A scoping review of the benefits and challenges of mHealth for clinical decision-making in neuro-physiotherapy

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ABSTRACT. – OBJECTIVE: Mobile health (mHealth) technologies have emerged as promising tools in the field of neuro-physiotherapy, offering innovative solutions for enhancing clinical decision-making processes. This scoping review explores the existing literature on the use of mHealth applications in neuro-physiotherapy with a specific focus on their impact on clinical decision-making.

MATERIALS AND METHODS: The PubMed, Google Scholar, Cochrane Library, ScienceDirect, and Scopus databases were comprehensively searched for both qualitative and quantitative peer-reviewed articles written in the English language and published till 2023 that focus on mHealth applications in neuro-physiotherapy and clinical decision-making.

RESULTS: The key findings from the 14 included studies highlighted the diverse array of mHealth applications employed in neuro-physiotherapy, ranging from wearable sensors and mobile apps to virtual reality platforms. Synthesis of the evidence from these studies demonstrated the potential of these technologies in clinical decision-making and improving patient outcomes, patients' and therapists' perspectives of these applications, their clinical clues, and the challenges with their use.

CONCLUSIONS: The findings from the review underscore the need for continued exploration of these technologies to optimize their effectiveness in rehabilitation settings and ultimately improve clinical decision-making and patient care in neuro-physiotherapy.

Key Words:
Mobile health, Clinical decision-making, Mobile clinical decision-making tools, Mobile health applications, Physiotherapy, Neurological disorders, Neuro-physiotherapy, Real-time data, Rehabilitation, Scoping review.

Abbreviations

WHO: World Health Organization; mHealth: Mobile Health; QoL: Quality of Life; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; ROBINS-I: Risk of Bias in non-randomized Studies-I; RCT: Randomized Controlled Trial; EBPI: Evidence-based patient information; mCDMS: mobile Clinical Decision-Making Support; PDSA: Plan, Do, Study, Act; SITT: Speed-Interactive Treadmill Training; MCI: Mild Cognitive Impairment; WISE: Wearable Inertial Sensors for Exergames.

Introduction

Neurological disorders, which range from stroke and traumatic brain injuries to neurodegenerative diseases such as Parkinson's and multiple sclerosis, present multifaceted challenges to both patients and healthcare practitioners[1]. Physical therapy is a cornerstone in managing these conditions, and the aim of physical therapy regimens is to optimize functional independence, mitigate impairments, and improve the overall quality of life (QoL) of patients[2]. The complex nature of neurological rehabilitation necessitates precise and adaptable clinical decision-making strategies. Historically, neurorehabilitation has relied heavily on subjective assessments, periodic clinic visits, and paper-based documentation, but this has limited the frequency and granularity of patient monitoring[3,4]. Further, an examination of the current state of neurorehabilitation practices reveals that the traditional models face inherent limitations in addressing the diverse needs of individuals with neurological conditions[5,6]. These

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limitations include the episodic nature of clinic visits, the reliance on subjective assessments, and the challenges in obtaining a holistic view of a patient's daily life and activities[7]. These challenges in capturing the dynamic nature of neurological conditions inherent in the traditional models often result in delayed interventions and suboptimal outcomes. With the continuous increase in the global prevalence of neurological conditions, there is an urgent need for innovative, efficient, and patient-centric approaches[8]. The answer to this may lie in the field of mobile health (mHealth), which has been spurred by technological advances in the last few decades.

The World Health Organization defines mHealth as the utilization of mobile devices, such as phones, patient monitors, and digital assistants, for medical and public health practices[9]. mHealth technologies capitalize on features such as voice and messaging and extend to advanced functions that include GPS, Bluetooth, and 3G/4G systems[10]. Mobile technology has revolutionized the way healthcare professionals communicate with their patients. It has played a significant role in improving time management and reducing costs at all levels of healthcare, from hospital visits to individual appointments with physicians. As a result, the overall outcomes of healthcare have been greatly enhanced[11,12]. As a result of the widespread proliferation of mobile technologies, mHealth has become one of the most innovative and empowering fields driving the digital transformation of healthcare globally for the last 20 years[13]. Currently, over 259,000 mHealth applications are accessible on app stores, and they account for around 3.2 billion annual downloads[14]. These applications are used for the management and detection of a wide range of diseases. mHealth technologies have rapidly emerged as transformative tools in healthcare, revolutionizing clinical decision-making[15], particularly within specialized fields such as neuro-physiotherapy. The integration of mHealth into neurorehabilitation practices marks a paradigm shift in the field by offering novel opportunities to enhance patient care, monitor progress, and streamline decision-making processes[16]. For example, mHealth technologies can provide a continuous, real-world assessment of patients' movements, activities, and adherence to therapeutic exercises[17]. Wearable sensors, for instance, can be used to capture kinematic data and offer objective insights into motor function and gait patterns. In addition, smartphones equipped with accelerometers and gyroscopes can be used as portable motion analysis tools for the assessment of balance and coordination in various settings[18]. Apart from these advantages, mHealth applications often incorporate interactive elements that engage patients in their rehabilitation journey. For instance, gamification, virtual reality, and augmented reality features make therapy more enjoyable and encourage adherence to prescribed exercises[19,20]. Importantly, the ability of mHealth to extend therapy beyond the confines of the clinic promotes active patient involvement and empowers individuals to take charge of their rehabilitation[21]. This shift in patient's role from a passive recipient of care to an active participant is in alignment with patient-centered care principles and can potentially enhance treatment outcomes[22].

The incorporation of mHealth into neuro-physiotherapy extends beyond assessment tools to encompass various interventions and support systems and enhance patient well-being, rehabilitation progress, and integration into community[23]. Utilizing health apps for scheduled follow-up appointments enhances the efficiency of both doctors and patients, increasing the likelihood of follow-ups, minimizing missed appointments, and optimizing overall patient outcomes[24]. This is particularly valuable for individuals with mobility constraints or those residing in remote areas with limited access to specialized neurorehabilitation services[25]. As an extension of mHealth, telehealth, with the support of mHealth technologies, transcends geographical barriers, expanding the reach of expert neurorehabilitation care and improving the overall accessibility and equity of healthcare services. This surge in mHealth applications presents an unprecedented opportunity to enhance neurorehabilitation practices, offering real-time data, personalized interventions, and remote monitoring capabilities. However, as the use of mHealth in neuro-physiotherapy expands, there is a need to examine the breadth and depth of available evidence. Accordingly, the rationale for conducting this scoping review lies in the dynamic landscape of healthcare technology and the imperative to comprehensively map the existing literature in this evolving field. Accordingly, this scoping review intends to comprehensively overview existing knowledge to identify significant themes, gaps, and trends in the application of mHealth in neuro-physiotherapy. By elucidating the extent and nature of existing research, the aim is to enlighten clinicians, academics, and policymakers on the advantages and challenges of using mHealth in neurorehabilitation decision-making, directing future research, and supporting evidence-based developments. To this end, the article seeks to answer the following questions:

What are the advantages and challenges of mHealth technologies in terms of clinical decision-making in neuro-physiotherapy?

What is the clinical value of mHealth technologies in neuro-physiotherapy?

What are the outcomes of using mHealth-based interventions in neuro-physiotherapy?

What are the perspectives of patients, therapists, and other stakeholders on the use of mHealth technologies in neuro-physiotherapy?

What are the future challenges that need to be resolved to improve the clinical applicability of these technologies?

Materials and Methods

This scoping review was conducted according to the guidelines of Arksey and O'Malley[26], who introduced a 5-step framework for conducting scoping reviews. This paper was also written according to the preferred reporting items of the PRISMA-SCr checklist.

Literature Search Strategy

To identify relevant studies, PubMed, Google Scholar, The Cochrane Library, ScienceDirect, and Scopus were queried using the following search terms, which were strategically input in combination with the Boolean operators AND, OR, or NOT to expand or refine the search: "mobile health", OR "mhealth", OR "telemedicine", AND "neurology", AND "physical therapy", OR "physiotherapy" (see **Supplementary Table I**).

Inclusion and Exclusion Criteria

Peer-reviewed articles written in the English language and published till 2023 were considered. The date of the last search was December 2023. Articles that focus on mHealth applications in neuro-physiotherapy and clinical decision-making were screened out. More specifically, articles presenting information on the use of mobile health technologies, such as smartphone apps or wearable devices, in assessing, treating, or monitoring neurological conditions within neuro-physiotherapy were selected. Additionally, studies that explored the impact, effectiveness, challenges, or opportunities associated with mHealth tools in neuro-physiotherapy and decision-making were included.

Articles not written in English were excluded to ensure linguistic consistency for analysis. Additionally, studies that did not specifically address mHealth tools or lacked relevance to clinical decision-making in the context of neuro-physiotherapy were excluded. Conference abstracts, editorials, and commentaries were also excluded to prioritize peer-reviewed, substantive research. Furthermore, studies lacking full-text availability or studies with insufficient information for critical evaluation were excluded to maintain the robustness of the scoping review.

Study Selection

Based on the literature review, an autonomous assessment was conducted on the original publications, study titles, and abstracts. Two independent reviewers (KS and RB) scrutinized the full texts of papers meeting the inclusion criteria, and their findings were deliberated upon to establish a consensus. Any discrepancies were resolved by engaging a third independent reviewer (SM), and resolutions were reached through mutual agreement.

Data Charting

In alignment with the review questions, an Excel data charting form was created and iteratively improved as the two reviewers comprehensively examined the papers. The following information was extracted and systematically documented: demographic details, such as authors, study year, location, design, sample size, participant age, and intervention; the characteristics of the intervention; contextual factors surrounding its implementation; expected and reported outcomes; a descriptive narrative of the intervention process; and the identified facilitators and barriers to the implementation and utilization of the intervention. Quality assessment of RCTs was done using the PEDro scale (for items, see **Supplementary Table II**), while non-RCTs were assessed using the Risk of Bias in Non-Randomized Studies-I (ROBINS-I) tool using Robvis (web-based app designed for visualization of RoB assessments, UK, https://mcguinlu.shinyapps.io/robvis/).

Results

Results of the Literature Search

The initial search yielded a total of 1,684 records from the examined databases. After duplicates (n = 43) were removed, the remaining 1,641 records were screened for eligibility. According to the exclusion criteria, 1,452 records were excluded for miscellaneous reasons when they did not fit the scope of the review and did not answer the research question, and 173 were excluded because they did not report original research findings (including 121 protocols, 35 literature reviews, and 17 conference papers). This resulted in a final set of 16 articles for full-text assessment. After a review of these articles, one was further excluded because it did not focus on physical therapy, and another one was excluded for being a case report. Ultimately, 14 studies[27-40] were included in the final qualitative analysis (Figure 1).

General Characteristics of the Included Studies

Of the 14 included studies, 7 were RCTs with mHealth intervention and control groups, while the remaining 7 non-RCT studies included observational studies, pilot studies, and a qualitative descriptive study. The RCTs[27-29,31,33,38,40], and one pilot study[37] included intervention and control groups comprising patients undergoing neuro-physical rehabilitation therapy. Two observational studies[32,34], examined patients undergoing neuro-physical rehabilitation, and the third observational study[30] included only physiotherapists and occupational therapists. One qual-

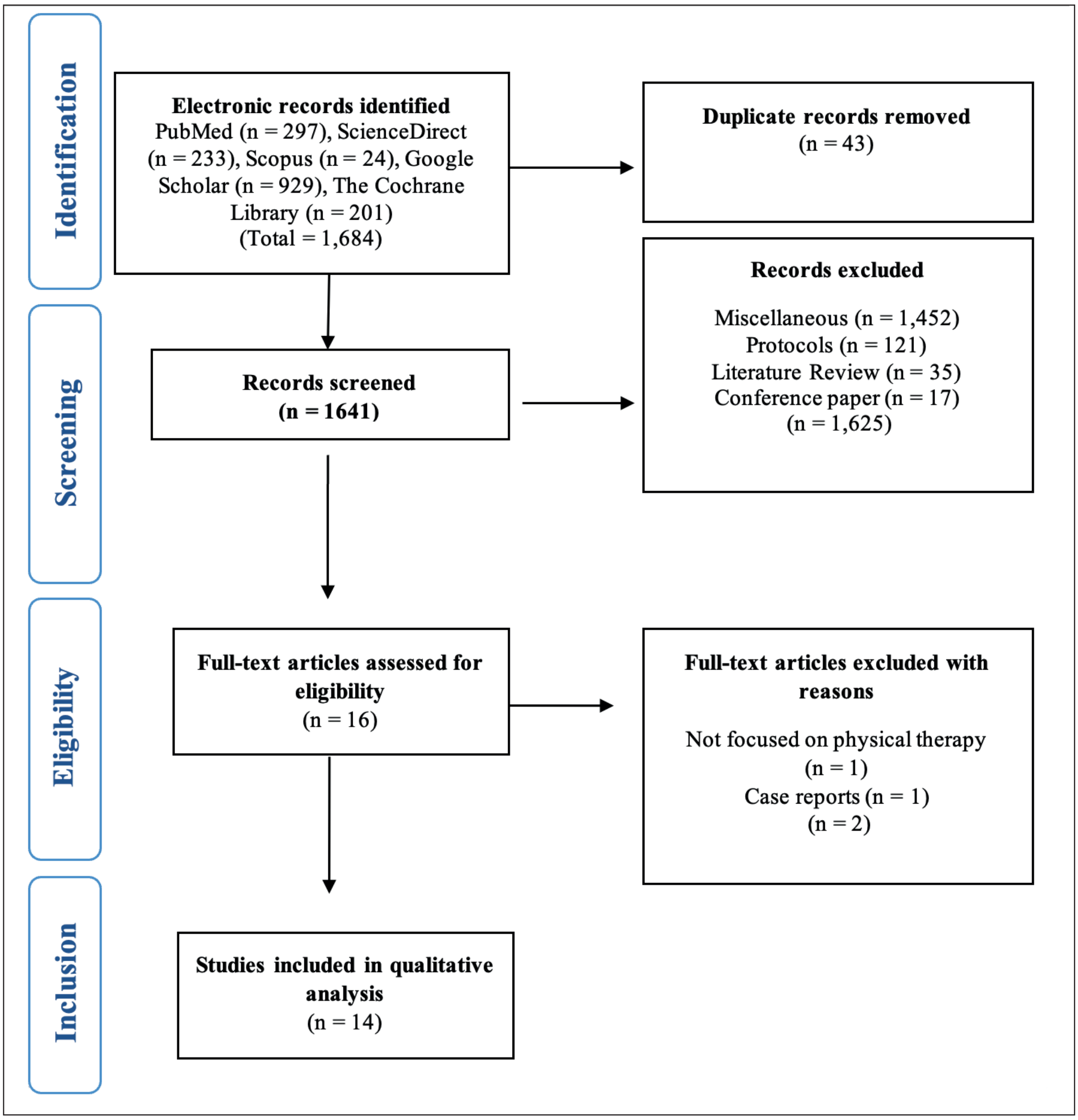

Figure 1. PRISMA flow chart depicting the selection of the included studies.

itative descriptive study[35] and one pilot study[36] included both patients and physiotherapists. The final non-RCT study[39], which was a pilot study, included patients, caregivers, physiotherapists, and local community groups. Most of the studies were reported from the USA (n = 4)[29,32,34,38], followed by Spain (n = 2)[33,37], Germany (n = 1)[31], Netherlands (n = 1)[36], UK (n = 1)[30], Korea (n = 1)[28], Thailand (n = 1)[40], New Zealand (n = 1)[35], Romania (n = 1)[39], and Belgium/Israel (n = 1)[27]. An overview of the characteristics of participants and interventions in each study is presented in Table I.

mHealth/mCDMS Tools used in Neuro-Physiotherapy

In the studies reviewed, different mHealth applications were employed, including CuPiD and ABF-gait (Belgium and Isreal)[27], Virtual Active (South Korea)[28], Wellpepper mobile app (USA)[29], ViaTherapy (UK)[30], the evidence-based patient information (EBPI) app (Germany)[31], the wearable inertial sensors for exergames (WISE) system (USA)[32], the Farmalarm app (Inmovens Solution, Barcelona, Spain)[33], Tele-FootX (LEGSys, BioSensics, Newton, MA, USA)[34], exciteBCI (New Zealand)[35], Remote monitoring system (Nijmegen, Netherlands)[36], and the ROX-Pro© system (https://a-champs.com)[37]. In addition, the majority of the studies[27-39] (n = 13) used applications that also had a mobile clinical decision-making support (mCDMS) function. For example, one study[27] used CuPiD for delivering feedback and cues through earphones or smartphone speakers, while another[38] employed mastery, persuasion, modeling, and appraisal techniques, supplemented by phone calls, for clinical decision-making. The other mCDMS tools included a smartphone-based human tracking technology for communication[28]; a two-way text message system for communication to enhance decision-making[29]; the "Plan, Do, Study, Act" (PDSA) cycle[30]; feedback through photos and videos exchanged between patients and physiotherapists for better decision-making regarding their exercises[31]; an instructor-programmed UI[32]; virtual and remote coaching *via* integrated video calls[34]; a MULTI-ACT methodology involving patient-reported outcomes for notifications and alerts[39]; an algorithm analyzing continuously collected accelerometer and barometer data to identify fall incidents during walking bouts[36]; and a system involving small devices delivering visual, auditory, and vibration stimuli for patient interaction to improve the decision-making process[37].

Impact of mHealth Tools on Clinical Decision-Making

Overall, these studies collectively reveal insights into the strengths, weaknesses, and areas for development through their examination of various clinical decision-making approaches. For instance, in the case of four of the mCDMS tools, namely, smartphone-based tracking[28], two-way text messaging[29], remote coaching *via* video calls[34], and the use of small devices to deliver stimuli for patient interaction[28,29,34,37], the feedback data delivered *via* the technologies indicated an improvement in the patients. Further, the model used in the pilot study by Bajenaru et al[39] was found to be useful for personalized medical decisions, guiding care goals, diagnostics, rehabilitation, and stroke prevention. Thus, these tools had a positive impact on clinical decision-making. However, some features proved to pose limitations to the clinical decision-making process. For example, the CuPiD and WISE systems did not have enough statistical data that needed to be validated[27,32]. Moreover, concerns were observed among therapists about the broad nature of algorithmically generated questions and the need for more specific inquiries[30], as well as a lack of interactivity in the case of one system (feedback through photos and videos)[31]. In the mCDMS tool devised by Alder et al[35], who used an electroencephalography headset that transmitted data to a mobile phone, the time required to set up the devices in various clinical settings proved to be a limitation[35]. Van den Bergh et al[36] reported that the Geosafe system needed improvements to remotely track falls (Table II).

Clinical Value

Overall, a significant improvement was observed in the intervention groups, which showed more notable progress in balance and were able to sustain a good QoL and active lifestyle compared to the control groups[27,28,31,32,34-38,40]. Thus, the mHealth technologies used in these studies had positive clinical value. In the case of the Hancock et al[30] study, the physiotherapists' confidence in accessing and applying Evidence-Based Practice (EBP) increased by 22% from the baseline. This indicates that their application has good clinical potential. Nasseri et al[31] found that the clinical impact of the tools was acceptable but had limitations. However, slight differences in balance and gait were observed with the Farmalarm mHealth app[33]. Moreover, they noted low rates of usage and adherence with this app, which could impact its clinical application[33].

Outcomes and Perspectives

As shown in Table II, in the majority of the studies, considerable improvements were associated with the use of mHealth applications, as the outcomes in the interventions were significantly better than those in the control groups. In one of the studies, therapists found the mHealth tool (ViaTherapy) concise and user-friendly, especially in the mobile app format[30]. Moreover, a positive usability rating was observed for a necklace-based application for recording falls, even though some variations were perceived in its utility[36].

Meanwhile, van den Bergh et al[36] discovered that physiotherapists appreciate objective recording of at-home activity and utilize fall monitoring to increase awareness of falls among individuals with Parkinson's disease. However, users of the device varied in terms of ease of use and levels of motivation, as indicated in Table II. The study by Park et al[34] reported high acceptability of and positive attitudes towards the system, with perceived benefits, and Alder et al[35] also reported favorable views and positive experiences with their smartphone-based application.

Quality Assessment of RCTs

The PEDro scale consists of 11 items for evaluating various aspects related to participant's selection, study design, randomization, blindness, and reporting, with a maximum possible score of 11. Each item was scored as present (Y) or absent (N). Notably, two studies[29,31] received a score of 10, which indicates high methodological quality, while the remaining studies scored 9 (Table III). These PEDro scores suggest that the majority of the RCTs assessed exhibit a relatively high level of methodological rigor.

Quality Assessment of Non-RCTs

All the non-RCT studies were assessed using Robvis for their level of bias in domains such as participant selection, confounding, and intervention with the exception of the van den Bergh study[36]; the remaining non-RCTs had moderate to serious biases in multiple domains (Figure 2).

Discussion

This scoping review delves into the realm of mHealth applications within the context of neuro-physiotherapy with the aim of providing a comprehensive exploration of the existing literature and evidence. Through this exploration, we seek to contribute to a deeper understanding of the current landscape in terms of the impact of mHealth applications on clinical decision making, outcomes and perspectives among patients and therapists, their clinical value, and current limitations and future challenges that need to be tackled. Based on the findings of these reviews, we point out gaps in the current knowledge and propose directions for future research and implementation in this evolving intersection of technology and healthcare practice.

In the present study, numerous mHealth apps/mCDMS tools utilized by physical therapists in the rehabilitation of patients with neurological disorders and their clinical impact were examined, as depicted in Tables I and II. Overall, the findings of the reviewed studies confirm the benefits of mHealth technologies that have been previously discussed in the literature. That is, these technologies offer real-time data collection, enabling physical therapists to track patients' movements and progress outside of clinical settings, fostering a more holistic understanding of their physical activity patterns. Moreover, by providing instant access to comprehensive data, mHealth and mCDMS tools empower physical therapists to tailor interventions based on individualized and up-to-date information, thereby optimizing treatment plans. Other advantages of these tools are that they facilitate remote monitoring, thus enabling healthcare professionals to bridge the gap between in-clinic sessions, promoting consistent engagement with prescribed exercises, and fostering a sense of autonomy and accountability among patients. As a result, the integration of mHealth and mCDMS into neuro-physiotherapy not only enhances the efficiency of clinical decision-making but also contributes to more personalized and patient-centric rehabilitation strategies. Similar to our conclusions, a systematic review[41] on 11 mHealth applications with a physical training component based on gamification, exercise prescription, and physical activity reported promising results in terms of improving physical function and activity during stroke therapy. Moreover, when physical exercise was com-

Table I. Summary of the features of the included studies.

Study ID	Country	Study design	Sample size	Gender (M:F)	Age (years)	Target group	Neurological condition	Rehab target	Intervention	mHealth tool	Type of mCDMS
(Ginis et al[27], 2016)	Belgium and Israel	RCT	Intervention = 22; Control = 18	NA	NA	Patients	Parkinson's disease	Gait, Balance, QoL	Exercise (walking)	CuPiD and ABF-gait app	Feedback and cues were delivered through earphones or the smartphone speaker (CuPiD)
(Plow and Goldin[38], 2017)	USA	RCT	mHealth intervention = 15 Traditional (paper-based) method = 16 Control = 15	39:0.7	57.8	Patients	Multiple neurological conditions	Physical function	Physical activity (exercise, walking)	Google Nexus tablet	Mastery, persuasion, modelling, and appraisal, as well as phone calls
(Lee et al[28], 2017)	Korea	RCT	Intervention = 18; Control = 16	Intervention = 11:7; Control = 10:6	Intervention = 55.1; Control = 52.06	Patients	Stroke	Gait	Speed-interactive treadmill training (SITT)	Virtual Active	Smartphone-based human tracking technology
(Ellis et al[29], 2019)	USA	RCT	Intervention = 26; Control = 25	Intervention = 15:11; Control = 13:12	64.1	Patients	Parkinson's disease	Physical function	Exercise and walking	Wellpepper mobile app	Communication through two-way text messages
(Hancock et al[30], 2019)	UK	Observational	13	NA	NA	Physiotherapists and occupational therapists	Stroke	Upper limb function	Task-specific activity	ViaTherapy	PDSA cycle
(Nasseri et al[31], 2020)	Germany	RCT	Intervention = 18; control = 20	Intervention = 10:8; Control = 9:11	Intervention = 49.6; Control = 52.5	Patients	Chronic progressive multiple sclerosis	Physical function	Physical activity	EBPI app	Feedback through pictures and videos
(Rajkumar et al[32], 2021)	USA	Observational	17	11:06	18-64	Patients	Neurological conditions	Upper limb function	Exergame exercise (five shoulder and elbow exercises)	WISE system	Instructor-programmed UI and virtual coaching
(Salgueiro et al[33], 2022)	Spain	RCT	Intervention = 15; Control = 15	Intervention = 10:5; Control = 10:5	Intervention = 57.27; Control = 64.53	Patients	Stroke	Trunk performance, Balance, Gait	Home-based core-stability exercises	Farmalarm App	NA
(Park et al[34], 2022)	USA	Observational	14	2:12	68.1	Patients	Mild cognitive impairment or dementia	Balance and cognition	Exergame exercise	Tele-FootX	Remote coaching *via* an integrated video call
(Aphiphaksakul and Siriphorn[40], 2022)	Thailand	RCT	Intervention = 16; Control = 16	Intervention = 6:10; Control = 7:9	59.38	Patients	Stroke	Locomotory function	Home-based exercise	Compass inclinometer application and balancing disc	The display showed three inclinometers indicating smartphone tilt. Participants followed exercise instructions and adjusted their movements based on the screen display
(Alder et al[35], 2023)	New Zealand	Qualitative descriptive	Patients = 6, Physiotherapists = 4	Patients = 3:3; Physiotherapists = 0:5	< 45 to > 65	Patients and physiotherapists	Stroke	Foot and ankle movement limiting locomotor function	Exercise	exciteBCI	An electroencephalography headset, a muscle stimulator, and a mobile app that communicate wirelessly and are used for decision-making

Table continued

Table I. ***(Continued).*** Summary of the features of the included studies.

Study ID	Country	Study design	Sample size	Gender (M:F)	Age (years)	Target group	Neurological condition	Rehab target	Intervention	mHealth tool	Type of mCDMS
(Bajenaru et al[39], 2023)	Romania	Observational	15 in pilot study; 11	NA	18-85	Local community groups, patients, physicians, caregivers	Stroke	Physical impairment, cognitive and emotional abilities	Home-based exercise	ALAMEDA	MULTI-ACT methodology (Patient-reported outcomes that allow individuals to receive notifications and alerts while tracking their health status across different dimensions)
(van den Bergh et al[36], 2023)	Netherlands	Two pilot studies	Pilot 1 = 30 (21 patients; 9 physiotherapists); Pilot 2 = 33 (25 patients; 8 physiotherapists)	15:06	Pilot 1 = 65.5; Pilot 2 = 68.7	Patients and physiotherapists	Parkinson's disease	Physical impairment	Physical activity	Remote monitoring system	An algorithm that relies on continuously collected accelerometer data and identifies fall incidents by analyzing both accelerometer and barometer data during walking bouts lasting for at least 10 min
(Villamil-Cabello et al[37], 2023)	Spain	Pilot study	Intervention = 12; Control = 7	Intervention = 10:2; Control = 4:2	72	Patients	Multiple neurological conditions	Motor and motor/cognitive, gait	Individualized home dual-task training	ROXPro© system	The use of small devices to deliver visual, auditory, and vibration stimuli for patient interaction

RCT: Randomized Controlled Trial; EBPI: Evidence-Based Patient Information; mCDMS: mobile Clinical Decision-Making Support; NA: Not Applicable.

Table II. Summary of the findings reported in the reviewed studies.

Study ID	mHealth devices	Impact on clinical decision making	Outcomes/Perspectives	Clinical value	Conclusion	Limitations
(Ginis et al[27], 2016)	Smartphone, a docking station, and two IMUs	The CuPiD system needs statistical data and validation.	Both groups demonstrated significant improvement. The CuPiD group exhibited notably more significant improvement in balance and sustained QoL at follow-up. Conversely, the control group experienced a decline in QoL.	Positive	CuPiD enhanced gait training and demonstrated good feasibility and high acceptance levels.	Small sample size
(Plow and Goldin[38], 2017)	Smartphone app and phone calls	NA	Both the mHealth intervention and traditional paper-based groups had notably higher effect sizes with regard to planned exercise and leisure-time physical activity than the contact-control group	NA	mHealth apps can boost physical activity in adults with neurological conditions.	Small sample size, generalizability
(Lee et al[28], 2017)	Smartphone	Improvement	The intervention group showed more improvement than the control group	Positive	SITT with smartphone tracking enhanced the walking ability of stroke patients.	Missing data, no long-term follow-up
(Ellis et al[29], 2019)	Smartphone	Improvement	A significant and clinically meaningful improvement was observed in the intervention (mHealth) group.	Positive	The mHealth app enhanced the exercise program, especially for less active participants.	Small sample size
(Hancock et al[30], 2019)	Smartphone	Some therapists expressed concerns about the broad nature of the introductory algorithmically generated questions. They expressed the desire for more specific inquiries that could help them gain a more detailed understanding of individuals with stroke and their specific needs.	Therapists observed that the tool was concise and user-friendly, primarily in mobile app format.	Confidence in accessing and applying Evidence-Based Practice (EBP) increased by 22% from the baseline.	The application improved the administration of upper limb therapy in post-stroke patients.	Use of one PDSA cycle, small sample size, generalizability
(Nasseri et al[31], 2020)	Smartphone	Lack of interactivity	The intervention group exhibited higher motivation for an active lifestyle.	Acceptable with limitations	Participants with MS were motivated by the concept of using a smartphone app for promoting an active lifestyle.	Small sample size, problems in randomization
(Rajkumar et al[32], 2021)	WISE system	Needs validation	Participants were interested in using the WISE system	Positive	The device needs further validation in clinical and telerehabilitation settings.	NA
(Salgueiro et al[33], 2022)	Smartphone	NA	Slight balance and gait differences were observed.	Usage of and adherence to the app was low.	Combining a telerehabilitation app with conventional physical therapy improves trunk function and sitting balance in chronic post-stroke cases.	Sampling not according to calculation
(Park et al[34], 2022)	Tablet and wearable sensors	Improvement	High acceptability of and positive attitudes towards the system, with perceived benefits	Acceptable	Tele-Exergame was beneficial for preserving cognitive function in older adults with MCI and dementia	Small sample size, short intervention times, lack of a control group

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Table II. ***(Continued).*** Summary of the findings reported in the reviewed studies.

Study ID	mHealth devices	Impact on clinical decision making	Outcomes/Perspectives	Clinical value	Conclusion	Limitations
(Aphiphaksakul and Siriphorn[40], 2022)	Smartphone	Visual feedback training	The intervention group showed significantly more significant improvements in PASS changing posture and BI than the control group, with no significant differences in other metrics.	Positive	Home-based training with balance discs and a smartphone inclinometer app can improve stroke patients' postural control and daily functioning.	NA
(Alder et al[35], 2023)	Smartphone	Some physiotherapists observed that the time required to set up both the headset and the app in various clinical settings had a negative effect on the decision-making process.	The results indicated that individuals who had suffered a stroke and physiotherapists held favorable views and had positive experiences with the exciteBCI intervention.	Positive from the physiotherapists' perspective	The findings provide crucial insights for developing rehabilitation technologies and emphasize the need for designs that strengthen the patient-therapist bond, prioritize social acceptability based on usage context, and utilize research methods to grasp usability in sustained use scenarios.	Sampling method, study design
(Bajenaru et al[39], 2023)	Wearable devices	The SDM model in the stroke pilot was found to play a vital role in personalized medical decisions, guiding care goals, diagnostics, rehabilitation, and stroke prevention. Its effectiveness hinges on the availability of solid medical evidence.	Create guidelines for patients using wearable sensing devices, conduct questionnaire data analysis, outline principles for decision-making, and identify specific applications.	The outcome of engaging with members of the local community and creating a targeted questionnaire to create a set of initial guidelines that offer choices for tailoring the patient data collection process.	Local community group members' preferences and recommendations have now been integrated into the ongoing design and development of the ALAMEDA system.	Small sample size
(van den Bergh et al[36], 2023)	Sensor necklace (GoSafe) and Vital@Home app	The system needs improvements in terms of clinical decision making	Positive usability ratings, particularly in terms of the user-friendliness of the necklace. However, users with limited digital literacy or cognitive impairment needed clarification on how to use the app. The perceived utility varied: some users felt motivated to increase their activity, while others who were already active did not experience any extra motivation.	Physiotherapists value objective at-home activity recording and use fall monitoring to raise awareness of the significance of falls in individuals with Parkinson's disease.	Both patients with Parkinson's disease and physiotherapists emphasize the potential of a remote monitoring system in aiding physical therapy, particularly in addressing physical activity and (near-) falls.	NA
(Villamil-Cabello et al[37], 2023)	Smartphone	Enhancement	A significant improvement was observed in the performance of both dual-task tests in the experimental group following the training program. In contrast, the control group exhibited a decline in performance in the verbal fluency test.	Positive	Implementing a mobile-based home exercise program is feasible and improves dual-task performance in people with dementia.	NA

NA: Not Applicable; WISE: Wearable Inertial Sensors for Exergames; QoL: Quality of Life; mHealth: mobile Health; SITT: Speed-Interactive Treadmill Training; MCI: Mild Cognitive Impairment; PDSA: Plan, Do, Study, Act.

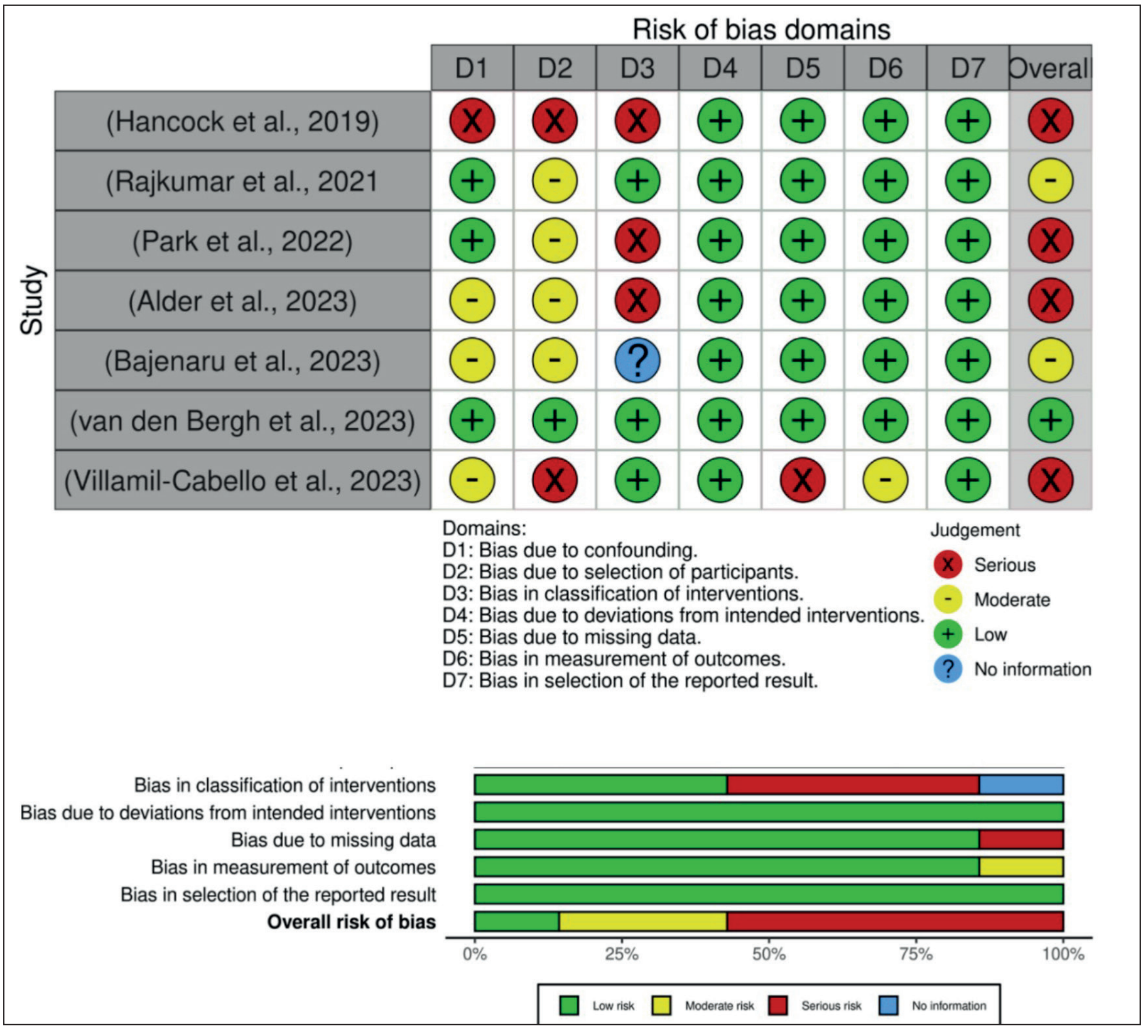

Figure 2. ROBINS-1 results for non-RCTs.

bined with telerehabilitation, it was found to result in an improvement in QoL, muscle strength and endurance, hand function, balance, and aerobic capacity in neurologic rehabilitation programs[42]. While most of the findings in the literature support the benefits of such technologies in terms of patient outcomes and clinical decision-making, one meta-analysis[43] of mobile application-based rehabilitation for neurological disorders showed that the mobile-based intervention did not outper-

Table III. Quality assessment of RCTs using the PEDro scale.

Study ID	Items											Score
	1	2	3	4	5	6	7	8	9	10	11	
(Ginis et al[27], 2016)	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	9
(Plow and Goldin[38], 2017)	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	9
(Lee et al[28], 2017)	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	9
(Ellis et al[29], 2019)	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	10
(Nasseri et al[31], 2020)	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	10
(Salgueiro et al[33], 2022)	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	9
(Aphiphaksakul and Siriphorn[40], 2022)	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	9

form standard therapy based on the results of the MiniBES Test and UPDRS III scores.

In terms of physicians' and patients' perspectives on the impact of mCDMS tools, the views reported in the present studies were mixed. That is, while some physical therapists and patients regarded the system as acceptable and user-friendly, some concerns were also raised by physical therapists. These were related to uncertainties or challenges related to the accuracy, reliability, or overall effectiveness of the mCDMS, as well as questions about its validity and appropriateness for physical therapeutic applications. These reservations could be influenced by factors such as technical glitches, inconsistent results, or a perceived lack of alignment with established physical therapy practices. The reports in the literature are also mixed. For example, one study[16] on NeurorehAPP (which contains 131 applications for neuro-physiotherapy) showed that the majority (85.41%) of the participants were satisfied with the application, and another one[44] reported that mCDMS was appreciated as a preparatory and exploratory tool that could enhance the therapeutic relationship. However, others have reported that physiotherapists primarily utilized the system to reinforce existing practices rather than actively engaging patients in decisions or learning from successful cases. Some other obstacles identified were disruptions to workflow, extended time spent on computer handling, the laborious process of entering patient data, and the challenge of dealing with frequent and, sometimes, inaccurate reminders[45,46].

Clinical Applications

The findings of the present scoping study provide significant insights into the current status of mHealth utilization and its significance in neurorehabilitation and highlight the advantages and gaps in the research. We believe that the observations will be helpful for healthcare practitioners, researchers, and mHealth application developers in terms of understanding and improving the influence of these applications on clinical decision-making processes.

Strengths and Limitations

mHealth applications have substantial advantages with regard to enhancing clinical decision-making within neuro-physiotherapy, as evidenced by this scoping review. Briefly, these include real-time access to patient data, continuous monitoring and dynamic adjustments to treatment plans, remote patient monitoring, collection of objective and longitudinal data, and designing personalized interventions. Additionally, mHealth platforms often incorporate interactive features, promoting patient engagement and adherence to prescribed exercises. Despite these strengths, there are concerns about data security and privacy, which must be addressed to ensure the ethical and secure implementation of mHealth solutions. Furthermore, the accessibility of technology may pose challenges for certain patient populations, potentially creating disparities in the delivery of neuro-physiotherapy services. The ongoing development and integration of mHealth technologies should consider these limitations to optimize their effectiveness in clinical decision-making for neuro-physiotherapy.

Conclusions

The synthesis of the existing literature on mHealth applications for clinical decision-making in neuro-physiotherapy reveals a diverse array of mHealth tools designed to support neuro-physiotherapists in decision-making processes, ranging from diagnostic aids to treatment monitoring and patient engagement platforms. Despite the promising strides made in the field, it is evident that further research is essential to establish the efficacy, usability, and long-term impact of these technologies on clinical outcomes.

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

Ethics Approval
Not applicable due to the design of the study.

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Data Availability

Data sharing does not apply to this article as no datasets were generated or analyzed during the current study.

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