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Review

Review

Mobile health (mHealth) usage, barriers, and technological considerations in persons with multiple sclerosis: a literature review

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ABSTRACT

Objectives: Persons with multiple sclerosis (MS) can face a number of potential healthcare-related barriers, for which mobile health (mHealth) technology can be potentially beneficial. This review aimed to understand the frequency, current uses, and potential barriers with mHealth usage among persons with MS.
Methods: A query string was used to identify articles on PubMed, MEDLINE, CINAHL, and IEEE Xplore that were published in English between January 2010 and December 2019. Abstracts were reviewed and selected based on *a priori* inclusion and exclusion criteria. Fifty-nine peer-reviewed research studies related to the study questions are summarized.
Results: The majority of persons with MS were reported as using smartphones, although rates of mHealth utilization varied widely. mHealth usage was grouped into 3 broad categories: (1) disability and symptom measurement; (2) interventions and symptom management; and (3) tracking and promoting adherence. While there have been an increasing number of mHealth options, certain limitations associated with MS (eg, poor dexterity, memory problems) may affect usage, although including persons with MS in the design process can address some of these issues.
Discussion: Given the increased attention to mHealth in this population and the current need for telehealth and at home devices, it is important that persons with MS and healthcare providers are involved in the development of new mHealth tools to ensure that the end product meets their needs. Considerations for addressing the potential mHealth use barriers in persons with MS are discussed.

Key words: multiple sclerosis, mHealth, telemedicine, health services

Lay summary

Mobile health (mHealth) has the possibility to improve access to care for persons with multiple sclerosis (MS). This literature review aimed to understand the frequency and types of mHealth use, as well as any barriers to use, by persons with MS. While use of devices like smartphones were common, the use of mHealth applications varied. The different types of mHealth tools identified included symptom measurement (eg, level of physical disability), symptom management (eg, improving fatigue), and treatment adherence (eg, reminders to take medications). A number of potential barriers were identified, including ones related to MS symptoms (eg, difficulties with vision, fine motor control (or alternately dexterity), memory), which can be addressed by including patients and their providers in the design process.

INTRODUCTION

Up to 1 million people in the United States are estimated to have multiple sclerosis (MS), a chronic neurological disorder.[1] Persons with MS can present with a wide array of symptoms, including difficulties with ambulation, cognition, vision, fine motor abilities, and fatigue. Effectively managing these symptoms and having access to appropriate healthcare services to address their MS-related needs can be challenging. For instance, cognitive dysfunction, which can affect up to 70% of persons with MS, can be progressive in nature and has been associated with greater difficulty completing daily activities, including functional tasks such as medication management, bill paying, decreased social engagement, and poorer health-related quality of life.[2–6] During the COVID-19 pandemic, persons with MS may not be able to get routine appointments because they are not considered urgent enough for face-to-face visits. In addition, persons with MS can face a number of healthcare-related barriers, including health insurance coverage, transportation, and accessibility.[7]

Because of the potential barriers to healthcare that persons with MS can face, one option for improving access to care has been through mobile health (mHealth) technology. The National Institutes of Health (NIH) defines mHealth as "the use of mobile and wireless devices (cellphones, tablets, [wearable devices such as a smartwatch], etc.) to improve health outcomes, healthcare services, and health research."[8] Many persons with MS have access to mobile technology, with one study noting that over 86% use a smartphone, tablet, or both.[9] While technology holds promise to offer persons with MS alternate methods for tracking and managing symptoms, communicating with their healthcare providers, and improving their health-related quality of life, it is unclear if available mHealth tools are meeting the needs of their intended consumer. For instance, while Salimzadeh et al.[10] found 104 MS-related applications in iTunes and Google Play, they noted that there was no corresponding evidence regarding the usability and utility of these applications in persons with MS.

This literature review aimed to gain a better understanding of mHealth usage among persons with MS by addressing the following 3 questions: (1) how frequently do persons with MS use mHealth; (2) what are the current uses of mHealth within the MS population, based on the literature; and (3) what are the potential barriers and technological considerations that may affect persons' with MS usage of mHealth.

METHODS

Articles were identified through PubMed, MEDLINE, CINAHL, and IEEE Xplore queries, conducted by the primary author (ESG), using the following search terms: *(multiple sclerosis OR multiple sclerosis[Mesh]) AND ("Telemedicine"[Mesh] OR "Computers, Handheld"[Mesh] OR electronic[tf] OR smart[tf] OR mobile*[tf] OR web*[tf] OR computer*[tf] OR smart*[tf] OR telemedicine[tf] OR technology*[tf] OR "Patient Participation"[Mesh] OR patient engagement technology OR telemanagement OR mHealth OR eHealth OR telehealth)*. Search results were limited *a priori* to studies that were published (including pre-prints) (1) in English and (2) between January 2010 and December 2019, resulting in 623 abstracts (Figure 1). One additional publication that met inclusion criteria was identified through ancestral review of the references and added to the total. After removing duplicate entries ($n = 140$), literature reviews, conference abstracts, protocols, letters to the editor, and corrections ($n = 121$) were excluded. The titles and abstracts were then screened by the primary author, with another 180 studies removed due to them not being about persons with MS or mHealth. The remaining 183 articles were assessed by the primary author to evaluate whether they explicitly referred to mobile technology and were related to the study questions. A cross-check second review was not done. If participants could access an intervention, assessment, or symptom management tool with either a mobile device (eg, smartphone or tablet) or another electronic device (eg, a laptop or desktop computer), the study could be included in the review as long as it was noted in the methods or results section that some of the participants did use a mobile device. A total of 59 studies were included. For articles that addressed the second and third study questions, the uses of mHealth, barriers to mHealth usage, and technological considerations were coded by the primary author, and then reviewed by all members of the research team to identify themes. As this was a review of published literature, no ethical approvals were required.

RESULTS

Frequency of mHealth use by persons with MS

Regular smartphone use was noted to be common among persons with MS, with 86.9% reporting in one study that they use the device at least once a day.[11] Engagement in physical activity, greater income, having 3 or more co-occurring conditions, female gender, and being unmarried have been associated with an increased odds of smartphone usage among persons with MS.[9] Usage has been noted to be lower in older adults,[12] as well as persons with MS who smoke or have greater levels of disability.[9]

Even though smartphone usage was high, a German-based survey found that most persons with MS (63%) have no experience using mHealth applications for their MS, with only 18% being current users of this technology.[13] Marrie et al.[9] noted that 46.2% of smart-

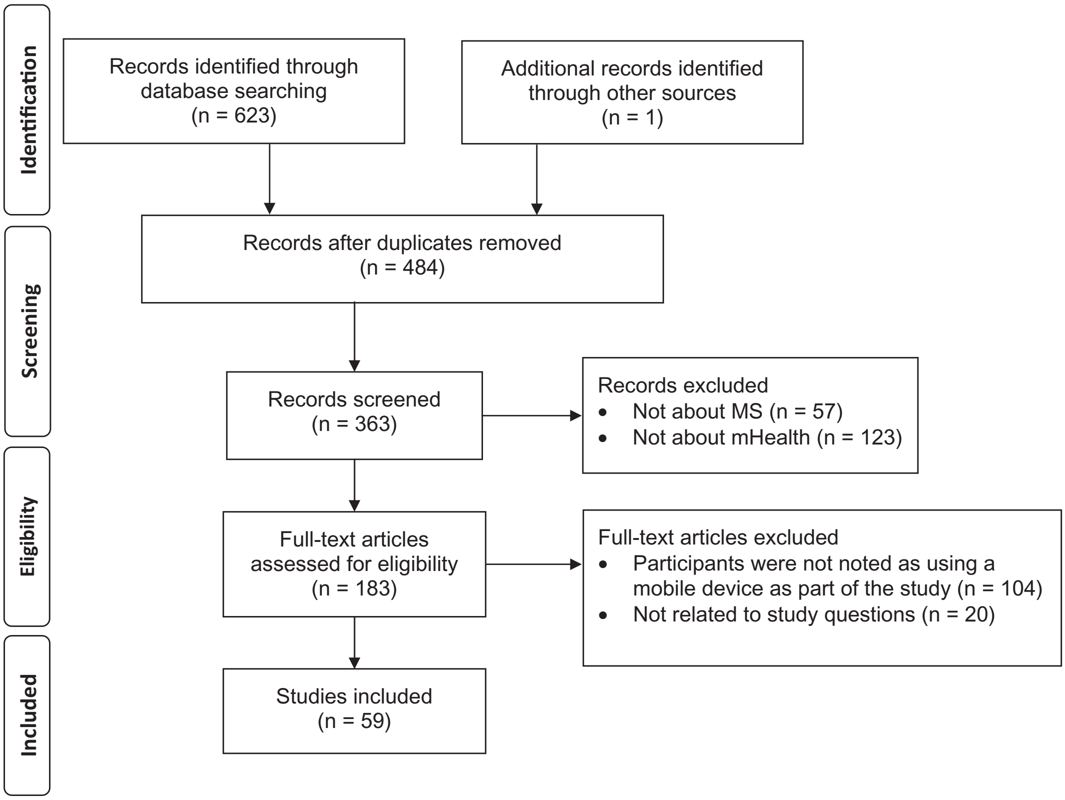

Figure 1. PRISMA flow diagram of article screening and selection for literature review.

phone and tablet users, who were based in the United States, endorsed using a mHealth application at least once. Higher education, income, number of co-occurring conditions, and engagement in physical activity have been associated with greater likelihood of mHealth application use.[9] As with smartphone usage, general self-reported mHealth application use decreased with older age[9]; however, that trend may differ with certain mHealth tools. For instance, Merlo et al.[14] found that older persons with MS were more likely to persist on repeat testing using the computerized MSReactor program.

Current uses of mHealth with persons with MS

Disability and symptom measurement

Several mHealth tools have focused on the measurement of persons' with MS symptoms and level of disability (Table 1). A number of applications, both mHealth-based and web-based that are accessible with a mobile device, have included patient-reported outcomes as a feature, such as questionnaires[15–20] and visual analogue scales.[21] Other efforts have focused on the use of mHealth tools to conduct objective measurements, such as remote Expanded Disability Status Scale (EDSS) evaluations using tele-video.[22] While there are several computer-based cognitive assessments used for persons with MS,[23–26] there have been 2 studies[14,27] investigating multi-domain evaluations that could be conducted using a tablet, as well as one tablet-based application focusing on processing speed that is included as part of a composite disability assessment.[28] Smartphone-based suites have also included one or more measures of objective cognitive functioning.[15,19] With mHealth-based cognitive assessments, there is an ongoing debate as to whether a technician needs to be present. Wojcik et al.[29] found largely similar performances on computerized assessments with and without a technician present, although participants were aware there was one nearby should problems with test administration arise.

Smartphone- or tablet-based cognitive assessments have also been included in mHealth disability composite measures. There have been at least 2 mHealth programs[30–33] based on the MS Functional Composite (MSFC), which traditionally consists of the Paced Auditory Serial Addition Test (processing speed), Nine Hole Peg Test (manual dexterity), and 25-Foot Walk (walking speed),[44] although there have been modifications such as including a measure of low contrast visual acuity[45] and using the Symbol Digit Modalities Test instead as the cognition measure.[46] Both mHealth programs assessed 4 domains of functioning (walking speed, manual dexterity, low contrast visual acuity, and processing speed), with the MS Performance Test also including a balance test.[30–33]

In addition to being part of composite measures, there have been standalone applications examining visual acuity[34] and fine motor abilities.[35,36] Given that ambulation is a significant component of disability measurements such as the MSFC,[44] EDSS,[47] and Patient Determined Disease Steps,[48–51] several studies[37–40] have used triaxial accelerometers as a way of measuring the level of ambulation-based disability. Furthermore, objective step counts and activity monitoring may also provide more accurate representations of functional ability compared to patient reports.[41–43]

Interventions and symptom management

Using mHealth as an interventional or symptom management tool has become more common (Table 2), with persons with MS noting that they use mHealth to improve their cognition, manage their stress and mood, and monitor their physical activity and diet.[13,52] In

Table 1. Current mHealth uses for disability and symptom measurement in persons with MS

Domain	Application/device details	Articles
Self-report measures	Patient-Reported Outcome Portals • Questionnaires included in these portals assess quality of life, fatigue, mood, anxiety, perceived cognition, social support, and physical symptoms (ie, pain, walking, and visual, sexual, bladder, and bowel functioning) • Can be used to track self-reported symptoms longitudinally	• Baldassari et al.[30] • Bove et al.[15] • Greiner et al.[17]a • Jongen et al.[18]b • Engelhard et al.[16]a • Midaglia et al.[19] • Newland et al.[20]
	Visual Analogue Scales • Feasible to administer visual analogue scales for anxiety, fatigue, pain, and quality of life on a smartphone or tablet • Tablet-based administration did not have higher reliability, which may have been partially due to the exclusion of persons with MS with more significant levels of impairment	• Kos et al.[21]
Remote disability assessments	Modified Tele-EDSS Evaluation[a] • Patient received an “in-home neuro kit” and followed verbal instructions from an examiner via video chat (73% completed with a smartphone and 15% with a tablet) • High level of acceptance • Good correlations between in-clinic and tele-EDSS evaluations, particularly for individuals with higher EDSS scores	• Bove et al.[22]
Cognitive evaluations	Cambridge Neuropsychological Test Automated Battery (CANTAB) • Assesses reaction time, spatial planning/executive functioning, visual memory and learning, and spatial working memory • Based on the level of difficulty selected, able to differentiate between groups (persons with MS vs healthy controls; stable MS vs recent relapse)	• Giedraitiene and Kaubrys[27]
	MSReactor[a] • Assesses working memory, processing speed, and visual attention • High test–retest reliability and acceptability • Performances stabilized within 2–3 re-evaluations	• Merlo et al.[14]
	Processing Speed Test (PST) • Assesses processing speed and included as part of the MS Performance Test • High test–retest reliability • Significantly associated with T2 lesion load	• Rao et al.[28]
	Smartphone-based Suites • Includes one or more measures of working memory, executive functioning, complex attention, and verbal fluency • Applications also includes self-report measures and measures of motor functioning	• Bove et al.[15] • Midaglia et al.[19]
Composite disability assessments	MSCopilot • Smartphone-based assessment • Similar classification accuracy compared to the traditional measures, as well as good test–retest reliability • Persons with MS indicated a preference for the mHealth version	• Maillart et al.[31]
	MS Performance Test (MSPT) • Tablet-based assessment • Good discriminability between persons with MS and healthy controls • Performances on the different measures were associated with physical disability-related patient-reported outcomes, as well as MRI metrics • Persons with MS reported a high level of satisfaction with its use	• Baldassari et al.[30] • Rhodes et al.[32] • Rudick et al.[33]
Visual acuity assessments	iPad-based LogMAR Visual Acuity Chart • High level of agreement with conventional analog testing	• Sattarnezhad et al.[34]
Fine motor functioning measures	Finger Tapping and Balloon Popping • Lower discriminatory power than the Nine-Hole Peg Test, but could be completed by all persons with MS participating in the study • Stronger correlations with clinician-derived neurological measurements	• Boukhvalova et al.[35]
	Level Test • Differentiated between persons with MS and healthy controls • Related to different neurological functions than the Finger Tapping and Balloon Popping tests, such as cerebellar, proprioception, and reaction time	• Boukhvalova et al.[36]
Mobility-based evaluations	Triaxial Accelerometers • Feasible for wrist-worn device to be used to track physical activity for longer periods of time (1 year) • Lower step counts were associated with greater disability, as measured by the EDSS • A cutoff of 3279.3 steps a day differentiated persons with MS with ambulatory impairment from persons with MS who were fully ambulatory with 99% classification accuracy, 90% sensitivity, and 100% specificity	• Sola-Valls et al.[37] • Block et al.[38] • Block et al.[39] • Psarakis et al.[40]

(continued)

Table 1. continued

Domain	Application/device details	Articles
	• Daily step count may be more sensitive that the EDSS or the 25-Foot Walk at detecting early changes in ambulatory functioning • Compensatory movements were associated with greater disability, as measured by the EDSS, and reduced mobility	
	GPS Monitoring • Persons' with MS self-reported walking ability was poorly associated with objective measurements, with 79.5% underestimating their abilities • Can be used to track activities, which may be omitted from manual logs if there are cognitive issues	• Neven et al.[41] • Chen et al.[42] • Dalla-Costa et al.[43]

EDSS: Expanded Disability Status Scale; mHealth: mobile health; MS: multiple sclerosis.

[a]Indicates that participants in the study could access the application through a mobile device or another electronic device (eg, desktop computer).

[b]Described as a "web-based program," but only access with a mobile device was noted.

the literature, at least 2 mHealth-based cognitive training programs have been examined,[53,54] which were well-received by persons with MS. In addition, text messages, received through either a mobile phone or pager, have been explored as a compensatory strategy.[55] Besides using wearable devices to track physical activity via methods such as step counts (see Table 1), mHealth has been used as an option to deliver web-based physiotherapy programs.[56,57] As fatigue is a common and often disabling symptom of MS,[58,59] there have also been 4 mHealth-based applications that promote fatigue self-management through various strategies, including cognitive behavioral therapy principles,[60] tele-monitoring and tele-coaching,[61] gamification,[62] and self-assessments and self-monitoring.[18,63]

Tracking and promoting adherence

Another common use within the MS population has been tracking and promoting adherence: about 44% of persons with MS in one survey noted that they use mHealth to remind them about their medications or upcoming appointments.[13] Similarly, 37% of the commercially available MS-related self-management applications focused on medication management.[10] Besides using applications to communicate with their clinicians about their care, persons with MS have reported using text messages, although they noted using secure online portals and email more frequently than texts or applications.[9] Some persons with MS have opted to have text message reminders sent to their mobile phones (vs via email or through a home monitoring device) to take their disease modifying therapy (DMT)[64] or engage in physical activity.[65] Text messages have also been incorporated, along with phone calls and emails, as part of a telemedicine-based patient support program.[66]

When given the choice, more than half of persons with MS will choose a digital diary over a paper diary to monitor their DMT adherence.[67] In addition, using a digital diary with reminders has been associated with a reduced risk of suboptimal adherence.[68] Tools such as MSdialog (web- and mobile-based)[17] and PatientConcept (mobile-based)[69] has been shown to help track DMT usage, and include other features that may promote adherence, such as health reports via patient-reported outcome measures, reminders, and appointment requests. For both applications, persons with MS have endorsed that they were useful in helping them communicate with their healthcare provider. It should be noted that several of the mHealth tools that have been developed for monitoring adherence are associated with specific DMTs, such as MSdialog and interferon beta-1a.[17]

Potential barriers and technological considerations

While mHealth is being used by persons with MS in a variety of contexts and for a variety of purposes, there are a number of potential barriers that may inhibit its use (Table 3). Although any limitation in function may affect mHealth usage for persons with MS, difficulties related to vision, fine motor dexterity, and cognitive functioning may be more salient, depending on the MS presentation, severity, and course of progression. For instance, persistent visual difficulties are common in MS,[70] and as such, individuals with this symptom may struggle to use mHealth tools with small or hard-to-read text.[62,71] Allowing for verbal cues or using larger text and buttons[11,72,73] may help compensate for these issues. Coupled with sensory and/or fine motor issues,[74] the size of the mobile device needs to be considered, particularly with applications with more complex components (eg, longer questionnaires).[18] In addition, given that up to 70% of persons with MS experience cognitive impairment,[2] including reminders in the application may be a valuable addition and assist with adherence to a mHealth program.[75,76]

Several of the problems identified in the literature are not unique to persons with MS. For instance, confusing interfaces have been noted to make it difficult for persons with MS to adopt mHealth tools,[63,77] which could influence mHealth usage in a variety of users. Other problems, such as cognitive impairment affecting users' abilities to remember tasks related to the mHealth tool,[41,42] can occur in other chronic health conditions. Some of these potential issues can be addressed in the design process, such as allowing users to retake a timed task if something unforeseen interferes with their performance.[35] Furthermore, if persons with MS are included throughout the design process, potential limitations can be identified and corrected earlier in development. However, other barriers such as limited cellular network coverage and disruptions in the signal,[41,61] may be out of developers' control.

DISCUSSION

Given the healthcare-related challenges that persons with MS can face[7] and the growing need for telehealth, mHealth offers an important option to access needed services and resources. However, in order for mHealth to be meaningful to persons with MS, it needs to be usable, useful, and satisfying. This literature review aimed to better understand persons' with MS use of mHealth and the potential barriers. Overall, the majority of persons with MS use devices like smartphones on a regular basis. Although rates of mHealth utiliza-

Table 2. Current mHealth uses for interventions and symptom management in persons with MS

Domain	Application/device details	Articles
Cognitive training	Project: EVO™ • Tablet-based program with 4 weeks of training (25 min a day, 5 days a week) • Improvement in processing speed (0.4 points below meaningful change)	• Bove et al.[53]
	Cognitive Training Kit (COGNI-TRAcK) • Three types of working memory exercises • Scheduled trainings (5 sessions a week for 8 weeks) were completed by 84% of persons with MS	• Tacchino et al.[54]
	NeuroPage • Participants could receive reminder messages via their mobile phone or a pager • Associated with reduced emotional distress and better recall of specific, intended tasks	• Goodwin et al.[55]
Physical activity	Web-based Physiotherapy[a] • Program could be accessed through a tablet or a computer • Several benefits for persons with MS, including being able to engage in the program based on their schedules and not needed to travel • Improvement in self-reported physical impact of MS • 40% were still adherent at 6 months	• Paul et al.[56] • Paul et al.[57]
Fatigue self-management	MS Energize • Developed using cognitive behavioral principles (eg, how thoughts and behaviors influence MS-related fatigue)	• Babbage et al.[60]
	MS TeleCoach • Used a combination of tele-monitoring (utilizing the integrated accelerometers and having participants report their fatigue impact levels) and tele-coaching (goal setting and motivational messages)	• D'hooghe et al.[61]
	More Stamina • Used gamification to promote behavior change related to fatigue management (eg, awarding points and achievements)	• Giunti et al.[62]
	MSmonitor[b] • Used self-assessments (eg, questionnaires and inventories) and self-monitoring (eg, activity diaries) • Modest negative correlation between how frequently persons with MS were using the diary option and their level of fatigue impact • 46% of persons with MS using the application reported that they had an improved understanding of their symptoms	• Jongen et al.[18] • Jongen et al.[63]

mHealth: mobile health; MS: multiple sclerosis.
[a]Indicates that participants in the study could access the application through a mobile device or another electronic device (eg, desktop computer).
[b]Described as a "web-based program," but only access with a mobile device was noted.

tion varied, it appears to be more common in the United States compared to parts of Europe, based on the reported data.[9,13] Some of the factors noted to be associated with mHealth usage (eg, level of education, income, age)[9] may be related to some of the barriers identified in the literature. For instance, older adults may be less likely to use mHealth because of limited digital literacy.[52] Clinicians and researchers working with older persons with MS should consider providing a training session with the device or application to help encourage mHealth usage.[21,56]

The use of mHealth as a component of MS-related care has grown over the past decade, with increased sophistication and options for end users. For instance, while earlier work investigated the use of a personal digital assistant (PDA) as a compensatory tool (eg, setting alarms and reminders),[83] less than a decade later there are standalone, mHealth-based cognitive training programs that involve domain-specific exercises,[53,54] allowing for persons with MS to engage in active training whenever and wherever it is convenient for them. The adoption of mobile devices as part of everyday life has also been reflected in individuals needing fewer instruments to engage in technology-based interventions. Rather than needing a home monitoring device connected through a landline to receive reminders, persons with MS can elect to get them sent directly to their cell phones.[65,84] While several of the identified applications were web-based and could be accessed via a mobile or non-mobile device,[14,16,17,22,56,57] a number of applications were designed specifically for smartphones,[15,19,20,31,35,36,60–62] tablets,[21,27,28,30,32–34,53] or both devices.[54,69]

In terms of current uses of mHealth in the MS population, both mHealth-based applications and web-based applications that can be accessed with a mobile device, options ranged from assessment tools used by clinicians to quantify disability to programs that can help persons with MS improve their working memory. Many of these mHealth tools have been developed recently, demonstrating the increased attention and availability of technology in MS-related care. Of the 21 studies that discussed disability and symptom measurement, 72% ($n = 18$) were initially published between 2017 and 2019, with half of those in 2019 alone. Similarly, 60% ($n = 6$) of the studies detailing intervention and symptom management mHealth tools were published in 2018 and 2019. Furthermore, smartphone- and tablet-specific programs have become more common, with almost two-thirds of the studies ($n = 14$) examining them initially published between 2018 and 2019. Although many of the mHealth applications focused on the provider (eg, disability evaluations), several of the identified tools can be used by persons with MS for tracking and improving their symptoms.

While there are a growing number of mHealth options for persons with MS, several potential barriers have been identified that might negatively influence the adoption of mHealth. Although the symptom presentation varies from person to person, many persons with MS experience cognitive, sensory, and/or physical difficulties,

Table 3. Potential barriers and considerations when developing mHealth tools for persons with MS

Potential barriers and issues	Considerations	Articles
• Information provided is false, biased, or outdated	• Provide a list of references	• Winberg et al.[74] • Giunti et al.[77] • Giunti et al.[75]

• Data collected by the application are not accurate
  • "Noise" due to task disruptions
  • Variations due to location of wearable device
  • Greater relative error with slower walking speeds with certain devices
  • User is unaware when a task ends if there is not a technician present
	• Allow users to retake the task if something unforeseen interfered in their performance
	• Consider using a wearable device that is worn on the waist over the non-dominant hip
	• Consider using more accurate device if working with persons with MS with greater walking impairment
	• Include an alarm (eg, vibration) to signal the user
		• Carignan et al.[78]
		• Balto et al.[79]
		• Boukhvalova et al.[35]

• Privacy concerns
  • Tracking location or data in real time
  • How data are shared
  • Security of users' data
	• Give users the option to share their data (eg, choice to give healthcare providers their ID)
	• Calculate relative location rather than users' real-time location
		• Chen et al.[42]
		• Griffin and Kehoe[11]
		• Giunti et al.[77]
		• Giunti et al.[75]
		• Lang et al.[69]
		• Ranjan et al.[80]
		• Simblett et al.[52]

• Data storage and transmission during use	• Store data locally, particularly when the device is not connected to Wi-Fi • Save data only at end of trial, with interim data in a buffer	• Carignan et al.[78] • Boukhvalova et al.[35]
• Limited cellular network or disruptions in the signal	• Be aware that this may cause issues in delivering information or collecting data	• Neven et al.[41] • D'hooghe et al.[61]
• Confusing interfaces	• Using a "simple design"	• Jongen et al.[63] • Giunti et al.[77] • Karnoe et al.[73] • Simblett et al.[52]

• Physical considerations related to MS
  • Poor dexterity (eg, difficulty turning on and off switches on small devices)
  • Visual impairments (eg, blurry vision)
	• Consider using larger devices (eg, tablets) with applications with more complex components
	• Use larger text and buttons
	  • Test different sizes with potential users to find optimal settings
	• Allow for verbal cues
		• Chen et al.[42]
		• Jongen et al.[18]
		• Winberg et al.[74]
		• Van Kessel et al.[71]
		• Boukhvalova et al.[35]
		• Griffin and Kehoe[11]
		• Giunti et al.[62]
		• Thirumalai et al.[72]
		• Karnoe et al.[73]
		• Simblett et al.[52]

• Cognitive difficulties
  • Forgetting to charge or turn off devices, log activities
	• Incorporate tasks into users' routine
	• Reminders
	  • Frequency needs to be considered, as persons with MS have expressed dissatisfaction with "constant" notifications
		• Chen et al.[42]
		• Neven et al.[41]
		• Paul et al.[56]
		• Winberg et al.[74]
		• Griffin and Kehoe[11]
		• Giunti et al.[77]
		• Tonheim and Babic[76]
		• Simblett et al.[52]

• Application is not customizable or options provided are "too general"	• Have customizable sections, such as goal settings • But include some pre-set options, such as common daily activities	• Jongen et al.[63] • Giunti et al.[77] • Tonheim and Babic[76] • Tonheim and Babic[81] • Simblett et al.[52]
• Premature discontinuation with interventions and longitudinal assessments	• Be aware that discontinuation occurs at the highest rate at the beginning and stabilizes over time • Individuals who perceive greater benefit from use were more persistent	• Bove et al.[15] • Engelhard et al.[16] • Midaglia et al.[19] • Paul et al.[57]
• Costs of device and data plan may be financially unattainable	• Consider factors such as overage charges depending on the users' data plan	• Penkert et al.[82] • Simblett et al.[52]
• Limited digital literacy	• Training session with device prior to independent user	• Paul et al.[56] • Kos et al.[21] • Simblett et al.[52]
• Application may collect critical or sensitive data that requires follow-up (eg, possible depression or abnormal lab result)	• Implement a system to alert users' healthcare providers for appropriate follow-up	• Engelhard et al.[16] • Lang et al.[69]

mHealth: mobile health; MS: multiple sclerosis.

which can impede their usage of certain mHealth tools.[52,62,71,74] Some barriers, such as digital literacy, costs, and interface design can apply to mHealth in general. Even some of the aforementioned disease-related barriers and their associated considerations, such as including reminders or adjusting the text size,[11,72,73,75,76] can apply to other populations. A number of studies included participants with other conditions besides MS,[41,42,74,78,80,82] suggesting that these barriers need to be considered when designing mHealth for a wide variety of patient users.

Some of these issues, such as factoring in the physical manifestations of MS, highlight the need to use user-centered design processes[85] during the development of new mHealth tools for persons with MS. Including persons with MS, as well as healthcare providers, during the design process can elucidate potential disease-related limitations and their solutions prior to the product being tested commercially. For instance, if a mHealth tool involves physical activity where falls or a cardiac event may be a possibility, a healthcare provider might bring up the need to include an emergency contact, while a person with MS may suggest ways of handling potential societal barriers. Furthermore, involving persons with MS throughout the development of new mHealth applications, particularly in the early stages, can increase the likelihood that these tools are meeting the needs of its end users and will be implemented in everyday life. It is important to note that while these procedures were largely used in the included studies, this may not always be the case in commercially available applications, as noted in Salimzadeh et al. review.[10]

With the recent finalization by the Center for Medicare and Medicaid Services of the Interoperability and Patient Access Rule,[86] required as part of the 21st Century Cures Act,[87] all certificated Health Information Technology (IT) systems (electronic health records and Insurance IT systems) will be required to use a standard Application Programming Interface to allow developers to create mHealth tools for persons with MS that interoperate with their clinicians' systems. This will open up a broad array of new opportunities to develop new tools that meet specific needs. It would be imperative to consider the lessons learned already, as demonstrated by this literature review, to rapidly develop the most effective, user-friendly mHealth tools possible.

Several caveats should be noted in the current review. Given that the review was limited to English language articles, studies published in other languages were not included. As such, mHealth usage may be different in other cultures and communities, potentially over-estimating or under-estimating the frequency of mHealth usage among persons with MS, and other types of mHealth applications and barriers may have been omitted from this review. In addition, as the current study was a literature review rather than a meta-analysis, the efficacy of these mHealth tools were not examined. As the number of mHealth tools available for persons with MS continue to grow, particularly interventional applications, the efficacy of technology-delivered programs compared to those delivered face-to-face will need to be closely examined to ensure patients are receiving efficacious services, even at a distance. Given the rapid development of telehealth services in response to COVID-19, there will likely be a plethora of new literature on mHealth's efficacy and effectiveness, including optimal delivery mechanisms and its impact on quality of life. Finally, as it was beyond the scope of the current review, other factors that may influence the utility of some of these mHealth tools (eg, costs, frequency of updates, and reliability) were not explored.

In conclusion, the majority of persons with MS have access to smart devices, with several individuals using them for mHealth. While there has been an increasing number of mHealth options for persons with MS, certain physical, cognitive, and technological barriers may affect usage. As such, it is important that persons with MS are involved in the design and testing stages of mHealth development to ensure that the end product meets theirs and their healthcare providers' needs.

AUTHOR CONTRIBUTIONS

ESG made substantial contributions to the conception, design, acquisition, and drafting of the literature review. All authors made substantial contributions to the interpretation of the data. APT, JKH, ACL, and TA made critical revisions of the manuscript. All authors provided final approval and agree to be accountable for all aspects of this work.

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CONFLICT OF INTEREST STATEMENT

None declared.

DATA AVAILABILITY STATEMENT

No new data were generated or analyzed in support of this research.

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