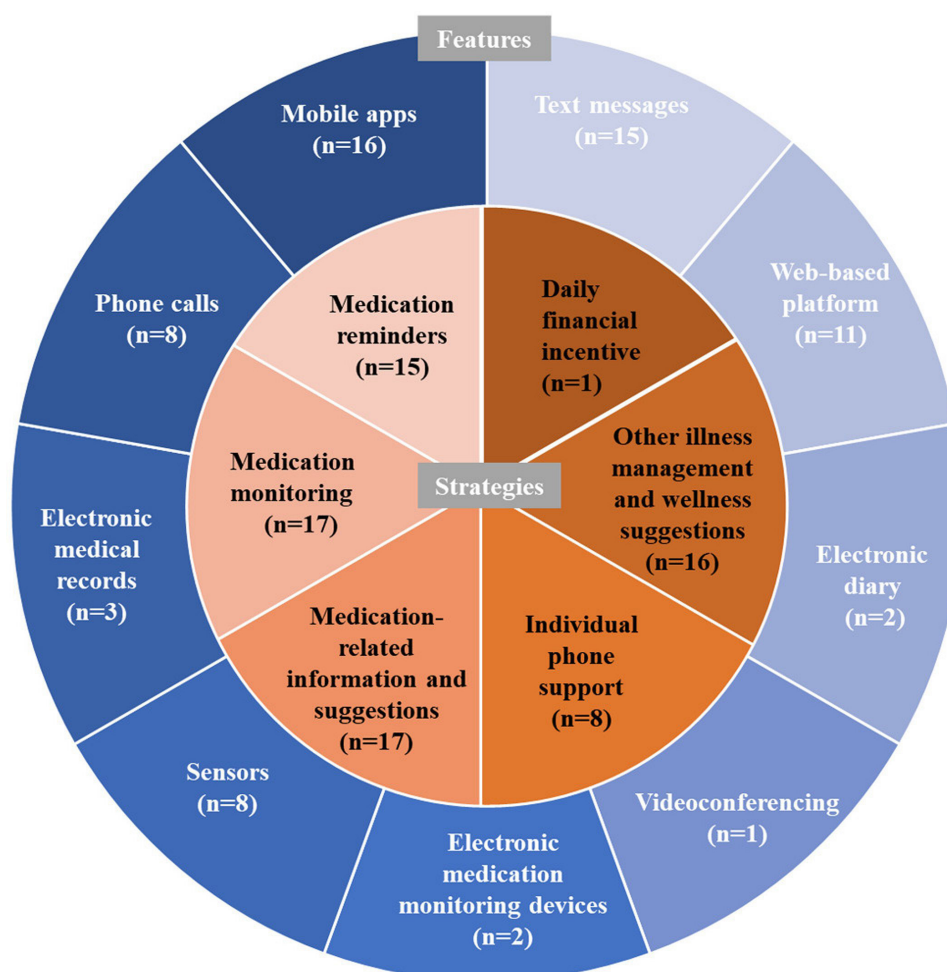

Figure 2 Features and strategies of digital health interventions.

incorporating a medication-taking survey and side effects via an interactive voice response system. Then, the patients responded by pressing '1' or '9'.

Text messages were used to send medication-taking reminders.[31 34 36 41 43–48] The frequency and content of SMS delivery varied across the studies. Patients were reminded to take antipsychotics once or two times a day, with compulsory messages lasting 3–12 months. Messages were provided for patients to remind them of visits and to advise them regarding early relapse warning signals and medication side effects for self-monitoring.[32 46 48 49] Meanwhile, CBT techniques were introduced into messages in Granholm et al's study.[33] Participants were encouraged through SMS to challenge problematic ideas and undertake behavioural practice. Moreover, patients' thoughts regarding medication, socialising and voices were elicited. In Xu et al's study, lay health supporters were selected from the patient family or the community, who undertook simple tasks, such as medication management and keeping track of side effects and relapse.[47] When patients failed to confirm that the scheduled medication had been taken, lay health supporters would check in with the patients and text back the results.

Based on the included studies, mobile apps served as medication reminders and monitors. These were information platforms where patients learnt about illness self-management and coping strategies for medication-related difficulties while transmitting adherence data to a secure cloud-based service.[28 35 37 50–59] In addition to reminders of appointments and events, reminders on mobile apps were also sent to patients in most of the included trials for taking their medicine. Mobile apps helped promote patients' ability to self-management, including educational information on managing symptoms and medication, cognitive rehabilitation and psychosocial strategies. These apps taught users active coping strategies to face illness-related difficulties. The original telemedicine platform (Telemedicine MoneoPlatform) was preinstalled on a smartphone by Krzystanek et al. This facilitated patients to initiate videoconferences with clinicians, observe educational video recordings, engage in cognitive training and schedule appointments at outpatient clinics.[28] Besides app-based medication reminders for successful check-ins, Guinart et al provided patients with rewards based on the loss aversion strategy.[60]

The digital medicine system (DMS) is a novel medication adherence assessment device developed to help HCPs evaluate patients' adherence to antipsychotics.[37 55–58 61–63] The wearable sensor patches detect a signal from the ingestible aripiprazole tablets with a sensor integrated into digital medicine and triggered in the stomach after patient consumption. Mobile apps receive the signal from the wearable sensor, delivering the information to the cloud-based server. Kopelowicz et al[37] set up an integrated call centre to help patients use the DMS. This call centre logged incoming and outgoing calls from and to patients with coordinated feedback to patients and research sites. Web-based platforms served as decision-aid tools for antipsychotics, automated non-adherence and served as risk monitoring.[64–67] Electronic devices, such as an electronic diary,[67] medication monitoring[68 69] and electronic medical records,[70] were incorporated to track and record medication-taking.

The framework of DHIs
Overall, five studies reported using a design framework as a guide during the development process of DHIs. In the studies by Xu and Cai et al, the development of lay health supporters, e-platform, awards, and iNtegration was guided by the health belief model as a theoretical framework.[43 44 47] This theory holds that individuals with schizophrenia may take their medications consistently provided they are 'cued' to act after assessing the advantages of medicine against the perceived disease threat. This framework allows patients to participate in safety procedures like text messaging to remind them to take medicine.

Based on the theory of planned behaviour, behavioural attitude, subjective norm and perceived behavioural control influence behavioural intention. According to the authors, telephone intervention-problem solving (TIPS) for SSDs includes these elements of adherence intention.[30 38 39] Throughout TIPS sessions, nurses discussed and emphasised the necessity for adherence, informed participants of its advantages, and helped them overcome adherence-related difficulties.

Self-determination theory analyses human motivation through intrinsic and extrinsic motivational factors. This theory emphasises that internalisation and integration help people develop and sustain self-regulatory behaviours conducive to their health and well-being. Välimäki et al[46] carried out a customised, patient-led intervention of SMS in which the participants selected the content, time, frequency, and conditions of SMS.

Measuring tools for medication adherence
Online supplemental file 2 demonstrated measuring medication adherence tools used in the included studies. Among the included studies, 10 used 2 or more measuring tools.[29 30 43–45 47 52 53 67 69] Self-report instruments were used in half (25/44, 56.8%) of the included studies to measure adherence. Seven studies included the Brief Adherence Rating Scale.[34 35 43 44 47 52 53] It was followed by Drug Attitude Inventory-10 (6 studies),[29 43–45 47 67] Medication Adherence Rating Scale (5 studies),[30 36 39 48 59] and Medication Adherence Questionnaire (3 studies).[45 54 67] Finally, five studies used other self-reporting tools,[30 32 41 50 52] and seven tools were not validated.[28 29 33 42 49 60 70] This was often developed following the uncommon operational definitions of medication adherence. For instance, Krzystanek et al[28] employed the dosage percentage confirmed by the patient regarding the planned ones to determine adherence.

Pill counts were the most frequent objective instruments to measure adherence, with six studies using it.[38 40 43 44 47 69] Four studies calculated the medication

refilling records,[43 44 47 61] the proportion of days covered (three studies)[55 63 64] and serum medication levels (one study).[38]

Five studies measured adherence using data from electronic or digital devices. In this group, three studies used data from digital technologies to evaluate adherence,[57 62 69] and medication event monitoring systems were used in two studies.[31 68] Finally, eight studies did not report the measurement tools.[37 46 51 56 58 65 66 71]

Acceptability, usability and feasibility of interventions

Overall, all DHI types to improve medication adherence of patients with schizophrenia reviewed were acceptable and feasible. Their implementation was practical, even if this aspect was not thoroughly explored.[35 36 48 50 52 53 56–58 63 65 72–78]

Text messages to improve antipsychotic medication adherence were feasible and acceptable for most patients with schizophrenia. Reportedly, patients found smartphone-based therapies to be practicable and permissible. Most patients were satisfied with digital technologies and ready to use them. Notifications could occasionally be viewed as unwanted if sent out frequently, repeatedly, or at the wrong times.[79] Though device-associated and treatment-emergent adverse events, mainly causing medical device skin irritations, were often modest and self-limiting, a significant percentage of patients could use the DMS with satisfactory outcomes.[56]

Efficacy of included DHIs

Most included interventional studies (19 studies) observed that DHIs could significantly improve medication adherence among patients with schizophrenia.[29 33 34 38–41 43 45 47 52 54 55 59–61 64 67 69] However, 11 studies found no significant impact in any of the measured adherence outcomes[28 30 31 35 36 44 48–50 63 70]; the remaining 14 studies reported no relevant adherence-related outcomes.[32 37 42 46 51 53 56–58 62 65 66 68 71] In figure 3, evidence of technologies used with reported outcomes of the studies regarding medication adherence is shown.

Uslu and Buldukoglu[39] employed the Medication Adherence Rating Scale to measure medication adherence in patients with schizophrenia. They found a significant improvement in adherence was observed among patients receiving individual phone support for 2 months than in the control group (9 vs 4, p<0.001). However, Beebe et al[30] observed that self-reported medication adherence was higher in experimental participants after 3 months, with no statistically significant differences (7.4 vs 6.8).

Xu et al[47] provided for patients with schizophrenia in a resource-poor community in rural China, including medication reminders and medication-related information with support from lay health supporters for 6 months. They observed that medication adherence determined by pill counts was 0.48 and 0.61 in the waitlist control and intervention groups (adjusted mean difference 0.12,
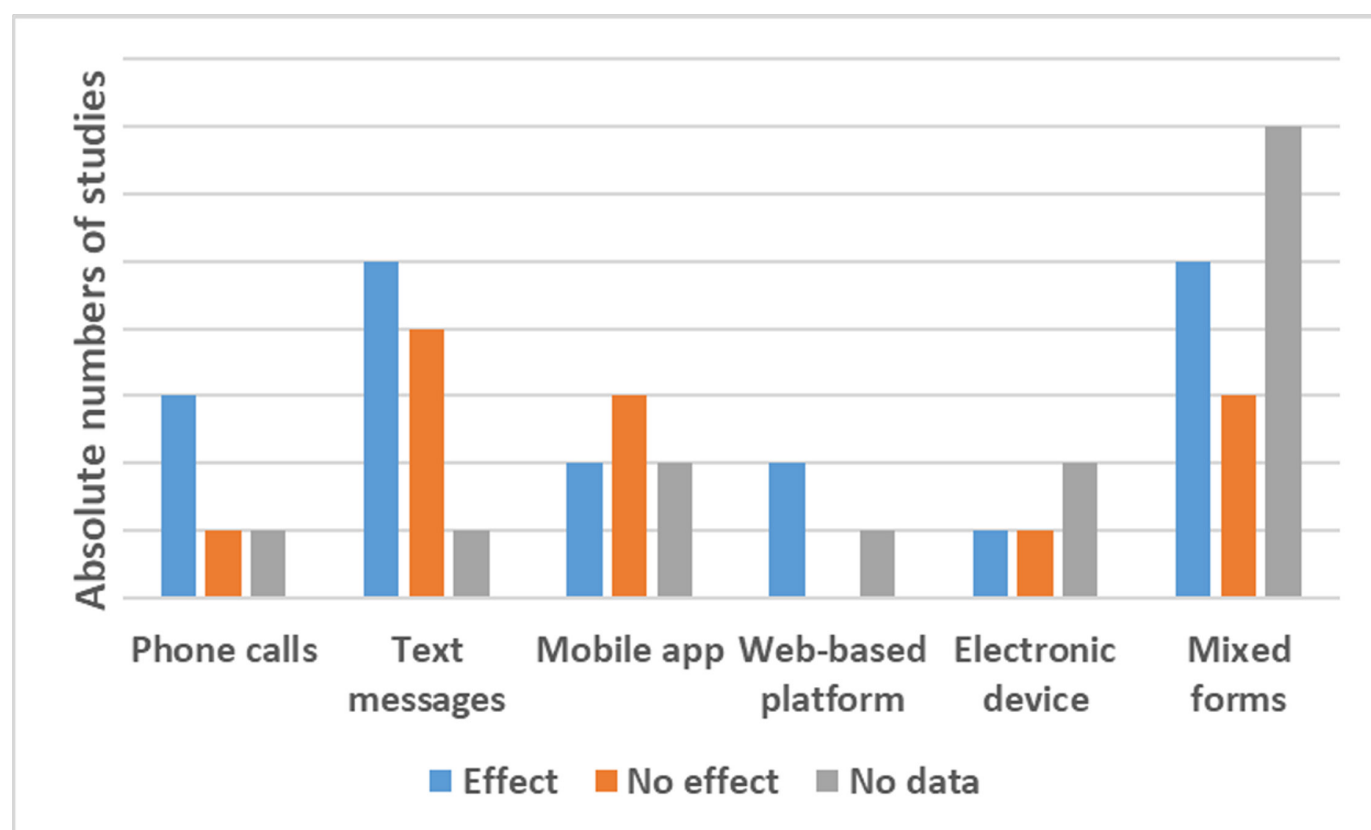

Figure 3 Evidence of medication adherence for digital health interventions classified by features.

95% CI 0.03 to 0.22; p=0.013; effect size 0.38). After the participants from the waitlist control group received the same intervention, Cai et al[13] observed that antipsychotic medication adherence improved from 0.48 in the control period to 0.58 within the extended intervention period (adjusted mean difference 0.11, 95% CI 0.04 to 0.19; p=0.004). However, Cai et al[14] conducted an 18-month follow-up survey after trial discontinuation, with no statistical difference in antipsychotic adherence (adjusted mean difference 0.05, 95% CI −0.06 to 0.16; p=0.41). Cullen et al[34] sent text messages, such as daily symptom check-in text messages, with a medication reminder or inspirational quote text, to patients with schizophrenia or schizoaffective disorder for 6 months. There was improved oral medication adherence of patients based on the Brief Adherence Rating Scale at 3 and 6 months in the intervention group. However, the differences were insignificant (69% vs 89%, p=0.11). Medication adherence determined by Medication Adherence Rating Scale in two pilot RCTs regarding text messages involving medication reminders or details about clinic appointments sent to participants undertaken by Röhricht et al (7.6 vs 7.7, 95% CI −0.79 to 0.50) and Sibeko et al (adjusted mean difference 0.49, 95% CI −1.44 to 2.43; p=0.603) could not identify significant changes between groups over time.[36 48]

Most included studies (23 studies) did not report relevant outcomes with psychiatric symptoms as secondary outcomes. Eleven studies reported significantly reduced psychiatric symptoms through interventions,[33–35 40 43 48 50–52 55 62] but six studies observed no significant impact in any of the measured symptoms.[30 38 44 47 69 70] Three studies found that their interventions significantly enhanced function,[43 46 51] but five studies found no difference.[31 47 48 52 69] Eight studies reported the outcome of healthcare use.[32 34 46 47 54 61 66 69] Only two studies observed that their interventions significantly decreased the rehospitalisation rate.[47 66]

Perceptions of DHIs

Digital intervention perceptions to increase medication adherence were discussed in 22 studies. All the interventions were deemed acceptable by groups of patients with schizophrenia, their caregivers and HCPs.

Text messaging equalised the ability of all patients with phones to participate in the intervention because, regardless of their phone type, they could receive and send text messages. Patients with schizophrenia enjoyed the emotional connection when they received text messages, helping them communicate with clinicians, and the majority showed a favourable attitude about texting.[75] Also, getting medication reminders made it easier for individuals to take their medications habitually.[35] Patients preferred messages with individualised content, timing and frequency.[80] Various components of preventative, wellness and illness management for patients with schizophrenia should be provided, except for automated medication reminders.[81] Participants appreciated personal and forceful statements that were inspiring and mildly humorous.[82] Some participants were concerned about data confidentiality and whether messages would reveal information about their disease and what was stated in therapy sessions to others. They recommended referring to the condition as an 'illness' rather than 'schizophrenia' to protect their privacy.[75]

Although technical cost and knowledge challenges were observed, patients were moderately interested in using mobile technologies to support adherence.[83] Mobile technologies facilitate patients to use services like psychosocial intervention strategies, illness self-management techniques and the ability to send other verbal and nonverbal communication anytime and anywhere.[84 85] Other than the symptom management techniques, participants focused on the smartphone-based interventions of scheduling and reminder features.[81 86] Schizophrenic individuals could experience challenges, such as cognitive deterioration while using electronic-based therapies and services. The appearance and organisation of apps should be considered for creating a user-friendly platform.[35 86] For example, an efficient layout with a changeable colour palette. Moreover, the low-level reading language and little overall text were employed to communicate the material meaning.

Patients with schizophrenia believed that a website and an online forum with information on symptoms, medication side effects and possible therapies could gather trustworthy details regarding their conditions.[79] On the one hand, most patients believed web-based decision-aid tools of medication that helped them understand the advantages and disadvantages of their current antipsychotic treatment and incorporate any desired changes were somewhat helpful. This is because using the tool clarified the benefits of antipsychotic medication, its justifications and side effects.[67] Conversely, patients concerned while completing the questionnaires may harbour negative feelings about medication or session outcomes.[75]

Patients with schizophrenia had a positive attitude towards DMS, enabling them to adhere to their antipsychotic medication, and the DMS patch could provide visual reminders.[63] In contrast, the DMS app on the patient's mobile phone could offer medication and missed doses. Patients felt that there were some issues with the DMS requiring improvement. The DMS could be smaller or track drug intake without patches to make it more convenient or reduce skin irritation. For example, the DMS app should be further optimised by sharing data between old and new patches and the app.[63] Caregivers of individuals with schizophrenia preferred digital adherence monitoring tools over non-digital ones. They preferred a pill embedded with an ingestible event monitoring (IEM) sensor system because it tracked patients' medication ingestion, physical activity, quality of rest and self-reported mood.[87] Besides, caregivers emphasised the need for wearable devices, such as smartwatches, to monitor the patient's condition and inform the physicians of the data captured.[79]

According to HCPs, digital technologies could facilitate patients' focus on therapeutic activities and reduce the clinician–patient gap.[75 76 88] The programmes should concentrate more on high-risk patients (ie, recently discharged or newly admitted). HCPs preferred adding messages to engage patients who had missed appointments.[75] Most HCPs thought IEM technology was in their patients' best interest, strengthening patient–provider therapeutic alliances or improving patient engagement with treatment. HCPs could access objective medication ingestion data from patients through the DMS rather than their self-reported adherence. This could guide discussions about medication adherence and treatment plans. However, implementing IEM could be hampered by their worries involving prohibitive technical costs, unclear follow-up actions and responsibility while using it.[89] HCPs also attached importance to building a system for people with low literacy levels and/or cognitive impairments.[85]

DISCUSSION

This scoping review provides an overview of DHIs to enhance adherence to oral antipsychotics in people with schizophrenia. The findings indicate that DHIs have been preliminarily applied in various forms, altering their adherence among patients with schizophrenia to varying degrees. Such interventions focused on reminding, monitoring and recording medication. The interventions provided information and solutions related to oral antipsychotics and illness management, aiding medication decision-making and providing individual phone support through telephone, texting, web-based platforms, mobile apps, sensors and electronic devices. We looked for evidence that various interventions had improved medication adherence and secondary outcomes such as illness severity and healthcare utilisation (by reducing unplanned or emergency consultations) among patients with schizophrenia. The review highlights diverse sources in the interventions and measuring adherence tools among the included studies, limiting the possibility of pooling outcome data in further systematic reviews.

Among the study population, most patients with schizophrenia were stable. This is because acute-stage individuals would not benefit from such interventions due to symptom aggravation and lack of insight. Therefore, the current findings could not be generalisable to a more typical population of patients with schizophrenia. When the schizophrenic symptoms get severe, helping them and their families identify the symptoms of recurrence and providing disease coping strategies becomes crucial.[54] Thus, active and passive patient data—self-reports of symptoms and functioning and sensors that record behaviour and physiology—should be merged to monitor recurrence signs and prevent relapse probability.[50] DHIs could be firmly incorporated with electronic health records (EHRs) in clinical practice. DHIs could be encouraged to self-assess discharge preparedness and report concerns before patients were discharged so physicians could deal with them through EHR data viewed through the safety dashboard.[90]

The adoption of DHIs seems to be yielding conflicting effects. One reason is that this scoping review included all interventions to enhance medication adherence. In contrast, helpful information on medication adherence was provided marginally in some studies, which may not be the most crucial outcome. Text messages and mobile apps were the main features of delivering oral antipsychotic adherence-enhancing DHIs in all included studies. Text messaging could solve issues like restricted accessibility, excessive expenses and ineffective healthcare delivery. However, Välimäki et al[46] identified the overstated power of a simple, one-way, tailored, minimally intrusive, technical approach to alter health behaviour. Such basic and unidirectional medication reminders were insufficient to address complicated problems for patients with schizophrenia. Based on the research of Xu et al,[47] medication adherence of patients was inconsistent at 6-month and 18-month follow-ups. This may be because the primary mechanism of their intervention may come from the texted cues to take medications rather than changed beliefs on the benefits of taking medicines vs cost. The programme's effect could fade after reminders were turned off, partly due to the potential cognitive impairment in patients with schizophrenia. Thus, people with schizophrenia may require ongoing reminders to take medications. Medication adherence is a challenging behaviour, affected by various individual, systemic and disease-related factors, such as socioeconomic level, the complexity of the regimen, and medication-related side effects. Therefore, other than unilateral behavioural interventions like medication reminders and information input, exploring and merging their experience and beliefs of medication adherence into interventions is required under the guidance of an appropriate theoretical framework. Contrarily, mobile apps are multifeatured platforms operated by users on Android or iPhone with or without data. This makes up for the limited content and format of SMS to actualise interactive contact between patients and HCPs. Moreover, designing technological systems for severe mental illness requires user-centred approaches. These diseases have a set of distinctive traits, such as cognitive impairments, salient symptoms and limited literacy, significantly affecting the use of technology-based services.[85] Therefore, the appearance and function of mobile apps should be more customisable and humanistic. The advent of DMS incorporating digital pills has garnered significant interest from stakeholders concerned with non-adherence to antipsychotics. Nevertheless, several pilot studies were undertaken thus far aimed at assessing their feasibility and preliminary acceptability in monitoring patients' medication adherence and physical activity, among other aspects.[56 78] To validate their efficacy in the future, it is imperative to carry out high-quality and multicentre RCTs.

Another significant problem in this research field is that there is no gold standard for determining medication

adherence. Self-reported assessment instrument is the commonly employed approach due to its low cost and easy implementation in different settings. Due to the well-established difficulty of reliably measuring adherence, the possible solution was to integrate at least two methods.[91] Future research should combine objective and subjective measures of medication adherence to enhance the reliability of research outcomes.[92] Most studies included in this review involved a single adherence measuring instrument.

All the DHIs to improve adherence to oral antipsychotics were acceptable to patients, caregivers and HCPs. Digitalisation provides real-time, or almost real-time, health information, decreases inefficiencies, enhances patient access, reduces the cost of care, improves the quality of care, improves outcomes and makes medicine more personalised.[14] HCPs may hesitate to use these technologies due to their responsibility when using digital technologies or their competence despite providing immense potential. The security and privacy issues of patient data also require attention. DHIs are developing quickly, bringing new concerns about privacy and safety.[93] Recent studies have indicated that people with schizophrenia have severe concerns about data privacy involving digital health tools.[79 94] It is advised that a standard for data storage, usage and sharing be reached with transparent and relevant policies for the user during application.[95] The user has the option to decline to share their data.[95] Monitoring and recording the medication adherence of patients with schizophrenia is an essential component of DHIs. However, patients and their families may require other features, and caregivers may choose DHIs to monitor physical activity, sleep quality, self-reported mood and coping strategies of patients. Prior studies have shown that patients with schizophrenia found it challenging to use DHIs, particularly when employing emerging technologies like digital medical systems, necessitating technical support.[47 63 74] Thus, initial training and ongoing technical assistance were crucial.

The value of DHIs in severe mental illness and other diseases is becoming more apparent. However, little research has been done on the broader economic impact of these interventions. Future studies should estimate the magnitude of burden reduction or cost savings generated from digital health tools. This review also emphasised that most recent studies focused on pilot trials, exploring the feasibility, acceptability and preliminary practice of DHIs. High-quality and multicentre RCTs should be used across cultural backgrounds to confirm their efficacy and enhance the evidence of using DHIs in the mental health field.

Limitations

The key strength of this scoping review is that it provides a broad literature overview. The issues raised in the design and development of DHIs and measuring tools may promote the future development of DHIs to improve medication adherence among patients with schizophrenia. Developing a protocol for a subsequent systematic review of this subject may benefit from the review's methodologies and search strategies. The notable review limitations are that studies published in English and grey literature were not searched, limiting the generalisability of the findings to other cultures since most of the included trials were conducted in the USA. The methodological limitations of the available evidence should be considered when reviewing the study results. Fundamental limitations include the lack of fully validated randomised controlled studies and the lack of universal measuring instruments of medication adherence, which precludes the drawing of definitive conclusions, particularly about the clinical effectiveness of different types of interventions. Our review mainly focuses on adult patients with schizophrenia to reduce the impact of the heterogeneity of the study population on different DHIs, making the review unable to fully consider the situation and perceptions of first-episode psychosis through DHIs. Therefore, further research should be explored in this area.

CONCLUSIONS

The scoping review indicates that DHIs were acceptable to patients with schizophrenia and clinicians. Additionally, due to the relative prevalence of smartphone-based, web-based, and sensor-based devices in daily life, real-time monitoring and oral antipsychotic treatment reminders are incredibly feasible. This review provides a more profound and better understanding. SMS and mobile apps have been frequently used to monitor and record patients' medication adherence. Simultaneously, pilot trials were undertaken using mobile apps, wearable devices and sensors. Thus, high-quality RCTs are lacking to validate their effectiveness. DHIs for adherence-enhanced oral antipsychotics may be combined with psychotherapeutic techniques guided by proper theoretical frameworks. This helps track the psychiatric symptoms and moods of patients with schizophrenia, as opposed to concentrating on single medication reminders. Additionally, greater attention should be paid to patients' needs, considering their accessibility.

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