mHealth impact on secondary stroke prevention: a scoping review of randomized controlled trials among stroke survivors between 2010–2020

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Background: A fundamental gap between clinical prevention and self-management awareness heightens the risk for stroke recurrence in approximately one-fourth of the highest risk stroke survivors annually. Secondary stroke prevention has the potential to be promoted by mobile health (mHealth) applications for effective real-world adoption of vascular risk factor mitigation. This scoping review aims to evaluate the impact of mHealth interventions and their effectiveness to reduce recurrent stroke rates among stroke survivors in randomized controlled trials (RCTs).

Methods: Scoping review in Ovid Medline, Cochrane Library, CINAHL, and Scopus for RCT literature employing mHealth among stroke populations published in English from 2010 to November 19, 2020. Small or pilot studies that included randomized design were included.

Results: A total of 352 abstracts met inclusion criteria; 31 full-text articles were assessed and 18 unique RCTs involving 1,453 patients ultimately fulfilled criteria. Twelve of 18 met the pre-defined primary outcome measure, including 2 studies evaluating feasibility. Eight of 18 only addressed recovery from index stroke deficits. Most outcomes focused on self-reported functional status, mood, quality of life or compliance with intervention; primary outcome was an objective metric in 4/18 (blood pressure readings, step number, obstructive sleep apnea support compliance). Intervention duration 2–12 months, with a median 9 weeks.

Conclusions: No high-quality evidence supporting mHealth applications to reduce recurrent stroke was found in this scoping review. Overall, most studies were relatively small, heterogenous, and employed subjective primary outcome measures. mHealth's potential as an effective tool for stroke stakeholders to reduce recurrent stroke rates has not been sufficiently demonstrated in this review. Future randomized studies are needed that explicitly evaluate stroke recurrence rate.

Keywords: mHealth; secondary stroke prevention; randomized clinical trial

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Introduction

At least one quarter of the approximately 800,000 strokes that occur annually in the United States are recurrent events, with the highest risk of recurrence or death from vascular events within the first 3 months after index stroke (1-3). Recurrent stroke is typically defined as a new focal neurological deficit otherwise meeting the standard definition of stroke that occurs at least 24 h following clinical stability of index stroke (4). Ninety percent of recurrent strokes are preventable through adequate control of vascular risk factors (3,5), yet most studies continue to show ineffective management of stroke survivors' underlying hypertension, hyperlipidemia, diabetes, and physical activity (5). Thus, despite compelling evidence supporting secondary prevention, a fundamental gap prevails between real-world adoption of vascular risk factor mitigation strategies and those recommended by stroke prevention health guidelines (6).

Multiple barriers have been recognized to explain these grim statistics, including a lack of motivation and effective self-management models, sedentary behavior, untreated mood dysfunction, and inadequate stroke health education (7-13). As many as 40% of stroke patients in the United States were unable to verbalize at least one risk factor for recurrent stroke. This considerable lack of awareness hampers self-management efforts and reduces adherence to secondary prevention (14).

Although mobile health (mHealth) applications are related to a broad range of interventions and lack a universally accepted definition, the digital health division of the World Health Organization defines mHealth as the "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices" (15,16). Mobile devices are facilitating the development of new telecommunication tools aimed at improving compliance in healthcare, and mHealth applications can be designed to provide real-time feedback to the user, allow individualized content and access to information about disease prevention, and facilitate social support (17). Therefore, mHealth may be an underutilized strategy in secondary stroke prevention.

Mobile applications can also improve compliance with treatment guidelines, provide disease risk/outcome information, and increase administrative efficiency (18). mHealth has also been reported to be advantageous in changing health behaviors, such as medication adherence, achieving exercise goals, and reducing anxiety to improve health outcomes in patients with chronic disease (19-21).

This study examines the available high-quality evidence as defined by randomized controlled trials (RCTs) of mHealth interventions and their ability to reduce recurrent stroke rates among stroke survivors. Maintaining healthy behaviors over the long term is one of the most challenging aspects to chronic disease, and mHealth technologies may represent a flexible and user-friendly solution to prevent stroke recurrence over the patient's lifetime. We present the following article in accordance with the PRISMA-ScR reporting checklist (available at https://mhealth.amegroups.com/article/view/10.21037/mhealth-21-27/rc).

Methods

We conducted a literature search for publications in Ovid Medline (2010–present), Cochrane Library (2010–present), CINAHL (2010–present), and Scopus (2010–present) for RCTs employing mHealth among secondary stroke populations. A search query was constructed in Medline around the concepts of mHealth (including mobile health, telehealth, telemedicine, and mobile and smartphone apps) and secondary stroke. We defined mHealth as the practice of medicine supported by portable diagnostic devices to provide services that facilitate health prevention and intervention via short-messaging-service (SMS), smartphone applications, handheld-imaging platforms, wearable devices, and miniaturized sensor-based technologies (22). Keywords and medical subject headings were both used in the query, and the search was then adapted for use in the other databases (see Appendix 1 for full Medline search strategy). All databases were searched from inception to November 19, 2020, with no limits applied to the search. We examined the reference lists of all included studies, and duplicates were removed.

The literature was screened for studies among adult patients with previous stroke that were published in the English language between 2010 and 2020. Studies prior to 2010 were excluded due to their lack of relevance in the technology-dependent field of mHealth. Studies were included if they reported the findings of RCTs employing mHealth strategies for secondary stroke prevention. Small or pilot studies were included provided they were of randomized design. Alternative (e.g., observational) study designs were excluded. Likewise, commentaries, letters to the editor, published protocol descriptions, nonhuman studies, and findings only published in abstract form, conference proceedings, or as a master's thesis or dissertation were also excluded. Interventions targeting healthcare professionals or that monitored patient data only were excluded.

Titles and abstracts were screened independently against the inclusion criteria by two authors (AA, TH). Each record was screened independently, with disagreements resolved through discussion and consensus. Full-text articles were screened by the authors (AA, TH) for final decisions regarding inclusion, with disagreement resolved by consulting a third author (CE). Information from each included article was organized using a structured form, including study design, pilot status, number of participants, study population, delivery agent, intervention, prespecified primary outcome, and results reported. The risk of bias was assessed by two authors independently (AA, TH). Publication bias of RCTs previously identified by Cochrane as bias risks are selection bias, performance bias, detection bias, attrition bias, reporting bias, among other less common causes (23).

Results

Our scoping literature review identified 352 abstracts, of which six were duplicates, two were written in languages other than English, and 43 were published prior to 2010. Two authors (TH, AA) reviewed the remaining 301 abstracts. The most common reason for exclusion was not an RCT (143 abstracts), followed by review article [69], RCT protocol only [34], studied intervention was not mHealth [18], or population studied was not stroke [6].

Thirty-one full-text articles were reviewed. Among those, 13 were excluded for the following reasons: duplication (2 abstracts), not an RCT [6], conference proceedings [1], and trial description only [4]. A total of 18 unique RCTs involving 1,453 patients fulfilled the criteria after full review (*Figure 1*).

The included studies were among diverse populations worldwide and included seven studies in Europe; three studies in the United States; two studies in each of China, Taiwan (China), and Africa (Ghana, Nigeria); and one study from each of Australia, Pakistan, and South Korea. Details of each study are included in *Table 1*. Eight studies enrolled participants with subacute stroke (as defined by <6 months of index stroke) (24-31), and 10 studied individuals with chronic stoke (21,32-40). Only two studies exclusively enrolled patients with ischemic stroke (IS) (25,29), with the remaining 16 studies including participants with a history of IS or hemorrhagic stroke. The length of the studies varied from two weeks to 12 months, with a median study duration of nine weeks. Interventions were diverse and included an mHealth interface of one-way communication tailored to the individual participants in four studies (27,31,35,36), a robotic-assist device in one study (28), a preloaded app or virtual reality program for smartphones or tablets in four studies (25-27,30), an interactive intervention (as defined by within-participant group communication) in two studies (21,38), a two-way audiovisual telehealth intervention in six studies (24,26,30,32,33,40), and a combination of a preprogramed app and telehealth (two-way) interaction in 9 studies (24-26,28-30,32,33,40). Six studies incorporated some form of one-way interaction (e.g., SMS education or reminders) (31,34-38), and six incorporated some form of telemonitoring or objective biometrics (21,24,29,31,33,39). Eight studies targeted stroke deficit recovery (cognitive, physical, behavioral medicine rehabilitation) (24-26,30,32,33,39,40), eight addressed vascular risk factors (exercise, blood pressure, obstructive sleep apnea, depression, health goals) (21,27,29,31,35-38), and seven rated overall functioning and other psychosocial scores as primary or secondary outcomes (24,27,28,30,32,33,40). No RCT data with a primary or secondary outcome of reduced recurrent stroke rates was found.

The risk of bias in RCTs was rated as low by the by the Cochrane Collaboration tool; however, all of the reported studies were vulnerable to selection and performance bias inherent to any study involving mHealth. Many (8/18) (21,25,26,30,31,33,36,40) of the reported studies were pilot or feasibility studies and thus were not powered for efficacy.

Three studies reported acceptable levels of feasibility (25,31,36), and in 10 studies, the primary outcome was achieved (21,24,25,29,30,32,33,35,36,39). The only study to employ a robotic-assist mHealth intervention failed to demonstrate improvement in the experimental group (28). However, the prespecified outcomes were quality of life (QOL)/self-rated depression scores, and both the control and experimental groups received the same amount of weekly human encouragement and engagement by study personnel. These interactions may have influenced participants' (regardless of robotic-assist device use) depression and QOL perceptions. Overall, the majority of studies achieved their primary outcome, and most demonstrated improvement in psychosocial domains (i.e., depression, QOL, and overall functional status).

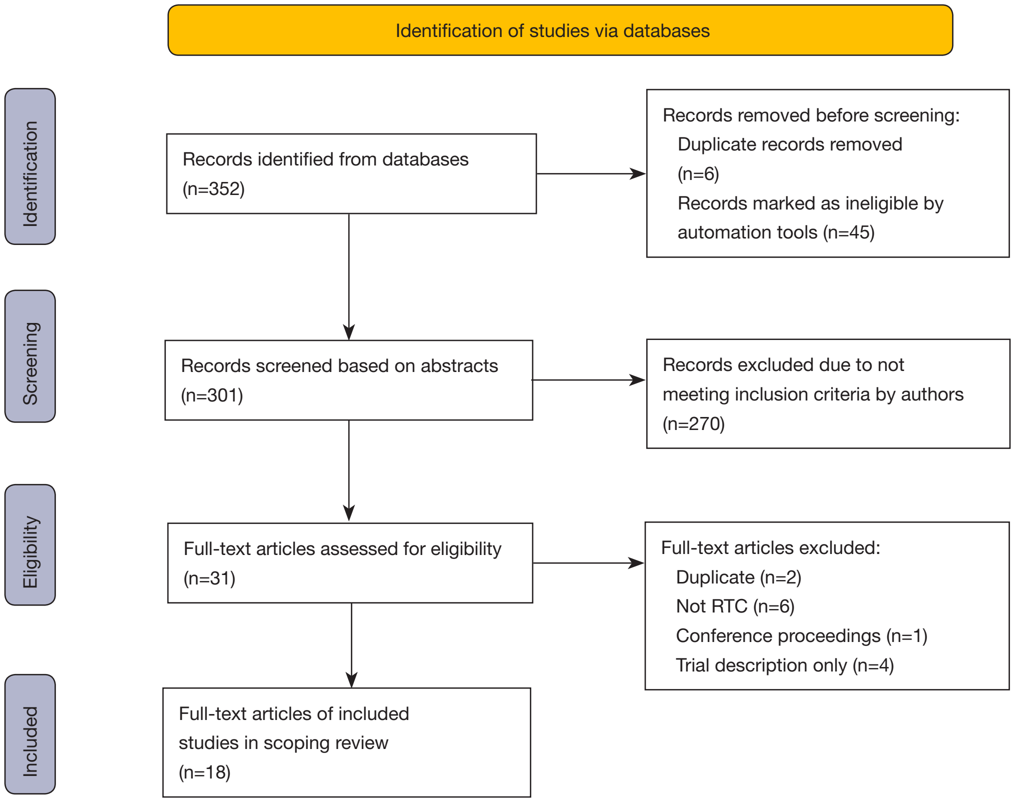

Figure 1 PRISMA 2020 flow diagram of search results.

Discussion

The burden of cerebrovascular disease is only expected to grow given the combination of our graying population and recent advances in acute stroke treatments leading to increased survival rates (41). Therefore, there is an urgent need to identify effective therapies to reduce recurrent stroke among those at high risk of additional cerebrovascular injury.

mHealth has been touted as a potential tool to reduce stroke recurrence by improving vascular risk factor profiles using widely available technology. However, it remains to be seen if this potential has been realized as demonstrated in robust clinical trials. The purpose of this review was to assess the application of mHealth interventions for secondary stroke prevention among published studies of randomized design.

Overall, this scoping review revealed very limited high-quality evidence supporting mHealth applications to reduce the risk of recurrent stroke among stroke survivors. This finding echoes previous reviews published in 2016 (42,43). Published evidence lags behind clinical implementation of an emerging tool such as mHealth, and rigorously designed large trials are likely ongoing (ClinicalTrials.gov Identifier: NCT04000971). However, it is still notable that no new studies were identified in the ensuing four years. Further, none of the included studies identified reduction in recurrent stroke rate as their primary outcome measure. Although improving vascular risk factors (e.g., decreasing blood pressure, addressing depression, treating sleep apnea, or increasing physical activity) can all be inferred as targeting recurrent stroke risk, most RCTs reported in this review identified explicit recovery from the index cerebrovascular event as the primary focus of their mHealth intervention. Among the studies focused on improvement in motor, speech, or cognitive deficits following stroke, most reported improvements in psychosocial outcomes in the experimental groups. Depression is an established independent risk factor for vascular events and death (44-46); therefore, strategies aimed at its mitigation are likely to contribute to an overall reduction in recurrent stroke (47,48).

There was diversity in the types of interventions used for secondary stroke prevention utilizing mHealth. Many

Table 1 Summary of reviewed literature

Articles	N	Study population*	Delivery agent	Intervention	Primary outcome measured	Reported results	Human interaction	Technical assistance
Cadilhac, 2020	54	Stroke survivors via Australian Clinical Registry	SMS or email messages	Personalized e-support and educational messages	Trial completion, goals obtained, and satisfaction	e-Delivery of post stroke goal setting by eHealth was feasible and acceptable. Participants in EG progressed towards goals	No human interaction. Messages were delivered via SMS	No
Chen, 2017	54	Stroke survivors with hemiplegia	Telerehabilitation	Bidirectional TR system with biofeedback instrument (ETNS) *vs.* conventional rehabilitation (CR)	Modified Barthel Index (measures disability and activities of daily living)	Home-based rehabilitation via TR and the ETNS is effective in improving functional recovery in stroke survivors with hemiplegia	Therapists provided therapy via TR twice daily for 12 weeks	Yes
Choi, 2016	24	Patients with a diagnosis of IS	Tablet PC and a smartphone	CR with mHealth rehabilitation	Motor function in a patient's hemiparetic arm	The program was feasible and effective for improving upper limb function when compared to CG	The EG received 30 minutes of conventional OT + 30 min of pre-programmed mHealth tablet in 10 sessions of M-F therapy x 2 weeks. EG also received education on how to use MoU-Rehab during the first session	No
Chumbler, 2012	52	Patients with a stroke diagnosis within 24 months	In-home messaging device and telephone	Three 1-hour tele-visits, daily messaging via device and 5 phone calls	Motor function as measured by the motor subscale of the telephone versions of the Functional Independence Measures. Overall function as measured by the Late-Life Function and Disability Instrument	Motor function and overall function improved in the EG	Intervention lasted three months and included three 1-hour tele- visits, five telephone intervention calls between tele-therapist and participant	Yes

Table 1 (*continued*)

Table 1 (*continued*)

Articles	N	Study population*	Delivery agent	Intervention	Primary outcome measured	Reported results	Human interaction	Technical assistance
Grau-Pellicer, 2019	41	Stroke survivors who had stroke in the last year and completed a daily CR program for 3 months	Smartphone, pedometer, Whatsapp group	Physical therapist guided sessions utilizing two mHealth apps called Fitlab Training and Fitlab Test with bidirectional feedback. The patients were monitored with a pedometer, GPS, and accelerometer. The participants were asked to participate in an 8-week exercise program and progressive daily ambulation	Community ambulation (self- report); sedentary behavior (self-report)	Community ambulation increased more in the EG than the CG. Sedentary behavior decreased more in the EG than the CG	Intervention was performed in groups of 4-6 participants with a physical therapist during 1-hour two days a week for 8 weeks	Yes
Kamal, 2015	200	Patients >1 month post stroke, (confirmed via neuroimaging)	SMS reminders	EG received daily medication reminders and twice weekly health information via SMS	Change in medication adherence after 2 months of receiving SMS.	EG had a larger increase in medication adherence	Only as part of usual care (described as provider follow ups at 1, 3, 5, 9, and 12 months after stroke)	No
Kang, 2019	76	Patients with first stroke diagnosis with baseline cognition and communication intact	mHealth stroke education app	EG got a stroke education application and the CG got stroke education pamphlets. Each group was instructed to read the content for 7-14 days for at least 5 minutes per day	Improved knowledge of stroke risk factors. Health related quality of life	The application did not result in statistically significant change in knowledge of stroke risk factors or health related quality of life when compared to conventional education	Study personnel helped install the application onto patient's personal smartphones and provided a 45-minute education session on using the application. Patients were provided the application but no set schedule for use	No

Table 1 (*continued*)

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Articles	N	Study population*	Delivery agent	Intervention	Primary outcome measured	Reported results	Human interaction	Technical assistance
Lee, 2017	34	Hemiparesis for 6 months or longer after single stroke diagnosis; MMSE of 24 or higher; ability to walk for 20 minutes independently; Brunnstrom of 4 or more	Smartphone with projector	Speed Interactive Treadmill Training (SITT) using smartphone-based human tracking technology three times per week for 6 weeks	Gait improvement	SITT improved gait function in stroke patients	Training was conducted under the supervision of two therapists for patient safety in-person during 35-minute sessions three times per week for 6 weeks	N/A
Lin, 2014	24	History of stroke for 6 months; living in long term care facility for more than 3 months; having active movement of the proximal upper extremity	Computer with webcam for therapist and computer and webcam with a regular monitor and touch screen monitor on the patient end.	Treatment program included three sessions for 4 weeks of tele-balance training	Improvement in balance and function	No significant difference between the TR and the CR	Training was conducted and supervised at "therapist end" via TR and nonmedical personnel assisted at "patient end" in-person during 50 minute sessions three times a week for 4 weeks.	Yes
Linder, 2015	99	Stroke <6 months with some function of their upper extremity, mRS > 1 pre-stroke, and "limited access" to rehab	Hand Mentor Pro (robot)	8 weeks of in-patient level rehab of UE performed at home with booklet and patient log *vs.* adding hand robot-assist device. Both groups had weekly calls with PT	Nonmotor outcomes (depression and QOL scores)	No difference between robot-assist and basic home PT program	Weekly phone calls were made to prescribe adjustments to the Home Exercise Program based on progress. Both groups had the same amount of human interaction	Yes
Sarfo, 2019	60	IS diagnosis <1 month plus BP >140 mmHg (average of 3 readings)	SMS and smartphone record keeping + one intervention cluster got nurse phone call	Bluetooth BP + smartphone for recording medication, record BPs and receive SMS messages	BP <140 mmHg at month 9	Feasibility—yes, but no efficacy	None (SMS)	No

Table 1 (*continued*)

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Articles	N	Study population*	Delivery agent	Intervention	Primary outcome measured	Reported results	Human interaction	Technical assistance
Torrisi, 2019	40	Subacute stroke who were in acute rehabilitation	iPad with cognitive exercise program + weekly video visit with PT	Two phases: (I) 12 weeks inpatient UC *vs.* EG with tablet and in-person evaluations weekly by PT; (II) 12 weeks out-patient phase after d/c where EG continued to do the tablet exercises with caregiver and videoconference weekly with PT	"Efficacy of VRRS"	Executive Cognitive outcomes neutral but EG improved in some motor tasks and depression scores were lower	In phase 1, EG patients used VRRS-Evo for cognitive rehabilitation training to monitor patients remotely at home via real-time interaction during 3 sessions. In phase 2, a psychologist monitored the progress of rehabilitation at home through videoconference for EG patients during 5 sessions	Yes
Smith, 2012	76	Men with stroke history	Online guided discussion forums and classes/email	Intensive intervention with online library, curriculum, online discussion groups and emails for CG over 9 weeks compared to online library access without anything else	CES score	CaGs improved, male stroke patients were neutral	Patients were assessed via phone by psychologists or by mail due to communication disorders. Intervention conditions were held in weekly sessions that communicated by email messages, chat rooms, and message boards.	Yes

Table 1 (*continued*)

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Articles	N	Study population*	Delivery agent	Intervention	Primary outcome measured	Reported results	Human interaction	Technical assistance
van den Berg, 2016	63	Patients with stroke history in rehabilitation	iPad exercise guide plus PT eval weekly (sometimes telemed)	12 weeks during rehabilitation, CG were given iPads with exercises and were evaluated weekly by PT. If PT was at home, this was done via telemedicine	Stroke Impact Scale on mobility	No change in SIS, but CG and patients felt better.	Patient and caregiver were provided with iPad loaded with caregiver-mediated exercises in addition to the UC. Told to do the exercises for 30 min a minimum of 5 times/week × 8 weeks + weekly evaluation sessions with the physiotherapist. Program continued after rehab d/c with weekly therapist evals performed over telemedicine	Yes
Paul, 2016	23	Patients with chronic stroke history	App tracking steps	6 weeks EG divided into groups of 4 with weekly physical activity goals and rewarded with electronic additions to their "fish tanks" when group and/or individual met goals	PE as defined by number of steps	EG had a significant increase in steps over the 6 weeks (doubled), CG decreased steps by 20%	Activation of STARFISH application on mobile device during a 30-minute demonstration session after week 1 and given the researchers' number for any issues	Yes
Owolabi, 2019	400	Patients with stroke history	Appt reminders, daily texts, in clinic educational videos and signed patient report card/ contract	12 months, EG received enhanced interventions, CG just text messages	Decrease in SBP at 12 months	No change in BP however the subset of stroke patients with HTN, both CG and EG had a decrease in BP	All participants received monthly appointment reminder phone calls. EG sent pre-appointment phone text, clinic check-ins to watch educational video with other EG patients and fill report card, and post-clinic phone text. These follow-up visits occurred regularly over a period of one-year after enrollment	Yes

Table 1 (*continued*)

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Articles	N	Study population*	Delivery agent	Intervention	Primary outcome measured	Reported results	Human interaction	Technical assistance
Gillham, 2010	53		Telephone	Enhances stroke prevention with stroke risk reduction education, motivational interviewing style discussion about behavioral change, and telephone support and follow-up	Readiness to Change Health Behaviors after Stroke at 3 months	Both groups increased from contemplation stage to action stage	EG received two telephone motivational interviewing sessions during the three-month study period at week 2 and week 6	No
Nilius, 2019	80	Patients with subacute (<3 months) ischemic stroke in rehabilitation and new diagnosis of mod-severe obstructive sleep apnea and relatively good Barthels	remote telemonitoring of CPAP with phone calls, house visits for noncompliant (<4 h) participants. EG had access to website for troubleshooting	6 months, EG got intervention, CG usual care	Usage of CPAP (average of at least 4 hours/night)	Very significant increase in CPAP compliance (doubled) in EG	The EG online data was reviewed weekly. If weekly usage dropped below 4 h/night, then patient was contacted via telephone or home-visits to discuss how to solve usage problem	Yes

*, study population were comprised of all adults. BP, blood pressure; CES, center of epidemiological studies; CaG, Caregiver; CG, control group; CPAP, continuous positive airway pressure; CR, conventional rehabilitation; e-, electronic; EG, experimental group; ETNS, electromyography-triggered neuromuscular stimulation; GPS, Global Positioning System; HTM, hypertension; IS, ischemic stroke; M-F, Monday through Friday; mmHg, millimeter of Mercury; MMSE, mini-mental state examination; MoU-Rehab, mobile upper extremity rehabilitation program; OT, occupational therapy; PC, personal computer; PE, physical activity; PT, physical therapy; QOL, quality of life; SBP, systolic blood pressure; SIS, stroke impact scale; SITT, speed interactive treadmill training; SMS, short message service; TR, telerehabilitation; UC, usual care; UE, upper extremity; VRRS, virtual reality rehabilitation system.

studies included using a novel mHealth application designed for the current study (27,28,30,32,39). Fewer studies used SMS or other bidirectional communication applications (31,32,35-37). A few studies used video as a means of patient monitoring and bidirectional communication (29,30,32,40). Other sources of intervention delivery were through remote patient metric monitoring (21,29,33), telerehabilitation delivery device (24,28), and patient or provider education delivery (34,36,38). The broad spectrum of intervention employed illustrates the complexity of conducting mHealth research among stroke populations.

QOL and daily functioning are often identified as high-priority outcomes among stroke survivors (49,50). mHealth applications may be a reasonable tool to achieve positive QOL assessments as all included studies with QOL endpoints reported improvements in the participants receiving the active mHealth intervention. These findings must be balanced with the subjective nature of the assessments and the inability to blind participants, which both introduce response bias, and may reflect the overall beneficial effect of merely engaging a patient around their health in any form.

Durability and usability of any intervention are critical components of its effectiveness. The behavioral changes necessary to improve vascular risk factor management require motivation, a factor even more vulnerable to waning engagement. Long-term outcomes, therefore, will be important to demonstrate continued success of any given mHealth intervention and should be incorporated in study design. The studies reported in this review did not address any potential durability of any mHealth intervention as the assessments occurred over a range of two weeks to 12 months, with a median of only nine weeks. No study reported follow-up beyond the immediate intervention period. Furthermore, most studies occurred in the chronic phase (>6 months from stroke event), well after the highest risk of stroke recurrence period has passed (1). All studies reported minimal issues related to usability. However, there is a selection bias considering that only patients who could operate the technology were included, and more than half of the studies (10) included some type of trouble-shooting mechanism or periodic feasibility check-up. Apart from providing technical assistance, no study attempted to determine the kind or frequency of study participant engagement associated with a successful outcome.

While still developing, the mHealth literature investigating the management of isolated vascular risk factors, such as smoking cessation, hypertension, or glycemic control, among populations with these conditions is more robust (51-53). mHealth has been proven to be an effective strategy to reduce glycosylated hemoglobin and improve smoking cessation or systolic blood pressure (54,55). However, it remains to be seen whether we can apply those results to a stroke patient who also has diabetes. Stroke is a multifactorial cumulative event; thus, reducing its recurrence is a complex proposition. Stroke survivors represent a heterogenous and clinically unique population, further emphasizing the difficulty of applying evidence derived from more narrowly defined clinical populations. Considering the complicated nature of the average stroke survivor, involving end-users in the development of a successful mHealth intervention to reduce recurrent stroke has been recommended, although rarely adopted (56-59).

The dearth of included studies as well as the incipient mHealth literature in general begs the question as to why mHealth remains understudied. Mobile technology has advanced rapidly, and its relative affordability has made it widely accessible to industry and the general public. Our ubiquitous reliance on cellular technology may have promoted the adoption of mHealth strategies at a rate faster than rigorous studies can be completed and published. In addition, the design of such studies is complex as they require tackling multiple vascular risk factors simultaneously (60,61). Other critical factors a successful mHealth intervention may need to address are low stroke health literacy and navigating the increasingly complicated post-acute healthcare landscape. Recruitment efforts may also be hampered by discouraging stroke survivors with little familiarity of the proposed technology or those who lack internet access. Limited broadband coverage has been proven to contribute to rural/urban health disparities and a decrease in mHealth use (62).

There are limitations to this qualitative review, and no secondary qualitative analysis was performed. The studies discussed were diverse in primary purpose and outcomes. This scoping review also did not review literature that included dissertations, recommendations, or conference proceedings, which could introduce bias as only peer-reviewed, published RCTs were included. Therefore, this study is vulnerable to possibly missing useful findings reported in other formats or unreported results (e.g., RCTs demonstrating the null hypothesis). Overall, however, our approach is considered rigorous given that we only included RCTs, with their associated risk of bias being low. Given the nature of the intervention, subject blinding was not feasible. Nine studies identified subjective outcomes (i.e., self-reported QOL, depression or functional status scores), potentially introducing performance bias. Enrolled populations were limited to those who could engage with and had access to the technology, creating a selection bias common to any implementation of mHealth. These latter factors limit the generalizability of any given mHealth intervention among a broader stroke population.

In summary, little high-quality evidence was found supporting mHealth that targeted stroke patients. Studies were heterogenous, lacked longitudinal follow-up, and involved a relatively small number of participants. While the majority of studies achieved their primary or secondary outcomes, many were purely subjective, and no single study identified secondary stroke prevention rate as the outcome measure of interest. Although mHealth may still prove to be a powerful way to address other clinically relevant targets (mood, daily living or functional outcomes), this lack of emphasis on secondary stroke prevention lays bare the gap in evidence addressing this population.

Consequently, systematically developing effective mHealth interventions is vital to harness the potential benefits of mobile technology as a healthcare surrogate. This review illustrates that mHealth for secondary stroke prevention remains understudied and also supports the critical need to design and complete RCTs utilizing different mHealth platforms with the specific aim to decrease recurrent stroke rates, especially in the highest risk period (<3 months post-stroke). If an appropriate tool or tools can be designed, tested, and implemented, the potential to impact stroke care and chronic disease management in general is immense.

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Footnote

Reporting Checklist: The authors have completed the PRISMA-ScR reporting checklist. Available at https://mhealth.amegroups.com/article/view/10.21037/mhealth-21-27/rc

Peer Review File: Available at https://mhealth.amegroups.com/article/view/10.21037/mhealth-21-27/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://mhealth.amegroups.com/article/view/10.21037/mhealth-21-27/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Supplementary

mHealth and secondary stroke prevention

mHealth Concept: included in search
mHealth
mobile health
telehealth
telemedicine
eHealth
mobile app*
smartphone app*
phone app*
“Mobile Applications”[Mesh] “Telemedicine”[Mesh]
“Smartphone”[Mesh]
“Cell Phone”[Mesh]

Secondary stroke concept: included in search
secondary stroke *
recurrent stroke*
recurring stroke*
stroke recurrence
secondary prevention adj3 stroke
“Stroke Rehabilitation”[Mesh]
(“Secondary Prevention”[Mesh] AND “Stroke”[Mesh])

Search Strategies
Run in Ovid Medline, Cochrane Library, Scopus and CINAHL
Total results: 481
Duplicates found in Endnote: 129
Results after deduplication: 352

Ovid Medline
Run 11/19/2020
Results 312

 https://dx.doi.org/10.21037/mhealth-21-27

	Searches	Results
1	mHealth.mp.	5,015
2	mobile health.mp.	8,161
3	telehealth.mp.	5,411
4	telemedicine.mp.	30,363
5	eHealth.mp.	4,107
6	mobile app*.mp.	9,726
7	smartphone app*.mp.	3,358
8	phone app*.mp.	1,138
9	exp Mobile Applications/	6,529
10	exp Telemedicine/	30,836
11	exp Cell Phone/	11,043
12	exp Smartphone/	4,093
13	or/1-12	64,734
14	secondary stroke*.mp.	1,198
15	recurrent stroke*.mp.	3,598
16	recurring stroke*.mp.	21
17	stroke recurrence.mp.	1,573
18	(secondary prevention adj3 stroke).mp.	1,158
19	exp Secondary Prevention/	20,707
20	exp Stroke/	137,964
21	19 and 20	2,028
22	exp Stroke Rehabilitation/	13,666
23	or/14-18,21-22	20,776
24	13 and 23	312

https://dx.doi.org/10.21037/mhealth-21-27

Cochrane Library
Run 11/19/2020
Results 84

ID Search Hits

1 (mHealth):ti,ab,kw 1190

2 ("mobile health"):ti,ab,kw 1109

3 (telehealth):ti,ab,kw 1706

4 (telemedicine):ti,ab,kw 3683

5 (eHealth):ti,ab,kw 919

6 ("mobile app*"):ti,ab,kw 692

7 ("smartphone app*"):ti,ab,kw 610

8 ("phone app*"):ti,ab,kw 197

9 MeSH descriptor: [Mobile Applications] explode all trees 640

10 MeSH descriptor: [Telemedicine] explode all trees 2547

11 MeSH descriptor: [Cell Phone] explode all trees 1354

12 MeSH descriptor: [Smartphone] explode all trees 397

13 #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 9782

14 ("secondary stroke*"):ti,ab,kw 363

15 ("recurrent stroke*"):ti,ab,kw 1030

16 ("recurring stroke*"):ti,ab,kw 4

17 ("stroke recurrence"):ti,ab,kw 377

18 (("secondary prevention" NEAR/3 stroke)):ti,ab,kw 418

19 MeSH descriptor: [Secondary Prevention] explode all trees 3156

20 MeSH descriptor: [Stroke] explode all trees 9802

21 #19 AND #20 331

22 MeSH descriptor: [Stroke Rehabilitation] explode all trees 2442

23 #14 OR #15 OR #16 OR #17 OR #18 OR #21 OR #22 4379

24 #13 AND #23 84

Scopus
Run 11/19/2020
Results 60

((TITLE-ABS-KEY (mhealth) OR TITLE-ABS-KEY ("mobile health") OR TITLE-ABS-KEY (telehealth) OR TITLE-ABS-KEY (telemedicine) OR TITLE-ABS-KEY (ehealth) OR TITLE-ABS-KEY ("mobile app*") OR TITLE-ABS-KEY ("smartphone app*") OR TITLE-ABS-KEY ("phone app*"))) AND ((TITLE-ABS-KEY ("secondary stroke*") OR TITLE-ABS-KEY ("recurrent stroke*") OR TITLE-ABS-KEY ("recurring stroke*") OR TITLE-ABS-KEY ("stroke recurrence") OR TITLE-ABS-KEY ("secondary prevention" W/3 stroke)))

CINAHL
Run 11/20/2020
Results 25

Search ID #	Search Terms	Results
S23	S13 AND S22	25
S22	S14 OR S15 OR S16 OR S17 OR S18 OR S21	3,860
S21	S19 AND S20	2,202
S20	(MH “Stroke+”)	71,107
S19	(MH “Recurrence+”)	49,011
S18	(“secondary prevention” N3 stroke)	513
S17	“stroke recurrence”	623
S16	“recurring stroke*”	6
S15	“recurrent stroke*”	1,517
S14	“secondary stroke*”	525
S13	(S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12)	42,070
S12	(MH “Smartphone+”)	2,852
S11	(MH “Cellular Phone”)	1,932
S10	(MH “Telemedicine+”)	14,756
S9	(MH “Mobile Applications+”)	8,039
S8	“phone app*”	593
S7	“smartphone app*”	1,846
S6	“mobile app*”	9,386
S5	eHealth	16,387
S4	telemedicine	19,544
S3	telehealth	19,486
S2	“mobile health”	18,035
S1	mHealth	15,836

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