The effects of mHealth in geriatric rehabilitation on health status: a systematic review

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Review

The effects of mHealth in geriatric rehabilitation on health status: A systematic review

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HIGHLIGHTS

- Health outcomes improve using mHealth in geriatric rehabilitation.
- Health outcomes and methodologies are very divers across studies.
- Reporting of integration into daily practice was minimal.
- Standardized measurement approaches and co-created interventions are needed.

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ABSTRACT

Background: Geriatric rehabilitation positively influences health outcomes in older adults after acute events. Integrating mobile health (mHealth) technologies with geriatric rehabilitation may further improve outcomes by increasing therapy time and independence, potentially enhancing functional recovery. Previous reviews have highlighted positive outcomes but also the need for further investigation of populations receiving geriatric rehabilitation.

Objective: Our main objective was to assess the effects of mHealth applications on the health status of older adults after acute events. A secondary objective was to examine the structure and process elements reported in these studies.

Methods: Systematic review, including studies from 2010 to January 2024. Studies were eligible if they involved older adults' post-acute care and used mHealth interventions, measured health outcomes and compared intervention and control groups. The adjusted Donabedian Structure-Process-Outcome (SPO) framework was used to present reported intervention processes and structures.

Results: After initial and secondary screenings of the literature, a total of nine studies reporting 26 health outcomes were included. mHealth interventions ranged from mobile apps to wearables to web platforms. While most outcomes showed improvement in both the intervention and control groups, a majority favored the intervention groups. Reporting of integration into daily practice was minimal.

Conclusion: While mHealth shows positive effects on health status in geriatric rehabilitation, the variability in outcomes and methodologies among studies, along with a generally high risk of bias, suggest cautious interpretation. Standardized measurement approaches and co-created interventions are needed to enhance successful uptake into blended care and keep geriatric rehabilitation accessible and affordable.

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1. Introduction

Geriatric rehabilitation is a comprehensive approach that involves diagnostic and therapeutic strategies. Geriatric rehabilitation aims to recover functioning after acute events by optimizing functional ability, encouraging activity, and maintaining both functional reserve and social engagement in older adults with specific characteristics and needs, associated with the ageing process (Achterberg et al., 2019; Grund et al., 2020). While geriatric rehabilitation after an acute event is known to improve health outcomes in older vulnerable adults (Bachmann et al., 2010), mobile applications (apps) or *mHealth* for training purposes may further support achievement of health objectives (Agarwal et al., 2016). Mobile apps allow users to train independently and adapt training to a personal schedule and load capacity, potentially encouraging brief periods of enjoyable exercise (Daly et al., 2021). These benefits of mHealth may also extend to geriatric rehabilitation, as increased therapy time is positively associated with functional recovery (Tijsen et al., 2019). In addition, it allows healthcare professionals to focus on the more complex needs of older adults in geriatric rehabilitation, helping to keep geriatric rehabilitation affordable and accessible.

Several studies and reviews of mHealth interventions for older adults and other vulnerable populations reported promising effects on outcomes across health status domains such as functional performance, social participation and quality of life (Gamble et al., 2024; Linn et al., 2021; Muellmann et al., 2018; Portenhauser et al., 2021; Solis-Navarro et al., 2022). However, understanding of effectiveness of mHealth on health outcomes among older populations in geriatric rehabilitation is still limited (Chen et al., 2023). In addition, reviews found that effectiveness of mHealth-based interventions depends on simplicity and adequate integration with usual care (Kraaijkamp et al., 2021; Nussbaum et al., 2019), which in turn requires changes to structures and care processes within a healthcare organization (Tossaint-Schoenmakers et al., 2021). Using the Donabedian Structure-Process-Outcome (SPO) framework, Tossaint et al. identified multiple indicators related to integration of eHealth, and added specific themes designed to assess the quality of healthcare regarding integration of eHealth. These authors also stressed that achieving desired outcomes requires the cooperation of the care receiver and healthcare professionals, together with use of well-attuned technology to change organizational structures and daily care processes (Tossaint-Schoenmakers et al., 2021).

Understanding effects on multiple health outcomes therefore requires systematic assessment of current evidence related to older populations in geriatric rehabilitation. As (changes to) structures and care processes may significantly affect evidence, a secondary objective was formulated to assess effectiveness of mHealth applications (Kraaijkamp et al., 2021; Nussbaum et al., 2019).

Main objective: What are the effects of mHealth applications, as used by older adults in geriatric rehabilitation, to support recovery after an acute event, on health status?

Secondary objective: What do included studies report on process and structure evaluation?

2. Methods

This systematic review assessed and reported studies according to The Preferred Reporting Items for Systematic reviews and Meta-Analyzes (PRISMA) Statement 2020 (Page et al., 2021). The review protocol is registered with the PROSPERO register of systematic reviews (registration number: CRD42023401992).

2.1. Search strategy

Keywords related to older adults, post-acute care, rehabilitation, recovery and mHealth interventions were selected in collaboration with a medical information specialist. To avoid limitations, outcomes and diagnoses were not specified. Mesh terms were used in MEDLINE and then translated to construct search strings for Web of Science and Embase. The first literature search of PubMed, Web of Science, Embase, EMcare and the Cochrane library was conducted in March 2023. Duplicates were identified and an initial screening of title and abstract was carried out by the first reviewer. Thereafter, the first and second reviewer performed a second screening of abstracts based on keywords related to older adults, post-acute care, rehabilitation, recovery and mHealth interventions, followed by identification of full-text papers for inclusion. Studies were eligible if they described the following criteria: (quasi) experiments, cohorts, pre-post designs; older adults with a mean age >70; post-acute care; the use of mHealth interventions solely or as an addition to usual care, supporting achievement of health objectives; use of a control group; outcomes within the domains of health status including body functions, activities, social participation, external factors and personal factors; publication period 2010-2023; abstract in the Dutch or English languages. Articles were excluded when patients were in a stable period of rehabilitation aimed at addressing a chronic condition. A third reviewer was invited to discuss any disagreement until consensus was reached.

A second search was executed in January 2024 to ensure the inclusion of current studies. The inclusion process is presented in a PRISMA flowchart (Page et al., 2021).

2.2. Data extraction

The following data were extracted by the first and second reviewer from included studies: publication information (author, year, journal); study design; inclusion-exclusion criteria; study population (age [mean-median-range] gender, diagnosis [if applicable]); setting (hospital, rehabilitation centre, nursing home, at home); description of the mHealth intervention process; intervention group (standalone or blended care) and control group (other intervention/usual care); process evaluation (feasibility, usability, usage, satisfaction); structure data (availability, description); statistical analysis; effects on primary and secondary outcomes; follow-up and conclusions.

2.3. Quality assessment

Two reviewers independently assessed the quality of the included articles using the revised Cochrane risk-of-bias tool for randomized trials (RoB2) and the Cochrane risk-of-bias in non-randomized studies of interventions (ROBINS-I) (Sterne et al., 2016, 2019). Scores are for five categories of bias: (1) arising from the randomization process; (2) due to deviations from intended interventions; (3) due to missing outcome data; (4) in measurement of the outcome; (5) in selection of the reported result in the RoB2 (ranging from *low risk, some concerns* to *high risk* of bias) (Sterne et al., 2019). The ROBINS-I contains eight categories of bias: (1) due to confounding; (2) in selection of participants; (3) in classification of interventions; (4) due to deviations from intended interventions; (5) due to missing data; (6) in measurement of outcomes; (7) in selection of the reported result; (8) overall bias (Sterne et al., 2016). Scores range from *low, moderate, serious, critical* to *no information*. Both will be presented separately in the results section.

2.4. Data synthesis and analysis

As extracted data were expected to be heterogeneous in terms of participants, interventions and outcomes, a narrative analysis was chosen (Boland et al., 2014). To provide a comprehensive overview of effects on health outcomes as well as the intervention process and structure, data are ordered according to the adjusted SPO framework (Tossaint-Schoenmakers et al., 2021). An extraction form with explanatory notes was constructed to demonstrate how indicators were scored for each article.

Health outcomes are described and categorized as: body functions and structures, activity, participation, environmental factors, and personal factors according to the International Classification of Functioning, Disability and Health (ICF) framework from The World Health Organization (WHO) (International classification of functioning, disability, and health : ICF, 2001). To categorize included health outcomes into the ICF framework, measurements were checked against the Sralab database.

Regarding the secondary aim of the study, indicators from the adjusted Donabedian SPO framework were used to coordinate descriptions of structure process and outcomes in the included studies (Tossaint-Schoenmakers et al., 2021).

3. Results

3.1. Selection of studies

Fig. 2 illustrates the Prisma flowchart of records retrieved from the literature search and the subsequent inclusion or exclusion of these records. A total of 10163 records were identified in the five databases. After removal of duplicates, 7276 records were screened on title and abstract, from which full texts of 76 studies were assessed for eligibility using set criteria. For a variety of reasons 67 studies were excluded, mostly due to different mean ages, different study designs or a non-post-acute phase (Fig. 1). Nine articles were finally included in our review (Fig. 1), with no new inclusions after a second search (Appendix A).

3.2. Characteristics of included studies

Characteristics of included studies are listed in Table 1. Mean age was over 70 (Hassett et al., 2020; Snoek et al., 2021; Wu et al., 2023) in three studies and over 75 in six studies (Cheng et al., 2022; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Zhang et al., 2022). One study included participants with multiple diagnoses (Hassett et al., 2020), seven out of nine studies focused on hip fractures (Cheng et al., 2022; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Wu et al., 2023; Zhang et al., 2022) and one on cardiovascular disease (Snoek et al., 2021). The most common inclusion criterion, besides advanced age, was a minimal level of physical function using baseline outcome measurements such as the Modified Functional Ambulatory Category (MFAC) ≥3, the performance-based Short Physical Performance Battery (SPPB) <12 or the pre-existing outcome for the Functional Independence Measure (FIM) >90. In four studies cognitive competence was specified as a minimal score of 15 (Pol et al., 2019) or 24 (Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Zhang et al., 2022) on the Mini-Mental State Examination (MMSE). Two studies reported cut of points of cognitive competence in their exclusion criteria, <19 for the Hong Kong version of Montreal Cognitive Assessment (HKMoCA) (Cheng et al., 2022) and ≥6 for the Abbreviated Mental Test (AMT) (Li et al., 2020). Three studies reported mean MMSE in their characteristics tables (Hassett et al., 2020; Pol et al., 2019; Zhang et al., 2022). Living situation and educational status were reported in five studies (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Pol et al., 2019; Zhang et al., 2022). Interventions mainly consisted of mobile phone and tablet apps or web platforms, with three studies using apps in combination with wearables (Cheng et al., 2022; Hassett et al., 2020; Snoek et al., 2021). Further information on interventions is reported below. A total of 26 outcomes, of which 19 were different outcomes, were reported. Seven studies focused on activity (n = 15, 58 %) (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Wu et al., 2023; Zhang et al., 2022) five reported on body functions (n = 10, 38 %) (Cheng et al., 2022; Li et al., 2020; Mora-Traverso et al., 2024; Snoek et al., 2021; Wu et al., 2023) and one study reported on participation (n = 1, 4 %) (Pol et al., 2019) (see Table 1).

3.3. Structure

In all included studies (N = 9), participants in both the intervention and control groups began rehabilitation in a hospital or tertiary care and continued at home after discharge (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022). Healthcare was provided by a multidisciplinary team in all studies (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022), and in all studies the control group received standard rehabilitation as usual care, either at home, in person,

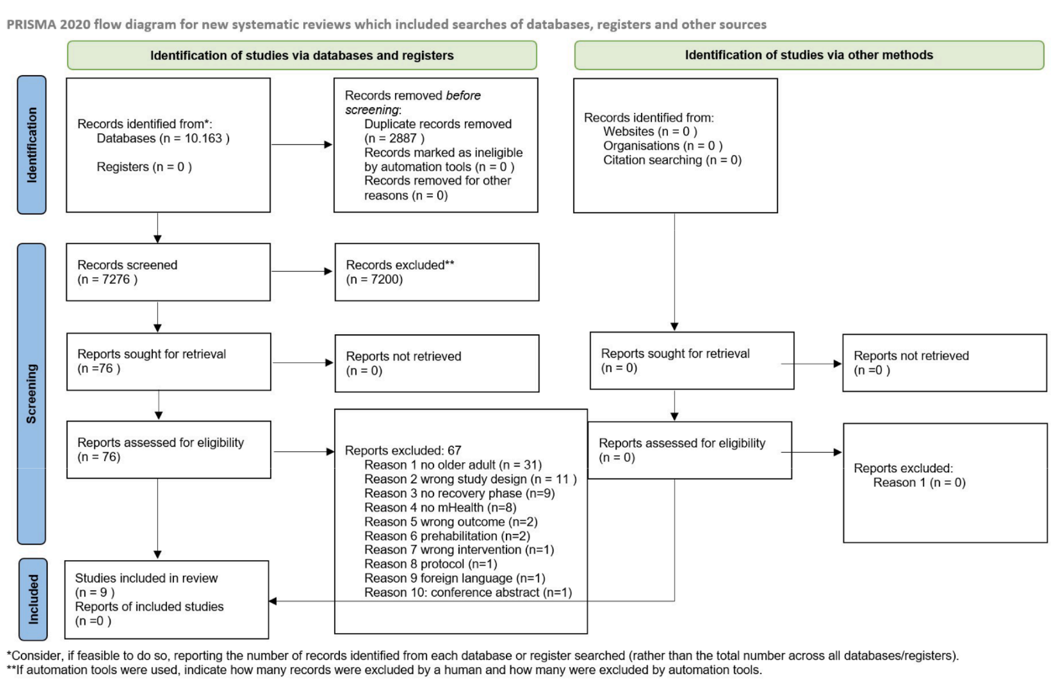

Fig. 1. Flowchart.

Table 1
Characteristics of included articles.

<table>
<tr><th rowspan="2">Author (Country date)</th><th rowspan="2">Study design</th><th rowspan="2">Setting</th><th rowspan="2">Diagnosis (N) I|C</th><th rowspan="2">Intervention I|C</th><th rowspan="2">Age (years) mean (SD) I|C</th><th rowspan="2">Female (%) I|C</th><th rowspan="2">In- and exclusion criteria</th><th colspan="3">Primary outcomes (measurements)</th><th rowspan="2">Baseline cognitive functions MMSE score (0-30) mean (SD) I|C</th><th colspan="2">Social status</th></tr>
<tr><th>Body functions</th><th>Activities</th><th>Participation</th><th>Living situation cohabiting n (%) I|C</th><th>Education Years (mean (SD) range) OR High/low I|C</th></tr>
<tr><td>Cheng et al. (Hongkong, 2021)</td><td>RCT</td><td>Tertiary care hospital for rehabilitation services and home-based</td><td>Hip fracture 19 | 20</td><td>home-based rehabilitation program with mobile app | home-based rehabilitation program with exercise pamphlet</td><td>75.8 (7.2) | 79 (8.8)</td><td>36 | 60</td><td>Hip fracture; 60–90 years; ability questions in Chinese; discharged home and with caregiver; MFAC ≥3 upon discharge; access to a smartphone or tablet; written informed consent. | bilateral hip fracture or cause malignancy; < 19 on HK-MoCA; conditions that preclude exercise; terminal illness; severe visual deficits or legally blind.</td><td>Functional impairment (Lower Extremity Functional Scale LEFS (0-80))</td><td>Walking capacity (Modified functional ambulatory category MFAC (1-7)) Individual's mobility problems (Elderly Mobility Scale EMS (0-20))</td><td></td><td>NR</td><td>8 (42.1) | 5 (25)</td><td>NR</td></tr>
<tr><td>Hassett et al. (Australia 2020)</td><td>Pragmatic RCT</td><td>Three hospitals and home based</td><td>Neurological 72 | 77 Cardiopulmonary 16 | 9 Orthopedic 41 | 48 Restorative 20 | 17</td><td>usual care + digitally enabled rehabilitation | usual care</td><td>70 (18) | 73 (15)</td><td>48 | 51</td><td>≥18 years; SPPB score < 12); life expectancy≥ 12 months; LOS ≥ 10 days; ability standing position. | Cognitive↓ or vision↓ for use devices; insufficient English language; medical condition(s); no interest in using devices; discharge to high care nursing home; too distant for follow-up.</td><td></td><td>Mobility (performance-based Short Physical Performance Battery (SPPB (continuous 0-3)) Percentage spent upright per day (%)</td><td></td><td>27 (3) | 27 (3)</td><td>70 (47) | 77 (51)</td><td>Years 12 (3) 5–20 | 12 (4) 4–32</td></tr>
<tr><td>Li et al. (Hongkong 2020)</td><td>Feasibility RCT</td><td>Geriatric day hospital and home-based</td><td>Hip fracture 15 | 15</td><td>Home-based with Caspar Health e-system and a mobile app | Home-based program through written sheets</td><td>76.5 (8.6)|82.1 (9.7)</td><td>93 | 69</td><td>Primary diagnosis of hip fracture; post hip-fracture surgery within 12 weeks of diagnosis; age ≥ 60; medically stable; pre fracture AMT score of 6; functional limitation in the basic ADL assessments. | Hip fracture due to malignancy; risk of falls due to postural hypotension; no understanding Cantonese, English or Mandarin instructions by patient and caregiver; no smartphone; visual difficulty</td><td>Muscle strength (un)affected side (Force gauge (kgf)) Pain (visual analogue scale VAS (0-100mm)</td><td>Fall risk and progress in walking speed (Timed Up-and-Go test TUG (sec)) Balance (Functional Reach test FR (cm))</td><td></td><td>NR</td><td>12(75) | 15 (100)</td><td>NR</td></tr>
<tr><td>Mora et al. (Spain, 2021)</td><td>Non-RCT</td><td>University hospital and home-based</td><td>Hip fracture 30 |34</td><td>@ctive-hip online platform | Home-based in-person rehabilitation with physiotherapy and occupational therapy sessions</td><td>75.77 (5.67)|80.38 (5.54)</td><td>73 | 79</td><td>Hip fracture surgery; age ≥65; pre fracture FIM index > 90 points; to allow weight-bearing 48 h after surgery; community-dwelling ; family caregiver with internet access. | MMSE <24 points); terminal disease; disability to begin rehabilitation during the 1st week after surgery.</td><td>Quality of life (EuroQol Quality of Life Questionnaire EQ-5D (1-100)) Hospital Anxiety and Depression Scale (HADS (0–21))</td><td>International Fitness Scale (IFIS 5 Likert scale from very poor to very good))</td><td></td><td>NR</td><td>NR</td><td>NR</td></tr>
<tr><td>Ortiz et al. (Spain, 2021)</td><td>Non-RCT</td><td>University hospital and home-based</td><td>Hip fracture 35 | 36</td><td>@ctive online program | Home-based in-person rehabilitation with physiotherapy and occupational therapy sessions</td><td>75.86 (5.79)|80.38 (5.54)</td><td>71.4 | 73.5</td><td>Hip fracture surgery; ≥ 65; FIM index > 90; could weight bear at 48 h after surgery; community-dwelling; access to internet. | MMSE score< 24; terminal disease; disability to begin rehabilitation during the 1st week after surgery.</td><td></td><td>Functional status (functional independence measure FIM (18-126)) Physical Performance (Timed Up-and-Go test TUG (sec)) Physical Performance (Short physical performance battery SPPB (0-12))</td><td></td><td>NR</td><td>NR</td><td></td></tr>
<tr><td>Pol et al. (Netherlands, 2019)</td><td>Three-armed randomized stepped wedge trial</td><td>Six skilled nursing facilities and home based</td><td>Traumatic hip fracture 87 | 76 | 77</td><td>Cognitive behavioral treatment with sensor monitoring and a web-application | cognitive behavioral treatment alone | care as usual</td><td>83.0 (6.7) | 83.5 (6.7) | 85.0 (7.2)</td><td>75 | 85.5 | 79.2</td><td>Traumatic hip fracture, ≥ 65 years; admission to a skilled nursing facility; indication of short-term rehabilitation; living alone; MMSE score ≥15. | terminally illness; permanent placement in a nursing home; no informed consent.</td><td></td><td></td><td>Patient-reported daily functioning (The Canadian Occupational Performance Measure (COPM (1-10))</td><td>24(NR) | 24(NR) | 24.5(NR)</td><td>NR| 4.5 (4) |NR</td><td>Low 36.1|38.4| 42.9 Middle 32.0 | 26.7 | 20.8 High 32| 34.9 | 36.4</td></tr>
<tr><td>Snoek et al. (Netherlands, 2023)</td><td>RCT</td><td>Six cardiac institutions in Europe and home-based</td><td>Cardiovascular 89 | 90</td><td>Home-based mobile cardiac rehabilitation with smartphone and heart rate belt | standard of care</td><td>72.4 (5.4)|73.6 (5.5)</td><td>22 | 16</td><td>≥ 65 years; diagnosis <3 months of a cardiovascular disease; declined participation in center-based cardiac rehabilitation | NR</td><td>Change in physical fitness (mean peak of oxygen uptake VO2peak (ml/kg−1/min−1))</td><td>Change in physical fitness (Self-reported moderate to vigorous physical activity MVPA (days per week))</td><td></td><td>NR</td><td>NR</td><td>NR</td></tr>
<tr><td>Wu et al. (China, 2023)</td><td>RCT</td><td>Hospital and home-based</td><td>Total hip 43 | 42</td><td>rehabilitation with mobile app and web portal | text version of the postoperative rehabilitation program with telephone follow-up</td><td>74.28 (5.06)|72.00 (6.77)</td><td>69.8 | 73.8</td><td>≥ 65 years; THR after first hip fractures; rehabilitation intervention was provided using the TR system in the telerehabilitation group; skillfully operate the TR system by patient and caregiver; no mental disorders with ability to cooperate with rehabilitation treatment. | Severe cognitive impairment; low pre-fracture functional level before fracture; no caregiver at home; no internet at home.</td><td>Hip function (Harris hip scale HHS (0-100)) Psychological recovery (self-rating anxiety scale SAS(20-80))</td><td>Physical function (functional independence measure FIM (18-126))</td><td></td><td>NR</td><td>NR</td><td>NR</td></tr>
<tr><td>Zhang et al. (China, 2022)</td><td>RCT</td><td>University hospital and home-based</td><td>Hip fracture 27 | 24</td><td>telerehabilitation with a web platform and mobile app | Telephone group with discharge follow-ups</td><td>77.00 (7.89) |75.17 (7.73)</td><td>62.96 | 66.67</td><td>Low-energy injury unilateral hip fracture with treatment hip arthroplasty or internal fixation; ≥60 years; no limb dysfunction before fracture; FIM ≥90 points; ability to cooperate rehabilitation; MMSE ≥24; presence caregiver; presence smartphone; | pathological fractures; serious chronic diseases.</td><td>Hip function (Harris hip scale HHS (0-100))</td><td>Functional status (functional independence measure FIM (18-126)) Functional walking ability and fall risk (timed up-and-go test TUG (sec)) Motor ability and fall risk (Short physical performance battery SPPB (0-12))</td><td></td><td>27.59 (1.58) | 27.21 (1.64)</td><td>21 (77.8)|17 (70.8)</td><td>Low 17 (63.96)| 9 (66.67) Middle 6 (22.22) | 4 (16.67) High 4 (14.81) | 4 (16.67)</td></tr>
</table>

AMT=Abbreviated Mental Test, range 0-10, 0=suggestive of severe impairment and 10=suggestive of normal cognitive function; C=Control group; COPM= Canadian Occupational Performance Measure, range 1–10; 1= not able to do at all and 10 =able to do extremely well; EMS= Elderly Mobility Scale, range 0-20, <10 dependent, 10-13 borderline dependent, >14 independent; EQ-5D=EuroQol Dimension 5, index range −0.59 to 1, 1 is the best possible health state; FIM=functional independence measure, range 18-126; higher the score => more independent; FR= Functional Reach test, in centimeters; H=hour; HHS=Harris hip scale, range 0-100; HK-MoCA= the Hong Kong version of Montreal Cognitive Assessment, range 0-30, <19 cut off for detection dementia; I= Intervention group; IFIS=International Fitness Scale, 5 Likert scale from very poor to very good; KG= kilogram; KGF= kilogram force; LEFS=Lower Extremity Functional Scale range 0-80; LOS= length of stay; MFAC=Modified functional ambulatory category; Min=minutes; ML=milliliter; MMSE= Mini Mental State Examination, range 0-30; MVPA=moderate to vigorous physical activity; N=numbers; NR=Not Reported; RCT=randomized controlled trial; SAS=self-rating anxiety scale, range 20-80, 20–44 Normal Range, 45–59 mild to moderate anxiety levels, 60–74 marked to severe anxiety levels, 75 and above extreme anxiety levels; SD=standard deviation; SEC=seconds; SPPB=Short Physical Performance Batter, range 0-12, continuous 0-3, higher score is higher performance; TUG= timed up-and-go test, in seconds, ≥12 seconds at risk for falling; VAS= visual analogue scale, 0 millimeter no pain to 100 millimeter very severe pain; VO2peak=peak of oxygen uptake

by telephone or text-based (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022).

3.4. Process

Four studies used an online web platform accessible by mobile devices (Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Wu et al., 2023; Zhang et al., 2022), whereas five used a mobile app that participants could install (or was issued by researchers) on their mobile phones and tablets (Cheng et al., 2022; Li et al., 2020; Pol et al., 2019; Snoek et al., 2021; Zhang et al., 2022). Four studies included a wearable such as an activity or heart rate monitor (Hassett et al., 2020; Pol et al., 2019; Snoek et al., 2021; Zhang et al., 2022). All articles reported information on the technology, its features, functions for mHealth and content of the intervention (Table 2) [18-26]. The most commonly reported intended uses of mHealth were self-management (9) [18-26], treatment (9) [18-26] and communication (8) (Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022). One study used the mHealth function "reminders" (Zhang et al., 2022). Intervention duration varied from 3 weeks to 6 months, and varied in frequency and intensity (see Table 2 for details).

3.5. Outcome

Primary outcomes are presented according to ICF (Table 3), with nine different outcomes measured for the ICF domain body functions five studies (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Snoek et al., 2021), while outcome data on activities were reported in seven studies (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Ortiz-Pina et al., 2021; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022). Measurements used in more than one study included the FIM (Ortiz-Pina et al., 2021; Wu et al., 2023; Zhang et al., 2022), the SPPB and the TUG (Ortiz-Pina et al., 2021; Zhang et al., 2022). One study reported the Canadian Occupational Performance Measure (COPM) in the participation domain as primary outcome (Pol et al., 2019). Differences between groups were reported by all studies using varying methods (see final column of Table 3). Variables ($n = 26$) improved for 70 % of both intervention and control groups, (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022), with a higher number favorable in intervention groups (17) as illustrated in the harvest plot (Fig. 2) (Hassett et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022). Except for Hassett et al., who reported a minimal clinically important difference (MCID) for SPPB measurements (0.5-1) at 6 months in favor of the intervention group (Hassett et al., 2020), no other study reported an MCID. For comparison, the MCIDs for most outcomes (according to *Sralab Rehabilitation Measures*) are listed in Appendix B.

3.5.1. Body functions

Wu et al. and Li et al. measured mobility of the hip joint with the HHS (Li et al., 2020; Wu et al., 2023). Both reported increased mobility at the latest assessment in both the intervention and control groups, favoring the intervention group (Li et al., 2020; Wu et al., 2023). Snoek et al., measuring physical fitness, found a higher peak VO2 in the intervention group and no difference in the control group at 6 months (Snoek et al., 2021). Li et al. measured muscle strength and pain (Li et al., 2020) and found no significant differences within or between groups upon final assessment at 6 weeks (Li et al., 2020). Other measurements of ICF body function included anxiety (Mora-Traverso et al., 2024; Wu et al., 2023) (SAS, HADS) and quality of life (EQ-5D) (Mora-Traverso et al., 2024). Anxiety decreased over time for all groups, with significant differences between intervention and control groups in two studies (Mora-Traverso et al., 2024; Wu et al., 2023). Quality of life increased overall, and favored the intervention group ($p = 0.001$) (Mora-Traverso et al., 2024).

3.5.2. Activities

The FIM was reported in the activity category to measure disability by Wu, Zhang and Ortiz (Ortiz-Pina et al., 2021; Wu et al., 2023; Zhang et al., 2022). Participants in the intervention groups of these three studies scored an increase of >40 points after 3 months (Ortiz-Pina et al., 2021; Zhang et al., 2022)and 6 months (Wu et al., 2023), with control group increases of >30 points (Ortiz-Pina et al., 2021; Wu et al., 2023; Zhang et al., 2022), so all groups scored above the 22 points needed for clinical relevance. The three studies favored the intervention group, with a significant difference between groups (Ortiz-Pina et al., 2021; Wu et al., 2023; Zhang et al., 2022) . There was no report for mean difference and confidence interval within groups (Ortiz-Pina et al., 2021; Wu et al., 2023; Zhang et al., 2022). Mobility as measured by TUG was the primary objective of three studies (Li et al., 2020; Ortiz-Pina et al., 2021; Zhang et al., 2022). A decrease in time (in seconds) was noted for both groups at 6 weeks (Li et al.) or 3 months (Ortiz et al.) (Li et al., 2020; Ortiz-Pina et al., 2021), but significantly favored the intervention group only in the Ortiz et al. study (Ortiz-Pina et al., 2021), where both the intervention and controls groups reached the MCID of 10.8 s., with a non-significant z-score for the within-group difference (Ortiz-Pina et al., 2021). Zhang et al. found no within-group differences, with a significant difference favoring the intervention group (Zhang et al., 2022). A better SPPB in favor of intervention groups was reported in three studies (Hassett et al., 2020; Ortiz-Pina et al., 2021), with the third presenting group differences at only one time point (Zhang et al., 2022). Hassett et al. reported an increase in time spent in an upright posture per day in both groups, but found no significant differences at 6 months (Hassett et al., 2020). Using the LEFS, MFAC and EMS (Cheng et al., 2022) as measurements for mobility, Cheng et al. found no significant differences between groups at 1- and 2-month follow-ups (Cheng et al., 2022). For self-reported moderate to vigorous physical activity (MVPA), significant differences between intervention and control groups were found at 12 months and fitness level IFIS at 3 months (Mora-Traverso et al., 2024; Snoek et al., 2021). Functional reach showed no significant difference between groups at 6 weeks (Li et al., 2020).

3.5.3. Participation

Regarding the COPM, which measures self-received daily functioning, Pol et al. found an overall increase at 6 weeks, as well as a significant difference in favor of the intervention group (Pol et al., 2019).

Table 2
Content of technology and intervention details.

Author	Technology | Features	mHealth function	Intervention	Control
Cheng et al. RCT	Mobile app on smartphone or tablet | Preloaded exercises at four different levels; progress summary; push reminders; educational content; video libraries of practical skills and information for caregivers.	Information, Self-management, treatment.	Briefing sessions for care receivers and caregivers before discharge on intervention and installment and usage of mHealth. **mHealth**: Home-based rehabilitation for 2 months with 20-30 minutes daily exercises with mobile app.	Briefing sessions for care receivers and caregivers before discharge on home-based rehabilitation. Home-based rehabilitation for 2 months with 20-30 minutes daily exercises with pamphlet.
Hassett et al. RCT	Activity monitors and handheld computer devices | Exercises through virtual reality video games	Self-management, treatment, communication	6 months usual rehabilitation care, with series of repetitive exercises guided by the physiotherapist, tailored management by the multidisciplinary team, and a fall prevention brochure. **mHealth**: 30 to 60 minutes of digitally enabled rehabilitation 5 days per week with digital devices with remote monitoring and communication post-discharge. The exercises and devices were individually prescribed by a trial physiotherapist according to an intervention protocol that matched different task-specific exercises on different devices to common mobility limitations.	6 months usual rehabilitation care, with series of repetitive exercises guided by the physiotherapist, tailored management by the multidisciplinary team, and a fall prevention brochure.
Li et al. RCT	Application Caspar Health e-system for mobile phones and tablets | Tailormade TR program videos, e-calendar, upload training progress videos, review attendance records	Self-management, information, treatment, communication	A 3-week home-based treatment program with trunk, lower-limb strengthening, stretching, coordination, balance and functional exercises tailored individually in frequency and duration. **mHealth**: a tailormade program with e-calendar and exercise videos. Performance feedback is sent to the case therapist after each exercise session, followed up twice a week by the case therapist who adjusts the treatment in the app.	A 3-week home-based treatment program with trunk, lower-limb strengthening, stretching, coordination, balance and functional exercises tailored individually in frequency and duration. Performance feedback was sent to the case therapist by log sheets after each exercise session, followed up twice a week for adjusting treatment through a written home program.
Mora et al. Non-RCT	Online platform, @ctive-hip to use on mobile phone or tablet | Online-based sessions per week on-demand (pre-recorded) instructional videos for exercises and advice on environmental safety.	Information, Self-management, treatment, communication	**mHealth:** A 12-week multidisciplinary telerehabilitation intervention with five 50-to-60-min online-based sessions per week (two occupational therapy and three sessions of physical exercise) with content through the @etivehip Online platform. Tailored according to four difficulty levels.	Usual care by the Andalusian Public Health Care System (between 5 and 15 sessions of home-based in-person rehabilitation).
Ortiz et al. Non-RCT	Online platform, @ctive-hip to use on mobile phone or tablet | Online-based sessions per week on-demand (pre-recorded) instructional videos for exercises and advice on environmental safety.	Information, Self-management, treatment, communication	Usual care during a hospital stay and a caregivers' workshop and an informational leaflet with recommendations and exercises for home was given to patients and caregivers. **mHealth**: 12-week multidisciplinary telerehabilitation program including on-demand (pre-recorded) instructional videos and written instructions for activities and exercises appropriate to the patients' functional status. Exercises included were lower and upper body strengthening exercises, balance exercises, and cardiovascular exercises. Build-up of training sessions: three warm-up exercises, 10 exercises with minimal 10 repetitions in week 1 to max 24 repetitions last week. The occupational therapy sessions consisted of videos for advice on safe activities of daily living self-care activities, walking aids and a safe home. There were weekly videoconferences with PTs or Ots and on request.	Usual care during a hospital stay and a caregivers' workshop and an informational leaflet with recommendations and exercises for home was given to patients and caregivers. Usual postoperative home-based in-person rehabilitation –15 sessions of physiotherapy and Occupational therapy.
Pol et al. RCT	Wearable activity monitor (PAM) and SO-HIP web application | Visualization of daily functioning, administration of participants' data, asking questions	Self-management, treatment, communication	Usual care through the multidisciplinary rehabilitation program followed by home-based occupational therapy coaching program **mHealth:** sensor monitoring to visualize mobility and integrate this in treatment strategies	Group I: Usual care through the multidisciplinary rehabilitation program. Group II: Usual care through the multidisciplinary rehabilitation program followed by home-based occupational therapy coaching program.

(*continued on next page*)

Table 2 (*continued*)

Author	Technology | Features	mHealth function	Intervention	Control
Snoek et al. RCT	Application MobiHealth and heart rate monitor | Measure and register physical activity, heart frequency and intensity, monitor progress. Healthcare professional access to a portal to monitor progress	Self-management, treatment, communication	**mHealth**: Patients perform moderate exercise based on individual selected level of intensity and self-chosen type of activity at 5 days per week for at least half an hour and fill in the rate of perceived exertion (BORG-score) and data on frequency and intensity transferred to a secured website to monitor progress. Motivational interviewing was applied by telephone: weekly in the 1st month, every other week in the 2nd month, and monthly until completion at 6 months.	No care or locally defined standard of care, such as primary care.
Wu et al. RCT	App on a tablet with internet access, corresponding website on mobile healthcare professional| Information videos, exercises, uploading videos of patients progression and weekly video conference	Information, Self-management treatment, communication	**mHealth**: Medical information pushing with rehabilitation videos for the 12-week home-based training with 5-10 repetitions 3 times a day. Video recording of recovery progress were send by participant twice a week. They received weekly briefings by videoconference with the doctor.	Participants received a text version of the rehabilitation program. They received weekly follow-up telephone calls for updating on progress and answering questions.
Zhang et al. RCT	Physician side—a website platform, and a patient side—an application (APP) installed on a smartphone, wearables | Personalized rehabilitation programs, rehabilitation videos, health knowledge and monitoring vital signs	Information, reminders, Self-management, treatment, communication.	Routine discharge instructions 1–2 days after surgery: bedside rehabilitation instructions and health education. **mHealth:** Remote video assessment and guidance rehabilitation through remote video assessment, to adjust training through the *home-oriented post-operative rehabilitation management system for geriatric hip fractures* at 2 weeks, 1 month, 2 months, and 3 months after discharge	Routine discharge instructions 1–2 days after surgery: bedside rehabilitation instructions and health education. Follow-up by telephone for inquiry, assessment, guidance, questions and encouragement at 2 weeks, 1 month, 2 months, and 3 months.

3.6. Report on process and structure evaluation

The reported indicators of included studies are presented according to the Donabedian Structure, Process and Outcome (SPO) framework, adjusted for eHealth according to Tossaint (Tossaint-Schoenmakers et al., 2021). Four studies described the intervention in a separate protocol article (Hassett et al., 2020; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021), while six of nine studies included information on technology usability (Table 4) (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019). Two studies added goal-setting to their intervention (Hassett et al., 2020; Li et al., 2020), four studies described the use of behavioral change strategies (Cheng et al., 2022; Hassett et al., 2020; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021), and adherence was reported in seven studies (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021). All studies reported patient-centred healthcare actions that included an option for tailored treatment (Table C.1) (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022). One study reported development of an mHealth intervention in their protocol, together with the participation of care receivers and caregivers (Mora-Traverso et al., 2024). A table with details per indicator is available upon request.

3.7. Risk of bias

The overall risk of bias (RoB) in the six randomized controlled trials varied from 'some concern' (Hassett et al., 2020; Li et al., 2020; Pol et al., 2019) to 'high' (Cheng et al., 2022; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022). The randomization process was rated as low risk in six of the seven RCTs (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Pol et al., 2019; Snoek et al., 2021; Zhang et al., 2022), while fivestudies raised some concern regarding deviations from intended interventions (Hassett et al., 2020) or had a high risk of bias (Cheng et al., 2022; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022) (Appendix C).

For the two non-randomized trials, overall RoB was 'serious' (Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021). Both confounding and non-blinding showed serious RoB, while other sections had moderate or low RoB (Appendix D, Tables E.1-E.3).

4. Discussion

In this review of older adult's use of mHealth, all studies showed improved primary outcomes in both the intervention and control groups (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022). Together they reported on 26 positive outcomes of which 17 in favor of the intervention group (Cheng et al., 2022; Hassett et al., 2020; Li et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Pol et al., 2019; Snoek et al., 2021; Wu et al., 2023; Zhang et al., 2022). The ICF domain body function favoured intervention groups in three studies (Mora-Traverso et al., 2024; Wu et al., 2023; Zhang et al., 2022), while activity outcomes favored intervention groups in five studies (Hassett et al., 2020; Mora-Traverso et al., 2024; Ortiz-Pina et al., 2021; Wu et al., 2023; Zhang et al., 2022). Although MCIDs were generally not reported, values at follow-up timepoints actually reached the MCID for SPPB (MCID of 0.5-1) (Hassett et al., 2020; Ortiz-Pina et al., 2021) , TUG (MCID of -10.8) (Li et al., 2020; Ortiz-Pina et al., 2021) and FIM (MCID of 22) (Li et al., 2020; Wu et al., 2023; Zhang et al., 2022) .

Types of outcomes, presented here by ICF domains, also varied widely. Outcomes were mostly in the activity domain including: *functional status* or *physical function,* measured by FIM; *mobility* or *motor ability and fall risk,* measured by the SPPB; *fall risk and progress in walking speed* or *functional walkability and fall risk,* measured by TUG. Furthermore, despite the fact that participation is one of the main goals of geriatric rehabilitation, only one article described a participation-related outcome. Two earlier reviews (Kraaijkamp et al., 2021; Preitschopf et al., 2023) also noted the surprising lack of attention for this

Table 3
Primary outcomes.

1 Cheng et al. (2021) **	LEFS 20 (17.5-28)* | 20 (14–16)*	LEFS (1) 42 (29.5-56)*|34.5 (26-7.5)*	LEFS (2) 52 (30–62.5)*|47.5 (34.5-54)*		ND	LEFS (1) 16 (10.5-22)*;0.005 | 13.5(8.5-21)*; 0.01 LEFS(2) 18 (13-34)*; <0.001 | 22(19-33)*; <0.001	LEFS (1) NR; 0.945 LEFS (2) NR;0.411
	MFAC 6 (5-6) | 5 (4.5-6)*	MFAC (1) 6 (6-6) | 6 (5-6)*	MFAC (2) 6 (6-7) | 6 (6-6)*		ND	MFAC (1) 1(0-1)*; 0.266 | 0.5 (0-1)*; 0.399 MFAC (2) 1(0.5-2) *; 0.002 | 1(0-1.5)*; 0.008	MFAC (1) NR;0.901 MFAC (2) NR; 0.728
	EMS 14 (8.5-15)* | 13 15 (10-14)*	EMS (1) 15 (14-17.5)* | NR (14-16)*	EMS (2) 17 (15.5-19.5)* |NR (16-18)*		ND	EMS (1) 3 (1-5.5)*; 0.004 EMS (2) 2 (0.5-5)*; 0.081	EMS (1) NR; 0.351 EMS (2) NR; 0.647
2 Hassett et al. (2022)	SPPB^ 1.5(0.7)|1.5(0.8)	SPPB^ (0.75) 2.1(0.6)|1.8 (0.8)	SPPB^ (6) 2.3 (0.6)|2.1 (0.8)		I	NR	SPPB; (6) 0.2 (0.1 to 0.3); 0.006
	Percentage spent upright per day 8.0 (6.7)|7.5(5.7)	Percentage spent upright per day (0.75) 14.5 (8.4)|14.2 (8.6)	Percentage spent upright per day (6) 18.2(9.8)|18.4(10.2)		C	NR	Percentage spent upright per day; (6) −0.2 (−2.7 to 2.3); 0.87
3 Li et al. (2020)	Muscle strength affected side 4.3 (1.7) |3.8 (2.1)	Muscle strength affected side (0.75) 6.3 (1.8) | 6.1 (2.9)	Muscle strength affected side (1.5) 5.4 (1.7) | 6.7 (2.5)		ND	Muscle strength affected side (1.5) NR; 0.017 | NR	Muscle strength affected side (1.5) NR; 0.666
	Muscle strength non-affected side 7.0 (2.6) | 6.8 (2.9)	Muscle strength non-affected side (0.75) 7.4 (1.8) | 7.0 (2.3)	Muscle strength non-affected side(1.5) 6.2 (1.5) | 7.6 (2.7)		ND	Muscle strength non-affected side (1.5) NR; 0.52 | NR	Muscle strength non-affected side (1.5) NR; 0.510
	Pain VAS 3.47 (2.6) | 2.4 (2.6)	Pain VAS (0.75) 1.8 (1.9) | 1.5 (1.8)	Pain VAS (1.5) 1.8 (2.1) | 1.9 (2.7)		ND	Pain VAS (1.5) NR; 0.364 | NR	Pain VAS (1.5) NR; 0.550
	TUG 39.7 (26) | 45.2 (15.8)	TUG (0.75 33.8 (19.6) | 39.5 (18.0)	TUG (1.5) 29.9 (22.6) | 31.8 (16.8)		ND	TUG (1.5) NR; 0.701 | NR	TUG (1.5) NR; 0.467
	FR 4.1 (3.9) | 3.7 (3.0)	FR (0.75) 5.2 (3.5) | 5.5 (3.4)	FR (1.5) 5.3 (2.6) | 5.4 (1.7)		ND	FR (1.5) NR; 0.041 | NR	FR (1.5) NR; 0.751
4 Mora et al. (2021)** **Serious**	HADS	HADS (3)			I	NR	HADS (3) ** -0.16 (-0.27 to -0.05); 0.007
	EQ-5D	EQ-5D (3)			I	EQ-5D (3) NR; >0.001	EQ-5D (3)** 6.41 (-4.45 to 17.28); 0.010
	IFIS 19.4 (3.25)| 17.06 (4.49)	IFIS (3) 16.94 (15.63 to 18.24) 14.44 (13.22 to 5.66)			I	IFIS (3) NR; 0.161 | NR; 0.021	IFIS (3) ** 2.49 (0.67 to 4.32); 0.008

*presented in median (IQR)
** per protocol analysis
§ presented in Z-score differences

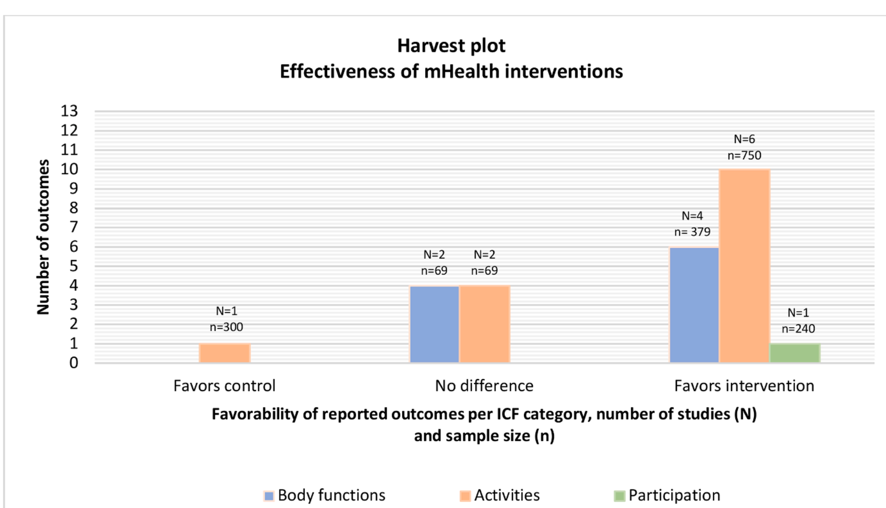

Fig. 2. Harvest plot: effectiveness of mHealth intervention.

Table 4
Structure, process and outcome (SPO) reported indicators.

Author			Cheng et al.[21]	Hassett et al.[18]	Li et al.[22]	Mora et al.[23]	Ortiz et al.[24]	Pol et al.[25]	Snoek et al.[19]	Wu et al.[20]	Zhang et al.[26]
SPO	Themes	Sub-themes									
Structure	Inner setting	Support of primary process	x	x			x	x	x	x	x
		Culture and leadership									
	Health care professional	Skills		x				x			
		Attitude									
	Care receiver and care giver	Daily life	x	x	x	x	x	x	x		
		Baseline characteristics	x	x		x	x	x		x	x
	Technology	Usability and functionality	x	x	x	x	x	x			
		Interaction with electronic health record							x		
	Outer setting	Finance, legislation, guidelines	x	x	x	x	x	x	x		
		Involvement stakeholders				x					
Process	Health care actions	Workflow		x	x		x	x	x		x
		Patient - centered	x	x	x	x	x	x	x	x	x
	Interpersonal actions	Personal		x				x			
		Goalsetting		x	x						
		Strategies behavioral change		x			x	x	x		
	Process management	Quality improvement		x			x	x			
		Error prevention							x		
Outcome	Experience of care recipient	Satisfaction	x		x			x			
		Convenience									
	Experience of health care professional	What's in it for me?									
		What's in it for them?	x					x			
	Efficiency	Operations	x		x	x	x	x	x	x	x
	Adherence		x		x	x	x	x	x		

important outcome.

Improvements in health outcomes in the studies included here reflect app-related findings in general rehabilitation (Nussbaum et al., 2019), with one review reporting mainly positive effects on functional outcomes and disease symptoms such as pain and quality of life. However, only 5 of 102 studies on the effects of mHealth interventions were RCTs, and those were small and excluded vulnerable populations (Nussbaum et al., 2019).

Reviews by both Nussbaum et al. (2019) and Solis-Navarro et al. (2022) suggest that mHealth can improve health outcomes of older adults in rehabilitation. However, as with our quality assessment, both reviews noted the lack of rigorous high quality RCTs. Furthermore, comparing results to improve certainty of evidence is difficult due to variation in the definition and measurement of health outcomes. For example, the SPPB was reported in three studies included in our review, two of which used a 0-12 scale, while the third reported a continuous scale of 0 to 3.

Furthermore, timeframes at the start and at follow-up, as well as settings (hospital, rehabilitation center and/or home-based) varied widely. All of these factors raise the question of how health outcome results can be adequately interpreted and used when developing guidelines for geriatric rehabilitation healthcare facilities. We suggest that an appropriate dataset on health outcomes, together with the standardized use of measurements and measurement timepoints, are needed.

In addition to effects on health outcomes, we also considered descriptions of structure and process elements. While all studies reported (some) details on patient characteristics, guidelines and patient-centred actions, there was little evidence of goal-setting or strategies for behavioral change. Both items are crucial to the usability of mHealth and consequent health outcomes, as behavioral strategies promote good adherence and low attrition rates (Chen et al., 2023; Daly et al., 2021). Intervention details mainly focused on the technology and features of the mHealth application and often reported positive adherence results. However, less information was provided on how interventions might be integrated with daily practice. According to one systematic review on usability of mHealth in geriatric rehabilitation, mHealth interventions are most likely to succeed when they use simple applications and integrate these with non-health interventions (Nussbaum et al., 2019). This concept was not prominent in the included studies using application interventions as opposed to usual care, and not integrated into the overall treatment, raising the question of when and how mHealth apps aid recovery, and what changes are needed in the organization and workflow.

Only one study reported the inclusion of end-user input (e. g. older adults, their caregivers and healthcare professionals). In a review of app availability for frail adults, Soto-Bagaria et al. emphasized the importance of involving users in app development in order to ensure *ease of use* and *tailoring* (Soto-Bagaria et al., 2023). Both factors enhance motivation and adherence, especially the ability to adapt to personal goals and physical function. In addition to the app itself, the development of mHealth-based interventions in geriatric rehabilitation should include end-user input concerning barriers and facilitators (Tossaint-Schoenmakers et al., 2022). These might include supervision, such as home visits or phone calls by a healthcare professional, access to a helpdesk, the attitude expected of end users and their views on intervention complexity (Tossaint-Schoenmakers et al., 2022; Wong et al., 2023; Wong et al., 2022). In summary, a prerequisite for successful integration of a complex intervention is prior research focused on structure and process changes, in co-creation with end users, aimed at determining how mHealth adds value in geriatric rehabilitation.

The first strength of this review was the extensive search, with a broad view on reported health outcomes. In addition we included an overview of the interventions, presented in the adjusted Donabedian SPO model, which provides comprehensive insight in the (presentation on) content of mHealth in geriatric rehabilitation. The reported indicators of this model highlighted the minimal reporting of the development and integration of interventions. To increase research quality, studies should focus on how changes at the structure and process levels might facilitate future investigations.

One limitation across studies was heterogeneity, which was sufficient to exclude meta-analysis (Boland et al., 2014). Studies variously reported different thresholds for baseline cognitive functions, 19 different health outcomes, and mHealth interventions that varied from web-based platforms to mobile apps to the sharing of hospital computer systems. Timeframes also differed widely. The heterogeneity corresponds with our broad inclusion criteria regarding diagnosis and health outcomes. However, in this way, insights are based on the older population in the post-acute setting, which is characterized by its multiple diagnoses and its (risk of) frailty. Furthermore, although health outcomes differ, most studies include some form of mobility or functioning, which shows interest in similar goals which adds to the conversation on important health outcomes. In addition, in our protocol, we proposed to combine these assessments according to the Recommendations, Assessment, Development and Evaluation (GRADE) method to establish the body of evidence for a specific outcome. However, we judged this not feasible on the same criteria as we discarded meta-analyzes. Other reviews on mHealth interventions have reported similar limitations and therefore recommended comprehensive RCTs (Gamble et al., 2024; Lee et al., 2022; Linn et al., 2021; Solis-Navarro et al., 2022). This further emphasizes the need for consensus on the definition of important health outcomes for older adults in geriatric rehabilitation, as well as the standardized use of measurements to enable the evaluation of the effects of mHealth in older adults recovering from an acute event..

5. Conclusion

This systematic review adds to the understanding of the positive effect of mHealth in geriatric rehabilitation, as included studies show improvements in health outcomes favorable for most intervention groups. The broad variability in outcomes, and methodologies among studies, along with a generally high risk of bias, suggest cautious interpretation. Also, there is a lack of consensus on key elements of applications and structure and process elements of blended care. Therefore, co-created interventions that incorporate insights from older adults, healthcare professionals and stakeholders are needed for successful uptake in daily practice, followed by the standardized investigation of the implementation and impact of blended interventions on health status. Optimized in that way, mHealth could offer a personalized tool for independent use, to improve health status after an acute event in older adults in geriatric rehabilitation and keep geriatric rehabilitation accessible and affordable.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author (s) used Chat GPT in order to execute rephrase suggestions of the authors own text. After using this tool/service, the author (s) reviewed and edited the content as needed and take (s) full responsibility for the content of the publication.

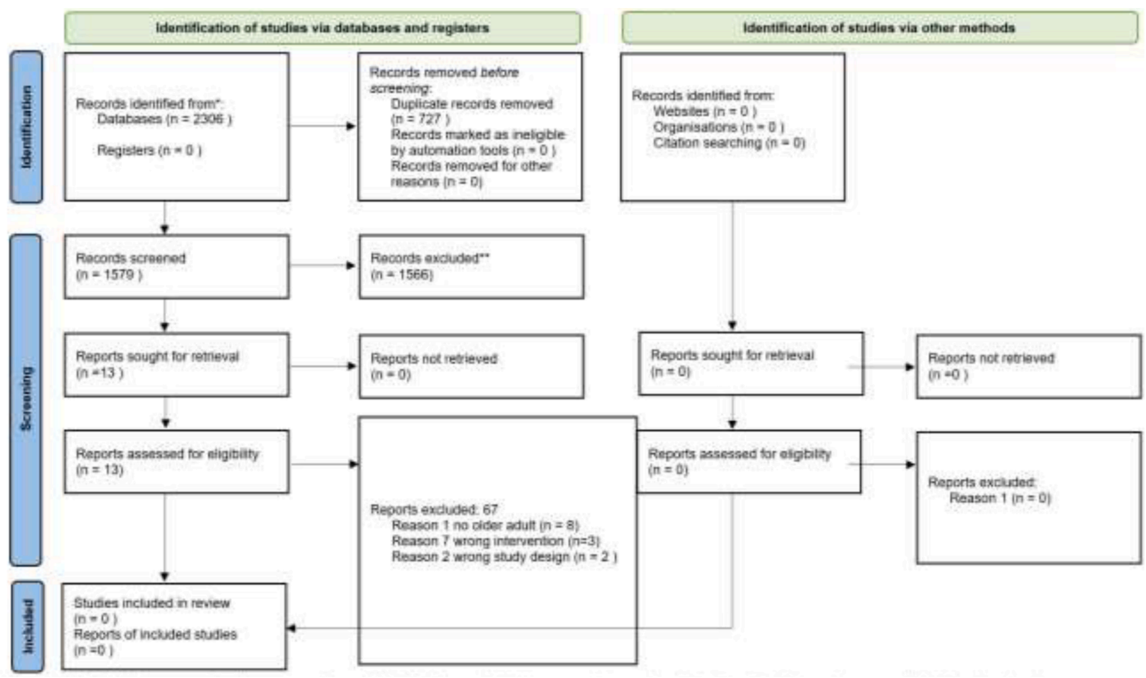
CRediT authorship contribution statement

Loes Oostrik: Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Marije Holstege:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Jorit Meesters:** Writing – review & editing. **Wilco Achterberg:** Writing – review & editing. **Eléonore F van Dam van Isselt:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A



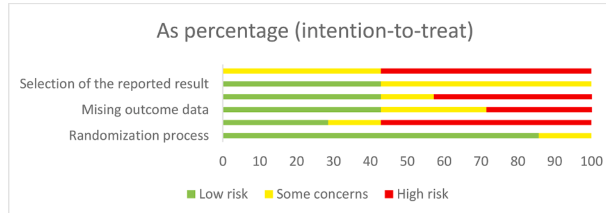
Appendix B

Minimal clinical differences for measurements according to sralab.org
SPPB=> 0.5-1
EMS=> 2-2.6 COPM-P => 3.0 points
COPM-S => 3.2 points
FIM => FIM Total Score = 22 points, FIM Motor Subscale = 17 points, FIM Cognitive Subscale = 3 points
SAS => NR
MFAC => MDC => 0.482.
HHS => moderate improvement threshold 40 points
LEFS => MCID = 6 points or 11.3 % (hip impairment) 9 scale points.
TUG => 10.8 s
VAS pain => NR
FR => 4,1 -9
EQ-5D EuroQol => NR
VO2peak => NR

Appendix C

Overview Risk of Bias assessed with the Cochrane ROB-tool for RCTs.

Study ID:
SR1 Cheng et al.
SR2 Hassett et al.
SR3 Li et al.
SR4 Pol et al.
SR5 Snoek et al.
SR6 Wu et al.
SR7 Zhang et al.



Intention-to-treat													
Unique ID	**Study ID**	**Experimental**	**Comparator**	**Outcome**	**Weight**	**D1**	**D2**	**D3**	**D4**	**D5**	**Overall**		
mHealthSR1	SR1	Homebased rehab with mobile app	Homebased rehab with exercise pamphlet	MFAC; EMS; LEFS	1	+	-	-	-	!	-	+	Low risk
mHealthSR2	SR2	Usual care and devices targeting mobility and PA	Usual care	SPPB; upright time %day	1	+	!	+	+	+	!	!	Some concerns
mHealthSR3	SR3	Homerehab Caspar health e-system + app	Homerehab + paper-and-pencil instructions	TUG; FR; Muscle strength; Pain	1	+	+	+	+	!	!	-	High risk
mHealthSR4	SR4	CBT- based coaching or CBT based	Usual care	COPM	1	+	+	!	!	+	!		
mHealthSR5	SR5	Homebased mobile cardiac rehabilitation	Primary care	Vo2peak, MVPA	1	+	-	!	-	+	-	D1	Randomisation process
mHealthSR6	SR6	Telerehabilitation	Telephone	HHS, FIM, SAS	1	!	-	+	+	!	-	D2	Deviations from the intended interventions
mHealthSR7	SR7	Telerehabilitation	Telephone	HHS; FIM; TUG; SPPB	1	+	-	-	-	!	-	D3	Missing outcome data
												D4	Measurement of the outcome
												D5	Selection of the reported result

Appendix D

Table E.1
Reaching an overall RoB judgement for a specific outcome according to ROBINS-tool.

Response option	Criteria
Low risk of bias (the study is comparable to a well-performed randomized trial);	The study is judged to be at **low risk of bias for all domains**.
Moderate risk of bias (the study appears to provide sound evidence for a non-randomized study but cannot be considered comparable to a well-performed randomized trial);	The study is judged to be at **low or moderate risk of bias for all domains**.
Serious risk of bias (the study has some important problems);	The study is judged to be at **serious risk of bias** in at least one domain, but not at critical risk of bias in any domain.
Critical risk of bias (the study is too problematic to provide any useful evidence and should not be included in any synthesis);	The study is judged to be at **critical risk of bias in at least one domain.**
No information on which to base a judgement about risk of bias.	There is no clear indication that the study is at serious or critical risk of bias *and* there is a lack of information in one or more key domains of bias (*a judgement is required for this*).

Table E.2
Risk of bias assessment Mora et al. 2021.

Risk of bias assessment	Score
Bias due to confounding	Serious
Bias in selection of participants into the study	Low
Bias in classification of interventions	Low
Bias due to deviations from intended interventions	Serious
Bias due to missing data	Low
Bias in measurement of outcomes	Low
Bias in selection of the reported result	Low
Overall bias	Serious

Table E.3
Risk of bias assessment Ortiz-Pena et al. 2021.

Risk of bias assessment	Score
Bias due to confounding	Serious
Bias in selection of participants into the study	Low
Bias in classification of interventions	Low
Bias due to deviations from intended interventions	Serious
Bias due to missing data	Moderate
Bias in measurement of outcomes	Low
Bias in selection of the reported result	Low
Overall bias	Serious

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