Technologies used to facilitate remote rehabilitation of adults with deconditioning, musculoskeletal conditions, stroke, or traumatic brain injury – An umbrella review

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Abstract

Objective: To provide an overview of technologies (devices, tools, or software applications) used to facilitate remote rehabilitation of adults with deconditioning, musculoskeletal conditions, stroke, or traumatic brain injury and to summarise the quantitative evidence of their efficacy.

Introduction: Healthcare providers are considering how to meet longer-term rehabilitation needs of people whose health or level of activity and participation has been impacted directly or indirectly by the COVID-19 pandemic. Demands on rehabilitation services are increasing, driving a need for more services to be delivered in homes and communities. This review will identify the effectiveness of healthcare technologies that can facilitate remote rehabilitation.

Inclusion criteria: This review included quantitative systematic reviews where participants were adults requiring rehabilitation for musculoskeletal conditions, stroke, traumatic brain injury or older adults requiring rehabilitation for deconditioning. Interventions included a technology and focused on recovery or rehabilitation with one of the following primary outcomes: physical activity levels, balance and/or gait, physical performance (mobility), or functional performance. Secondary outcomes included levels of pain, cognitive function, health-related quality of life and adverse effects.

Methods: Five databases were searched from January 2016 to December 2020 to identify English-language publications. Critical appraisal of five systematic reviews was conducted independently by two reviewers, using the JBI critical appraisal checklist for systematic reviews and research syntheses. Data extraction was performed independently by two reviewers using a standard JBI data extraction tool. Data were summarized using a tabular format with supporting text.

Results: Despite the large number of systematic reviews found in the initial search, only five met the inclusion criteria. Of these, each explored a different technology which included: wearable activity trackers, computer-based activities, non-immersive virtual reality, mobile apps, web-based rehabilitation interventions, electronic-health-based interventions (web-based or app-based with a wearable activity tracker). Computer-based activities were beneficial for improving cognitive function but showed no benefit on quality of life in post-stroke rehabilitation. Interventions that included wearable activity trackers showed mixed findings for increasing levels of physical activity for community dwelling older adults with deconditioning. Mobile apps were beneficial for increasing levels of physical activity and physical or functional performance for post-stroke rehabilitation. Web-based rehabilitation that contained a variety of components to support home exercise was not effective in improving physical performance or quality of life, reducing pain, or increasing levels of physical activity among individuals with rheumatoid arthritis. Electronic-health-based interventions (web- or app-based with a wearable activity tracker) were effective in improving physical performance and reducing pain of individuals with osteoarthritis in the knee or hip. Therapy in the form of screen-based non-immersive virtual reality could be successfully transferred to the home environment for improving balance/gait of individuals with stroke.

Conclusions: The small number of heterogeneous systematic reviews included in this umbrella review and the very low quality of evidence, mostly from single small primary studies, makes it difficult to draw overall conclusions that differ from the original review findings. This highlights a paucity of strong, high-quality evidence underpinning technologies that can be used to facilitate remote rehabilitation in the wake of the COVID-19 pandemic.

Keywords: Rehabilitation; musculoskeletal conditions, cerebrovascular conditions, deconditioning, digital intervention

Summary of findings

Effectiveness of remote rehabilitation of adults with deconditioning, musculoskeletal conditions or stroke			
Bibliography: Edwards DJ, Carrier JA, Davies J, Williams J. An umbrella review of technologies used to facilitate remote rehabilitation of adults with deconditioning, musculoskeletal conditions, stroke, or traumatic brain injury			
Outcomes	**Impact**	**No of participants (/reviews)**	**Certainty of the evidence (GRADE)**
1. Mobile based apps compared no control group for post stroke rehabilitation			
Physical performance **Finger function (narrative)** 9 Hole Peg Test	[a]One review showed an improvement for those in the intervention group	12 out of 15 (1 review)	NR
Range of motion (narrative) Several instruments were used to measure this outcome	[a]One review showed an improvement for those in the intervention group	6 (1 review)	NR
Degree of disability (narrative) Modified Rankin Scale	One review showed significant improvement for those for those in the intervention group	30 (1 review)	NR
ADL (narrative) Barthel Index	One review showed significant improvement for those for those in the intervention group	30 (1 review)	NR
2. Mobile based apps compared to passive control group for post stroke rehabilitation			
Physical activity (narrative)		24 (1 review)	NR

Several instruments were used to measure this outcome	One review showed significant improvement for those in the intervention group compared to those in the control group		
Sedentary behaviour (narrative) Several instruments were used to measure this outcome	One review did not find any difference between those in the intervention and control group	24 (1 review)	NR
Physical performance **Muscle strength (narrative)** Manual Muscle Test	One review showed significant improvement for those in the intervention group compared to those in the control group	24 (1 review)	NR
Finger Function (narrative) Several instruments were used to measure this outcome	One review showed significant improvement for those in the intervention group compared to those in the control group	24 (1 review)	NR
3. Computer-based activities compared no control group for post stroke rehabilitation			
Cognitive function (narrative) Several instruments were used to measure this outcome	One review showed significant improvement for those in the intervention group	21 (1 review)	NR
4. Computer-based activities compared to standard care for post stroke rehabilitation			
Cognitive function (narrative) Several instruments were used to measure this outcome	One review showed significant improvement for those in the intervention group compared to those in the control group	43 (1 review)	NR
QoL (narrative) SS-QoL	One review did not find any difference between those in	43 (1 review)	NR

	the intervention and control group		
4. Home based non immersive VR vs clinic based conventional therapy for post stroke rehabilitation			
Balance/Gait (narrative) Berg Balance Scale POMA-B POMA-A	Three reviews showed an improvement for those in both the intervention and control groups which was not significant	90 (1 review) 30 (1 review) 30 (1 review)	NR
10-meter Walk Test Timed Up and Go test	Two reviews did not find any difference between those in the intervention and control group	46 (1 review) 43 (1 review)	NR
5. Wearable activity trackers compared to passive control group for older adults with deconditioning			
Physical Activity **Step count (meta-analysis)** Measured objectively using an accelerometer or pedometer	One review showed significant improvement for those in the intervention group and also showed significant improvement for those in the intervention group compared to those in the control group	207 (1 review)	NR
Step count (narrative) Measured objectively using an accelerometer or pedometer	One review showed significant improvement for those in the intervention group compared to those in the control group	32 (1 review)	NR
MPVA (meta-analysis) Measured objectively using an accelerometer or pedometer	IG↑ / IG > CG	83 (1 review)	NR
MPVA (narrative)	One review did not find any difference between those in	235 (1 review)	NR

Measured objectively using *a wrist worn* accelerometer or pedometer	the intervention and control group		
Measured objectively using *an ankle worn* accelerometer or pedometer	One review showed significant improvement for those in the intervention group compared to those in the control group	235 (1 review)	NR
6. Wearable activity trackers compared to active control group for older adults with deconditioning			
Physical Activity **Step count (meta-analysis)** Measured objectively using an accelerometer or pedometer	IG ≡ CG	201 (1 review)	NR
Step count (narrative) Measured objectively using an accelerometer or pedometer	Mixed findings Some studies showed an improvement for those in the intervention group and others did not find any difference between those in the intervention and control group	362 (1 review)	NR
MPVA (narrative) Measured objectively using accelerometer or pedometer	Mixed findings Some studies showed an improvement for those in the intervention group whereas either showed significant improvement for those in the intervention group compared to those in the control group or did not find any difference	132 (1 review)	NR
7. Web-based rehabilitation compared to general information for rheumatoid arthritis			
MVPA (mean difference) Measured objectively using an accelerometer or pedometer	IG ≡ CG	108 to 155[b] (1 review)	Very Low

Physical performance **Short term (mean difference)** Questionnaire and activity monitor **Medium term (mean difference)** Questionnaire and activity monitor **Long term (mean difference)** Questionnaire and activity monitor	IG ≡ CG IG ≡ CG IG ≡ CG	155 (1 review) 155 (1 review) 108 (1 review)	Very Low Very Low Very Low
QoL (mean difference) Several instruments were used to measure this outcome	IG ≡ CG	108 to 155[b] (1 review)	Very Low
8. Web-based rehabilitation compared to usual care for rheumatoid arthritis			
Physical performance **Long term (meta-analysis)** Several instruments were used to measure this outcome	IG ≡ CG	144 (1 review)	Very Low
9. Web-based rehabilitation compared to waiting list for rheumatoid arthritis			
Pain **Short term (mean difference)** Several instruments were used to measure this outcome **Medium term (mean difference)** Several instruments were used to measure this outcome	IG ≡ CG IG ≡ CG	93 (I review) 88 (1 review)	Very Low Very Low
Pain **Long term (mean difference)** Numeric rating scale	IG ≡ CG	144 (1 review)	Very Low
QoL (mean difference) Several instruments were used to measure this outcome	IG ≡ CG	93 to 88[b] (1 review)	Very Low
10. Web-based rehabilitation (different types of access to online social support and gamification features) compared to no access to website for rheumatoid arthritis			
Time doing exercise (mean difference) Exercise Behaviour Scale	CG↑ or IG ≡ CG	63 to 68[b] (1 review)	Very Low

11. Electronic health-supported[c] home exercise interventions for osteoarthritis in the knee or hip			
Physical performance **3MFU (meta-analysis)** Several instruments were used to measure this outcome	IG↑ / IG> CG	333 (1 review)	NR
Physical performance **9-12MFU (meta-analysis)** Several instruments were used to measure this outcome	IG↑ / IG> CG	290 (1 review)	NR
Pain **3MFU (meta analysis)** Several instruments were used to measure this outcome	IG < CG	516 (1 review)	NR
9-12MFU (meta-analysis) Several instruments were used to measure this outcome	IG < CG	280 (1 review)	NR

[a] analytic statistics not conducted
[b] participant numbers vary depending on intervention and follow up time point
[c:] web-based or app based with a wearable activity tracker

Key: 12MFU: nine to twelve month follow up; 3MFU: three month follow up; ADL: activities of daily living; MVPA: moderate to vigorous physical activity; NR: not reported; POMA-B: performance-oriented mobility assessment-balance subscale; POMA-G: performance-oriented mobility assessment-gait subscale; SS-QoL: Stroke Specific Quality of Life scale; VR: virtual reality

CG↑: significant improvement for control group
IG < CG: significant reductions in intervention group compared to control group
IG ≡ CG: no difference between intervention groups and control groups
IG> CG: significant improvement in intervention group compared to control group
IG↑: significant improvement for intervention group

Introduction

The coronavirus disease 2019 (COVID-19) pandemic placed intense pressure on all aspects of healthcare. It is anticipated that the need for rehabilitation will increase as a consequence of the pandemic,[1,2] and the importance of rehabilitation in the recovery from COVID-19 has been stressed by the World Health Organisation.[3] Rehabilitation services will have to meet the differing needs of several populations, including those who have had COVID-19[4–6] and those whose health and level of activity and participation has been impacted indirectly.[1] This increased demand has led to recognition that the way in which rehabilitation is delivered will have to change,[1,7] with a need for more services delivered in homes and communities.[1,8] The restrictions imposed due to COVID-19 drove an increase in the use of technology in healthcare delivery[8,9] and there is considerable appetite to capitalise on this to enable rehabilitation services to manage the expected demand.

The field of healthcare technologies is vast and growing. It encompasses communication tools that allow remote consultations,[10,11] smart objects[12,13] and wearable devices[14–16] that can measure physical and physiological variables, technologies (including immersive and non-immersive virtual reality [VR] and augmented reality [AR]) that allow gamification of rehabilitation activities,[17–19] assistive and adaptive technologies,[20,21] and web- or mobile-based tools (including apps) that permit self-management and recording and sharing of information and patient-reported outcomes.[22,23] Some technologies are nascent and others are more established. Some are suitable for and have been evaluated in home or community settings, others require or have only been evaluated with clinician supervision. The abundance of literature means it can be difficult for clinicians and other stakeholders to identify technologies that could facilitate remote rehabilitation of individuals during and in the wake of the COVID-19 pandemic.

Our primary aim was to identify technologies that may facilitate remote rehabilitation at the current time or in the very near future. The field of remote rehabilitation is relatively new and terms are not well defined. The term telerehabilitation[24] is commonly interpreted as referring to rehabilitation performed with the use of information and communication technologies. For our purpose, remote rehabilitation is defined as rehabilitation that takes place outside a clinical setting, for example in the home or community, without face-to-face clinical supervision. This may incorporate telerehabilitation, but is not limited as such and can also include technologies that measure a physiological variable outside the clinic, or permit gamification of rehabilitation exercises outside the clinic, without information and communication technologies.

Robotic devices, immersive VR or AR and e-textiles were excluded as they were considered not readily accessible in the UK National Health Service. Technologies that facilitated only remote communication between patient and clinician, such as phone calls and video consultations, were excluded as they have already rapidly been adopted across the UK National Health Service in response to the pandemic, with service evaluations underway.[25] Technologies we anticipated encountering were wearable devices, sensors, apps, gamification, non-immersive VR or AR, and smart objects.

Preliminary searches indicated that many systematic reviews have been conducted on the use of technologies that may facilitate remote rehabilitation (for example[26–30]). A comprehensive review of these systematic reviews is warranted to analyse the available evidence, its quality and limitations and highlight technologies that may be suitable for consideration for use in clinical practice. A preliminary search of PROSPERO, MEDLINE, the Cochrane Database of Systematic Reviews and the JBI Database of Systematic Reviews and Implementation Reports was conducted and no current or underway umbrella reviews on the topic were identified. There is a Cochrane rapid living systematic review that aims to provide current scientific knowledge on COVID-19 rehabilitation, but this is focussed on rehabilitation needs and not on technologies available to facilitate remote rehabilitation of identified patient cohorts.[2]

The increased demand on rehabilitation services will come not only from individuals recovering from COVID-19, but also individuals who have had pauses in planned care, individuals who avoided accessing healthcare services and received delayed diagnosis or treatment, and individuals whose physical or mental health has been affected by lockdown restrictions.[31] This covers a vast multitude of conditions, and it is not feasible or practicable to consider the use of technologies across all conditions in one body of work. Following discussion with the project steering committee it was decided that the focus of this umbrella review would be on technologies that may facilitate the remote rehabilitation of musculoskeletal and selected neurological conditions and deconditioning, as they align well with both the expertise of the project team and areas of high demand during and in the wake of the pandemic.

The following conditions were included: musculoskeletal conditions, stroke, traumatic brain injury, and deconditioning.

Musculoskeletal conditions. Not only is joint or muscle pain a common symptom of COVID-19[32] but COVID-19 patients who experience pain may be at risk of progressive muscle injury.[33] In addition, the number of individuals waiting for trauma and orthopaedic elective surgeries has been considerably affected by the pandemic.[34,35] Demand for rehabilitation of musculoskeletal conditions is therefore likely to be substantially impacted by COVID-19. The need for orthopaedic practice to incorporate new technologies, and for this to be supported by review of emerging literature has been explicitly acknowledged.[36]

Stroke. The virus that causes COVID-19, severe acute respiratory syndrome coronavirus 2, may predispose to stroke.[37] In addition, the number of hospital admissions for stroke decreased in the early stages of the pandemic;[38,39] however, the severity of admissions increased[39], thought to be due to individuals with symptoms avoiding presentation.[40] The demand on stroke rehabilitation services is therefore set to be considerable. Recent reviews have recommended that telemedicine be employed where possible to enable provision of stroke outpatient care services as the pandemic recedes.[38,40] *Traumatic brain injury.*

Traumatic brain injury was also included as it makes the largest contribution to trauma-related mortality worldwide and the use of technology in rehabilitation has been deemed essential.[41]

Deconditioning. The COVID-19 pandemic has been highlighted as having an ‘immense’ deconditioning effect, particularly in older adults[42] and the aim of reversing the effects of this deconditioning has been highlighted as an urgent priority.

Each of these conditions was considered as a separate entity, not as a heterogeneous single population.

Review question

What is the evidence for the effectiveness of technologies (devices, tools, or software applications) used to facilitate remote rehabilitation of adults with deconditioning, musculoskeletal conditions, stroke, or traumatic brain injury?

The aim is to provide an overview of technologies (devices, tools, or software applications) that have been used to facilitate remote rehabilitation of adults with deconditioning, musculoskeletal conditions, stroke, or traumatic brain injury and summarise the quantitative evidence of their efficacy.
The specific objectives are to

1. determine what technologies exist
2. determine the effectiveness of these technologies when used in remote rehabilitation settings

Inclusion Criteria

The inclusion criteria were shaped using PICO but we also felt that context was important to include.

Types of participants

This umbrella review considered the following population groups:

- Adults requiring rehabilitation for musculoskeletal conditions including inflammatory arthritis, osteoarthritis, post-operative care for joint replacement surgery, regional problems such as back, neck and shoulder pain, and other conditions affecting the muscles, tendons, ligaments, or bones.
- Adults requiring rehabilitation for motor impairments after stroke or traumatic brain injury.
- Older adults over 65 years of age requiring rehabilitation because of deconditioning, defined as a decline in physical function of the body due to reduced physical activity. To encompass all technologies that may be applicable to this group, the review considered technologies used to increase physical activity levels in healthy older adults.

During the screening process it became necessary to develop some exclusion criteria for those systematic reviews where a pooled analysis had been conducted, more specifically

- where a range of diseases and healthcare conditions had been explored as well as that met the inclusion criteria but where the results were presented using a pooled analysis.
- where the participants were defined as healthy younger adults over 18 years of age or where the results were presented using a pooled analysis for both younger and older healthy adults.

Interventions

This umbrella review considered systematic reviews that evaluated technologies that focused on recovery and rehabilitation. For this project, technologies are defined as any device, tool, or software application, that could be used remotely to measure, monitor or record patient data. This includes but is not limited to wearable devices, sensors, apps, gamification, non-immersive VR or AR, or smart objects.

The following exclusion criteria were applied:

- Interventions that included the following technologies: artificial intelligence (defined as the simulation of human intelligence processes), robotic devices, immersive VR or AR, e-textiles.
- Systematic reviews that were conducted across a range of healthcare technologies where the results were conducted using a pooled analysis.
- Technologies that simply permit communication, but do not measure, monitor or record patient data, including telephone calls, emails, texting or video calls.

Comparators

This umbrella review considered systematic reviews that compared the intervention to usual care or a control group.

Context

Remote rehabilitation refers to all rehabilitation performed outside a clinical setting, for example in the home or community, without face-to-face clinical supervision. The following exclusion criteria were applied:

- Systematic reviews from low- and middle-income countries.

- Systematic reviews that included a technology but were delivered in a laboratory or clinical setting (including hospital inpatient and outpatient settings).
- Systematic reviews that were conducted across a range of settings where the results were conducted using a pooled analysis.

Outcomes

This umbrella review considered systematic reviews that included the following primary outcomes

- Physical activity: Physical activity evaluated by measuring the number of steps walked per day or week using a pedometer or accelerometer, walking minutes day or week, or time spent undertaking moderate to vigorous activity at the end of the intervention.
- Balance and/or gait: Balance and/or gait evaluated using objective measures such as the Berg Balance Scale, Functional Gait Assessment, Activities-specific Balance Confidence scale, 10-meter walk test, 6-minute walk test, five times sit-to-stand, or timed up and go test.
- Physical performance (mobility): Level of physical performance evaluated using objective measures such as the Fugl-Meyer assessment, Action Research Arm Test (upper extremity subsection), or Wolf Motor Functioning Test.
- Functional performance (activities of daily living): Ability to perform functional activities in everyday life evaluated using objective measures such as the Barthel Index, Nottingham Extended Activities of Daily Living Scale, Frenchay Activities Index, Functional Independence Measure, or other disease-specific measures.

This umbrella review considered the following secondary outcomes

- Levels of pain evaluated using a numerical rating scale, brief pain inventory, or disease-specific scale such as the Western Ontario and McMaster Universities Osteoarthritis Index.
- Cognitive function evaluated using objective measures such as the Montreal Cognitive Assessment, the Trail Making Test A and B, or the Digit Span Forward and Backward.
- Health-related quality of life (QoL) evaluated using subjective or objective measures such as the EuroQoL Five Dimensions questionnaire (EQ-5D), Medical Outcomes Study short form 36 health survey (SF-36), Short-Form Six Dimensions Questionnaire (SF-36) or disease-specific QoL tools.
- Adverse effects

Types of Research Syntheses

This umbrella review considered published systematic reviews and meta-analyses of quantitative studies (randomized controlled trials (RCTs), quasi-experimental, and pre-post design). An eligible systematic review was considered one where a clearly focused question was provided, where the review authors used a comprehensive literature search strategy (at least two databases, provided keyword/search strategy/ justified publication restrictions) and had conducted a risk of bias assessment.

Methods

This umbrella review was conducted according JBI methodology for umbrella reviews,[43] following the study protocol which was registered in PROSPERO (Prospective Register of Systematic Reviews) database (CRD42021240598). The manuscript was prepared using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.[44]

Search Strategy

The search strategy aimed to locate published research syntheses. An initial limited search of MEDLINE was undertaken to identify articles on the topic. The searches and preliminary keywords used were (wearable or remote or portable or mobile AND system* or device* or monitor* or tech* or track* or measur* or captur* or detect* or monitor* or sensor*) OR (internet or web or online or hand or wrist or cell* or smart* or mobile* or android near to comput* or device* or app or apps or application AND digital or health or intervention* or technolo* or program* or device) OR game* or gaming or gamification or exergame OR smart OR telehealth or telerehabilitation AND Rehabilit* or recover* AND home or communit* or remote* or distance* AND review or meta-analysis or synthesis or overview.

The text words contained in the titles and abstracts of relevant articles, and the index terms used to describe the articles were used to develop a full search strategy. The search strategy, including all identified keywords and index terms was adapted for each included information source (Appendix I) The reference list of all syntheses selected for critical appraisal were screened for additional articles. To identify published resources that have not yet been catalogued in the electronic databases, recent editions of Clinical Rehabilitation, Disability and Rehabilitation, JMIR mHealth and uHealth, JMIR Serious Games and the Journal of Medical Internet Research were hand-searched. Reference lists of included studies were scanned and forward citation tracking performed using ISI Web of Science searches.

Research syntheses published in the English language were included. Research syntheses published from January 2016 to December 2020 were included as we were only interested in technology that is current.

Comprehensive searches were conducted across five databases

- On the Ovid Platform: Medline PsycINFO, Embase
- On the Ebsco Platform: Cumulative Index of Nursing and Allied Health Literature (CINAHL)
- Physiotherapy Evidence Databases (PEDro)

Study Screening and Selection

Following the search, all citations retrieved were loaded into the reference management software EndNote (Clarivate Analytics, Philadelphia, PA, USA) and duplicates removed. All remaining citations were imported into the software programme Covidence (Covidence.org, Melbourne, Australia) where titles and abstracts were read independently by two members of the research team and considered against the topic inclusion criteria. All potentially relevant papers were retrieved in full, and their citation details imported into the JBI System for the Unified Management, Assessment and Review of Information (JBI SUMARI; Joanna Briggs Institute, Adelaide, Australia) and assessed in detail against the inclusion criteria by two independent reviewers using a purposely designed screening tool piloted on one review. Reasons for exclusion of full text articles that do not meet the inclusion criteria were recorded and reported in Appendix II. Any disagreements that arose between the reviewers at each stage of the selection process were resolved through discussion, or with a third reviewer. The results of the search are reported in full in the final report and presented in PRISMA flow diagram.[44]

Assessment of Methodological Quality

Eligible syntheses were critically appraised by two independent reviewers for methodological quality using the standardized critical appraisal instrument from JBI.[45] Any disagreements that arose between the reviewers were resolved through discussion, or with a third reviewer. The results of critical appraisal are reported in narrative form and in a table. All syntheses, regardless of the results of their methodological quality, underwent data extraction and synthesis (where possible).

Data Collection

Data was extracted from the included systematic reviews by two independent reviewers using the JBI data extraction tool in JBI SUMARI.[43] The data extracted included 1) type of review, 2) countries where the primary studies were conducted, 3) databases, 4) search timeframes; 5) number of studies included in the review; 6) participants (number and comorbidities); 7) type(s) of intervention(s) and comparison conditions (including duration and level of personal contact); 8) outcomes of significance (types and characteristics); 9) outcome measures; 10) assessment and follow up timeframes; 11) critical appraisal tools and ratings 12) methods of analysis and heterogeneity; 13) effect size and confidence intervals; 14) findings, 15) conclusions. Any disagreements between the reviewers were resolved through discussion or with a third reviewer.

Data Summary

The overlap of original research studies included in the systematic reviews were checked and no primary studies were duplicated across the systematic reviews (see Appendix III). The findings from the systematic reviews are presented in tables and as a narrative synthesis by the interventions and technologies used to facilitate remote rehabilitation and by the effectiveness of technologies used in remote rehabilitation across the different outcomes. The results of the systematic reviews included in the umbrella review that undertook a meta-analysis are presented in a “summary of evidence” table that includes the intervention, the included systematic reviews, and a simple visual indicator of the effectiveness of the intervention for each outcome using a colour coded traffic light system. In this system green represents an effective intervention, orange represents no effect or difference compared to a control treatment or usual treatment and red represents a detrimental intervention or one that is less effective than a control treatment.[43] An overall “Summary of Findings” table for the effects of the different technologies used in remote rehabilitation by outcome, impact, number of participants and studies is provided.

Results

Study inclusion

The database searches identified 1,205 records as being potentially relevant to the review. After the duplicates had been removed, the titles and abstracts of 425 were reviewed. One hundred and one full text publications were selected for retrieval and 96 were excluded (see Appendix II). All full text publications that met the inclusion criteria went forward to critical appraisal (n=5) and at the end of this process all five were considered suitable for inclusion. The PRISMA checklist was followed for the reporting of this review and the flow of studies through the review is presented in a PRISMA flow diagram (Figure 1).

Insert Figure 1 around here

Methodological quality

The results of the critical appraisal are presented in Table 1. All included systematic reviews had clear questions (Q1), appropriate inclusion criteria (Q2) used appropriate search strategies (Q3), used adequate sources (Q4), used appropriate criteria for appraising (Q5), critical appraisal was conducted by two reviewers (Q6), and used methods to minimise errors in data extraction (Q7). A considerable weakness in three of the five systematic reviews was the methods used to combine studies (Q8), which included failure to conduct a meta-analysis even when studies appeared to be homogeneous,[27] concern expressed by the authors about conducting a meta-analysis with a small number of studies that showed considerable heterogeneity[26] or conduct of a meta-analysis despite heterogeneity in the interventions.[46] Two systematic reviews assessed publication bias (Q9).[27,47] Two systematic reviews didn't report any recommendations (Q10)[26,47] and one systematic review provided recommendations based on the use of inappropriate meta-analysis (Q10).[46] Directives for research were provided in all systematic reviews except one (Q11).[46]

Characteristics of included systematic reviews

An overview of the systematic reviews is shown in Appendices IV and V. The five systematic reviews included a total of 23 RCTs, five quasi experimental studies, two case studies and one case control study that were relevant to the systematic review inclusion criteria.

The primary studies were published between 2007 and 2017. Four systematic reviews conducted their searches from database inception to February 2017,[47] May 2017,[27] July 2017,[46] or January 2018[48] and the remaining systematic review conducted their search from January 2008 to January 2018.[26]

The language restrictions across the systematic reviews were English only (n=3),[26,27,47] English or German (n=1),[46] and English, Dutch, German or French (n=1).[48]

The instruments used for bias appraisal for were the Cochrane risk of bias tool (n=3),[26,46,47] the criteria published by the Australian Evidence-Based Health Care Center,[27] the PEDro scale,[48] Newcastle Ottawa Scale and the National Heart,[48] Lung and Blood Institute checklist.[48] Due to the nature of many of the interventions it was impossible to blind participants or research personnel, some systematic reviews took this into account when making their assessments and others did not.

Insert table 1 around here

The total number of participants across all five systematic reviews was 2746 and the number of participants in each systematic review ranged from 120[48] to 1035.[26] Gender was reported in two systematic reviews,[46,48] but where gender was reported the majority of participants were female (61.6%). In one systematic review participants were community-dwelling older adults (mean age 65.5 years) who were following a sedentary lifestyle and had no specified health conditions.[26] In the other four systematic reviews participants had specific health conditions.[27,46–48] In two systematic reviews participants were individuals who had previously had a stroke.[27,48] One of these did not report the age of participants[27] and the other included participants with a mean age of 62.2 years.[48] In two systematic reviews participants had a musculoskeletal condition,[46,47] which included osteoarthritis of the knee or hip,[46,47] rheumatoid arthritis[47] or fibromyalgia,[47] and a mean age of 58.9 years. We did not find any relevant systematic reviews for patients with traumatic brain injury. All systematic reviews were of interventions that used technology in the home setting[26,27,46–48] with one systematic review additionally including residents in nursing homes.[26]

The included primary studies were conducted across a diverse range of countries which included USA,[26,27,46–48] Canada,[26] the Netherlands,[26,46,47] UK,[27] Korea[27], Russia,[27] Israel,[27] the Czech Republic,[27] Slovenia,[48] Spain,[48] Taiwan,[48] Australia[46,48] and Switzerland.[47] The number of databases searched ranged from four[27] to nine[47]. These included: AMED;[47] CENTRAL;[26,46–48] CINAHL;[26,27,46,47] EMBASE;[26,27,47] Google Scholar;[47] MEDLINE;[26] PEDro;[46–48] PSYCinfo[26,47] PubMed;[26,27,46,48] Rehab data;[48] Science Direct;[26] SCOPUS;[47] Sports Discus;[47] or Web of Science.[26,27,48]

A variety of methods of analysis were conducted which included a narrative synthesis (n=4),[26,27,47,48] meta-analysis using a random effects model and all calculated heterogeneity using I^2 (n=2)[26,46] or mean difference with 95% confidence intervals for continuous data and risk ratio with 95% confidence intervals for dichotomous outcomes.[47]

Findings of the Review

Technologies used to facilitate remote rehabilitation

The details of the interventions that used a technology to facilitate remote rehabilitation are displayed in Appendix VI. The rehabilitation focus across all five systematic reviews was on physical performance and one systematic review also explored cognitive function.[27] More specifically, the systematic reviews examined the effects of the intervention on level of physical activity and /or sedentary behaviour (n=3),[26,27,47] balance or gait (n=2),[27,48] physical performance (mobility; n=4),[27,46–48] cognitive function (n=1),[27] QoL (n=3),[27,46,47] functional performance (activities of daily living; n=1)[27] or pain (n=2).[46,47] Only two systematic reviews sought to report on adverse events.[27,47] For four of the five systematic reviews, the physical component of the intervention varied across the primary studies and included walking, general physical activity, or tailored activities designed to increase function, muscle strength, and/or joint range of motion. For one systematic review, the physical component of all included interventions was balance training.[48] All of the primary studies within the systematic reviews assessed outcomes at baseline and directly after the intervention was completed. Six primary studies (16%) also assessed outcomes during the intervention (usually at the mid-point). Only five primary studies (29%) conducted long-term follow up.

The technology used to facilitate remote rehabilitation varied across systematic reviews and included wearable activity trackers,[26,46] computer-based activities,[27] non-immersive VR,[48] mobile applications (apps),[27] web-based rehabilitation interventions,[47] and electronic-health based interventions (web-based or app-based with a wearable activity tracker).[46] Both systematic reviews of interventions that incorporated a wearable activity tracker[26,46] included primary studies of a variety of commercial and unbranded devices. The device was linked to either an interactive website, a mobile application, or both and was worn on the hip/waist, arm, or ankle.

Details of additional components of the interventions were reported in four of the systematic reviews.[26,46–48] The nature of these additional components varied across studies, but most commonly included the provision of information or educational materials and/or the provision of some level of support, either social, technical (e.g., coaching), or support from a healthcare professional via telephone or videoconferencing. The level of personal contact ranged from no contact (eight studies across four systematic reviews)[26,46–48] or very little contact (nine studies across two systematic reviews)[26,27] to full (remote) contact (13 studies across four systematic reviews).[26,27,47,48] Where there was very little contact, this involved the interventionist acting as a credible source in favour of promoting increasing physical activity[26] or providing initial instructions on how to use the technology.[27] Full contact involved a wide variety of activities and included the following: leading online group discussions or forums, overseeing a prescription, providing face-to-face phone consultations or support, videoconferencing during balance training to providing education, personalised activity daily or weekly schedules, regular feedback, weekly conventional physical therapy in clinic, weekly remote supervision from physiotherapists e-newsletters or face to face group meetings once every 3 months. No systematic review stratified results according to the additional content included with the intervention.

All five systematic reviews reported the duration of the interventions in the primary studies, which ranged from five weeks to 12 months for studies of wearable activity trackers,[26] two to seven weeks for studies of non-immersive VR,[48] 16 hours to six months for studies of mobile apps,[27] six to 52 weeks for studies of web-based rehabilitation interventions,[47] and three months for studies of electronic-health based interventions (web-based or app-based) with a wearable activity tracker.[46] Three systematic reviews[27,47,48] reported on the frequency of the interventions. Where details were provided sessions took place daily or weekly (ranging from one to five sessions) of between 15 to 70 minutes each time[27,48] or 1–2 hours a week.[47]

In all five systematic reviews, the design of the primary studies and the comparison groups against which the intervention groups were compared varied. Six studies across two systematic reviews[27,48] were single-arm studies without a control group. The other designs included two-armed designs with an active control group (10 studies across three systematic reviews),[26,46,48] passive control group (11 studies across four systematic reviews)[26,27,46,47] or three to five armed with both active and passive controls (four studies across two systematic reviews).[26,47] Passive control groups were either usual care, wait list control or health information.

Effectiveness of technologies used in remote rehabilitation

The interventions assessed by the included systematic reviews are presented in Tables 2 and 3.

Insert tables 2 and 3 around here

Physical activity

Three systematic reviews[26,27,47] involving 21 relevant studies evaluated the effectiveness of the technology used in remote rehabilitation on physical activity. This was done for participants who had previously had a stroke,[27] had osteoarthritis of the knee or hip,[47] rheumatoid arthritis[47] or fibromyalgia[47] and for participants who were community-dwelling older adults following a sedentary lifestyle.[26] Level of physical activity was quantified as the number of steps walked per day[26,27] time spent walking,[27] time spent undertaking moderate-to-vigorous activity[26,27,47] or average time spent on exercise.[47] Across the systematic reviews physical activity was evaluated using the Exercise Behaviour Scale[47] or a using a pedometer, accelerometer or activity monitor.[26,27] One systematic review also assessed the amount of time spent being sedentary or upright.[27]

Step count

One systematic review[26] found a large positive effect (effect size >0.8) for interventions that included a wearable activity tracker on daily step count for community dwelling older adults compared to those in a passive control group. However, in the same systematic review when interventions were compared to those in active control groups that used a pedometer a non-significant effect (effect size 0.22) on step count was observed. Two systematic reviews[26,27] were not able to pool data due to clinical heterogeneity in treatment comparisons and outcome measures, and did not perform a meta-analysis. Findings reported across studies within narrative syntheses (See Table 2) from these two systematic reviews[26,27] showed that those in the intervention group (wearable activity trackers for community dwelling older adults[26] or mobile apps for stroke survivors)[27] significantly increased their daily step count[26,27] or time spent walking[27] when compared to those in a passive control group. However, mixed findings (see Table 2) were reported across studies within the narrative synthesis of one systematic review when those in an intervention group (wearable activity trackers) were compared to those in an active group that involved the use of a pedometer.[26]

Amount of time spent in moderate-to-vigorous physical activity

One systematic review showed insufficient effects (no statistically significant differences) for interventions that included a wearable activity tracker on time spent in moderate-to-vigorous activity for community dwelling older adults compared to a passive control group.[26] Two systematic reviews[26,47] were not able to pool data due to clinical heterogeneity in treatment comparisons and outcome measures and as a consequence did not perform meta-analysis. One of these showed significant differences in the short term but insufficient long-term effects (no statistically significant differences) for web-based rehabilitation interventions that involved individualised physical activity vs general information on exercise and physical activity for patients with rheumatoid arthritis[47] but did not perform meta-analysis for the reasons stated above. The same systematic review also included one study that compared four experimental conditions that involved different types of access to online social support and gamification features and a control group that had no access to the website for patients with rheumatoid arthritis for the time spent exercising, but findings were uncertain across the different time points.

Sedentary behaviour

Only one systematic review reported on sedentary behaviour in the narrative synthesis and reported one primary study that measured this outcome and not find any significant effect of interventions that were delivered via a mobile app on sedentary time or upright time in stroke survivors.[27]

Summary

With regards to the overall effect, mobile apps for post-stroke rehabilitation and wearable activity trackers for community-dwelling older adults following a sedentary lifestyle are beneficial for improving physical performance. However, web-based rehabilitation interventions that contained a variety of components to support home exercise are not effective for improving physical activity in rheumatoid arthritis patients.

Balance and/or gait

Two systematic reviews[27,48] involving five relevant studies evaluated the effectiveness of technologies used in remote rehabilitation on balance and/or gait activity for individuals who had previously had a stroke.[27,48] Balance and/or gait were assessed using objective measures which included the Gait Speed Test,[27] 6-meter Walk Test[48] and 10-meter Walk Test,[27,48] the balance and gait subscales of the Performance-Oriented Mobility Assessment;[48] the Berg Balance Scale,[48] and the Timed Up and Go Test.[48] A number of other objective measures were recorded in three of the primary studies of one systematic review[48] but due to small sample sizes and a lack of a control group, effectiveness data for these were not reported in detail. However, reviewers were not able to pool data due to clinical heterogeneity in treatment comparisons and outcome measures and, as a consequence, did not perform meta-analysis. In one systematic review the results from one primary study where balance/gait outcome measures were used were not reported.[27] The remaining systematic review[48] reporting their results as a narrative synthesis showed that there was no statistically significant effect of home-based non-immersive VR rehabilitation on any balance or gait measures for stroke survivors compared to clinic-based conventional therapy.

Summary

With regards to the overall effect, equal improvements in balance and/or gait for home based non-immersive VR versus clinic based conventional therapy in post stroke rehabilitation are observed, suggesting that therapy could be successfully transferred to the home environment.

Physical performance

Three systematic reviews[27,46,47] involving nine relevant studies evaluated the effectiveness of technologies used in remote rehabilitation on physical performance for participants who had previously had a stroke[27] or had osteoarthritis of the knee or hip,[46,47] rheumatoid arthritis[47] or fibromyalgia[47]. Physical performance was assessed using the Hip Osteoarthritis Outcome Score,[46] Knee Osteoarthritis Outcome Score,[46] Western Ontario and MacMaster Universities Osteoarthritis Index,[46] Ibadan Knee/Hip Osteoarthritis Outcome Measure,[46] the Health Assessment Questionnaire[47] or the McMaster Toronto Arthritis Patient Preference Questionnaire.[47] Outcomes in the systematic review by Zhou et al[27] also included at muscle strength, finger function, degree of disability or range of motion evaluated using a variety of different outcome measures. Two systematic reviews[27,47] were not able to pool data due to clinical heterogeneity in treatment comparisons and outcome measures and as a consequence did not perform meta-analysis. One systematic review[46] found small (three months follow up) to medium (6-9 months follow up) positive effects (effect sizes 0.46 and 0.66 respectively) of electronic health-supported home exercise interventions (web-based or app based) with a wearable activity tracker on overall physical performance for patients with osteoarthritis in the knee or hip compared to those in a control group. One systematic review showed insufficient effects (no statistically significant differences) of web-based rehabilitation interventions on overall physical performance for patients with rheumatoid arthritis for the short, medium or long term but did not perform meta-analysis for the reasons stated above.[47] Findings from the narrative synthesis for the remaining systematic review[27] reported improvements in muscle function, finger function, degree of disability and range of motion for patients post stroke who used mobile based apps. However, sample sizes in the primary studies were too small for statistical analysis to be conducted and each outcome was only reported in one primary study and did not compare the results to a control group. For the same systematic review[27] the narrative synthesis reported that when the intervention (mobile apps) was compared to a passive control group then significant positive effects on muscle strength and finger function for stroke survivors were reported.

Summary

With regards to the overall effect, mobile apps are beneficial for improving physical performance for post-stroke rehabilitation and electronic health-supported home exercise interventions (web-based or app-based) with a wearable activity tracker (WAT)) are effective for improving physical performance for osteoarthritis in the knee or hip. However, web-based rehabilitation interventions that contained a variety of components to support home exercise are not effective for improving physical performance in rheumatoid arthritis patients.

Functional performance (activities of daily living)

The ability to perform functional activities in everyday life was assessed in one systematic review[27] involving two relevant studies. The outcome measure used was the Barthel Index[27]. Although other outcome measures were described (including the Instrumental Activities of Daily Living Scale, the short-form version of the Activity Measure for Post-Acute Care[27] and the Chedoke Arm and Hand Activity Inventory) effectiveness data was not reported for these outcomes. There were no meta-analyses that evaluated the effectiveness of an intervention on functional performance. The narrative synthesis within one systematic review reported significant improvements on mean scores on the Barthel Index from baseline to post intervention (mobile apps for post stroke rehabilitation). However, findings were based on just one primary study.

Summary

With regard to the overall effect, mobile apps are beneficial for improving functional performance for post stroke rehabilitation.

Pain

Two systematic reviews[46,47] involving four relevant studies evaluated the effectiveness of technologies used in remote rehabilitation on levels of pain for participants with osteoarthritis of the knee or hip,[47] rheumatoid arthritis[47] or fibromyalgia.[47] Level of pain was measured by a numerical rating scale or visual analogue scale,[46,47] the symptom component of the Rapid Assessment of Disease Activity in Rheumatology questionnaire[47] or the pain subscale of the Western Ontario and MacMaster Universities Osteoarthritis Index.[46] One systematic review showed medium short- and long-term positive effects (effect size -0.55 and -0.34) of electronic health-supported exercise interventions (web-based or app-based) with a wearable activity tracker on pain for patients with osteoarthritis in the knee or hip compared to a control group.[46] Another systematic review showed insufficient long term effects (no statistically significant differences) of web-based rehabilitation interventions on pain for patients with rheumatoid arthritis compared to usual care or a waiting list[47] but did not perform meta-analysis due to clinical heterogeneity in treatment comparisons and outcome measures.

Summary

With regards to the overall effect, electronic health-supported exercise interventions (web-based or app-based) with a wearable activity tracker are effective in reducing levels of pain for patients with osteoarthritis in the knee or hip. However, web-based rehabilitation interventions are not beneficial for reducing levels of pain in patients with rheumatoid arthritis.

Cognitive function

Cognitive function was assessed in one systematic review[27] involving two relevant studies for patients who had previously had a stroke[27] using a variety of objective measures that included the Frontal Assessment Battery, Montreal Cognitive Assessment, Wechsler Adult Intelligence Scale; Clock Drawing Test, Mini Mental Status Exam and Schulte's test. There were no meta-analyses that evaluated the effectiveness of an intervention on cognitive function. Results from the narrative synthesis showed performing cognitive tasks via computer-based activities significantly improved cognitive function from baseline to post intervention for patients recovering from a stroke.

Summary

With regards to the overall effect, computer-based activities are beneficial for improving cognitive function in post stroke rehabilitation.

Health-related quality of life

Health-related QoL was evaluated using a variety of measures including the World Health Organisation assessment of QoL instrument,[46] Hip Osteoarthritis Outcome Score,[46] Knee Osteoarthritis Outcome Score,[46] Stroke Specific Quality of Life scale,[27,47] Rheumatoid Arthritis QoL Scale,[47] 36-item Short Form Health Survey,[47] Arthritis Impact Measurement Scales 2 Short Form,[47] and the QoL Scale 2.[47] Three systematic reviews[27,46,47] involving five relevant studies evaluated the effectiveness of technologies used in remote rehabilitation on QoL. One systematic review[46] showed a small positive effect of electronic health-supported exercise interventions (web-based or app-based) with a wearable activity tracker compared to those in a control group on health-related QoL for patients with osteoarthritis of the knee in the short term (effect size 0.27) but not long term. Two systematic reviews[27,47] were not able to pool data due to clinical heterogeneity in treatment comparisons and outcome measures and as a consequence did not perform meta-analysis. One of these showed insufficient long term effects (no statistically significant differences) for web-based rehabilitation interventions compared to a waiting list or general information on exercise and physical activity for patients with rheumatoid arthritis[47] but did not perform meta-analysis due to the reasons stated above. The other systematic review[27] which reported the findings in a narrative synthesis did not find any significant improvements between computer-based activities compared to standard care. The remaining systematic review did not report any effectiveness data that explored mobile apps versus a passive control group.[46]

Summary

With regards to the overall effect, web-based rehabilitation interventions for rheumatoid arthritis and computer-based activities for post stroke rehabilitation are not effective for improving QoL.

Adverse effects

Two systematic reviews[27,47] involving 11 relevant studies set out to explore adverse events. However, only two of the studies in the systematic review by Zhou et al.[27] acknowledged adverse events and it was determined that both events were unrelated to the intervention. None of the studies in the systematic review reported by Srikesavan et al.[47] reported adverse effects.

Summary of Evidence

The summary of evidence where data was presented as a meta-analysis is presented in Table 4

Insert table 4 around here

Quality of the evidence

An overall assessment of the quality of the evidence for each comparison using GRADE (Grading of Recommendations, Assessment, Development and Evaluation) was not possible. Of the five systematic reviews included in this umbrella review only two completed GRADE[46,47] and the original GRADE scores derived from Schafer et al.[46] were rendered inaccurate because the umbrella review extracted a subset of relevant RCTs from the included systematic reviews for all interventions. The quality of the evidence for all outcomes for the one systematic review[47] that reported GRADE were reported as very low and hence all estimates of the effects for all outcomes are uncertain.

Discussion

In this umbrella review we have identified and summarised existing systematic reviews of technologies (devices, tools, or software applications) used to facilitate remote rehabilitation of adults with deconditioning, musculoskeletal conditions, stroke, or traumatic brain injury. Despite the large number of systematic reviews on this topic that were returned in the initial search, only five met the eligibility criteria for inclusion in this review and no systematic reviews were found for traumatic brain injury. Of these five systematic reviews each one explored a different technology. The small number of systematic reviews included in this umbrella review and the very low quality of evidence, mostly from single small primary studies within these systematic reviews, makes it difficult to draw conclusions that are different to those of the original systematic review. This highlights a paucity of strong, high-quality evidence underpinning technologies to facilitate remote rehabilitation in the wake of the COVID-19 pandemic.

Demand for rehabilitation of musculoskeletal conditions is expected to increase in coming months, in part due to direct and indirect effects of the COVID-19 pandemic.[34,35] Technology is seen as a key part of meeting this increased demand.[36] This umbrella review has demonstrated that web-based rehabilitations that contained a variety of components to support home exercise were not effective in improving physical performance or quality of life, reducing pain, or increasing levels of physical activity among individuals with rheumatoid arthritis compared to those in a variety of control group conditions. However, electronic-health-supported home exercise interventions (web- or app-based) with a wearable activity tracker were effective in improving physical performance and reducing pain of individuals with osteoarthritis in the knee or hip.

Demand for rehabilitation after a stroke is similarly expected to increase, with the use of technology again seen as key to managing demand.[38,40] This umbrella review has demonstrated that mobile apps were beneficial for increasing levels of physical activity and physical or functional performance for post-stroke rehabilitation. Therapy in the form of screen-based non-immersive virtual reality could be successfully transferred to the home environment for improving balance/gait post-stroke rehabilitation. Computer-based activities were beneficial for improving cognitive function but showed no benefit on quality of life in post-stroke rehabilitation.

Finally, the COVID-19 pandemic has been highlighted as having an 'immense' deconditioning effect, particularly in older adults[42] and reversing the effects of this deconditioning is an urgent priority. This umbrella review has demonstrated that interventions that included wearable activity trackers showed mixed findings for increasing levels of physical activity for community dwelling older adults with deconditioning.

Limitations

The number of systematic reviews that could be included for each condition was low. The primary limitation encountered when evaluating the literature on technologies to facilitate remote rehabilitation was heterogeneity in the interventions and/or populations considered in each systematic review that was not addressed with a pooled analysis. It was common for systematic reviews to include studies conducted across different settings (hospital, community, home) or not to state the setting in which the intervention was conducted. When evaluating the evidence to support the use of a technology in remote rehabilitation, care should be given to the setting in which it has been evaluated. Evidence for efficacy of a technology in a supported or hospital setting cannot be assumed to transfer to a remote setting. Similarly, it should also be acknowledged that in the majority of cases technology was used as part of a wider intervention. The efficacy of the technology is therefore inextricably linked with the other components of the intervention, which should be theory based and well detailed[49] but commonly are not.[47]

It was also common for reviews to combine a range of different technologies or to poorly define the technology aspects of the intervention. Common in studies of individuals with stroke or traumatic brain injury was pooling of studies using immersive and non-immersive VR, and common across all conditions considered was pooling of all interventions described as 'telerehabilitation' without consideration of the specific technology involved. Evidence for efficacy of a broadly defined genre of technology (e.g., telerehabilitation) cannot be assumed to transfer to all technologies that may fall within that grouping (e.g., telephone calls, text messages, video conferencing, mobile apps, VR, wearable devices), and combining different technologies makes it difficult to identify the effect size of each. Care should be taken to ensure that the technology under study is explicitly defined and analyses are pooled according to the specific technology. Another common issue was heterogeneity in populations or a wide age range of healthy individuals making it difficult to identify the effect size of a technology intervention for a specific population.

A further limitation of the work on this topic is that no systematic review stratified results according to the additional content included with the intervention. No technology was employed as a stand-alone rehabilitation tool, but technology was incorporated as part of a broader rehabilitation programme. To allow the impact of the technology to be fully understood, it is important that all components of the rehabilitation programme in both the intervention and control groups are well described. In addition, it should be clear whether the aim of the study is to determine if technology provides additional benefit over standard care or, alternatively, whether technology allows equivalence of care in a different (e.g., remote) setting.

The systematic reviews included in this umbrella review acknowledge their own limitations. This includes the small number of high quality primary studies available,[26,27,48] unknown generalisability of results across the target population,[26,27,48] heterogeneity in the details of the technologies used and the way they were integrated into interventions,[26,47,48] the difficulty in blinding participants to the intervention they received,[48] the unknown longer-term effects of the interventions[26] and the unknown impact of adherence on the reported effect sizes.[26] The systematic reviews were all of studies conducted in high-income countries and it is not known if the results are generalisable to low- and middle-income countries.

Conclusions and Recommendations

There is evidence that technology can be used to facilitate remote rehabilitation of individuals with osteoarthritis of the hip or knee, individuals with deconditioning and individuals with stroke. However, all components of the rehabilitation programme, along with the details of the technology and how it is used within the wider rehabilitation programme need to be considered. A widespread lack of systematic reporting of these details in existing studies make it difficult to make general recommendations about specific technologies. Future studies and reviews aiming to develop and determine the effectiveness of a technology need to carefully consider and explicitly define the setting in which an intervention is delivered, the details of the technology used in the intervention, the other components of the intervention, and the population that is studied. Healthcare professionals looking to use technology to facilitate remote rehabilitation need to carefully consider the setting, intervention, and population in which the technology has been studied and the way in which it will be integrated into care.

Conflicts of interest

Judith Carrier is a senior Associate Editor for JBI Evidence Synthesis, she has had no involvement in the editorial processing of the manuscript.

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Table 1: Critical appraisal scores

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Liu e al. 2020[26]	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y
Schafer et al. 2018[46]	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
Srikesavan et al. 2019[47]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
Zhou et al. 2018[27]	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Schroder et al. 2019[48]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
%	100.0	100.0	100.0	100.0	100.0	100.0	100	40.0	40.0	40.0	80.0

1. Is the review question clearly and explicitly stated?
2. Were the inclusion criteria appropriate for the review question?
3. Was the search strategy appropriate?
4. Were the sources and resources used to search for studies adequate?
5. Were the criteria for appraising studies appropriate?
6. Was critical appraisal conducted by two or more reviewers independently?
7. Were there methods to minimize errors in data extraction?
8. Were the methods used to combine studies appropriate?
9. Was the likelihood of publication bias assessed?
10. Were recommendations for policy and/or practice supported by the reported data?
11. Were the specific directives for new research appropriate?

Table 2: Interventions for remote rehabilitation assessed by the included systematic reviews

Interventions	Systematic reviews	Number of Participants (studies)	Outcomes	Effect size (95% CI) Heterogeneity I^2	Quality of evidence (GRADE)
WAT-based interventions vs a PCG	Liu et al. 2020[27]	207 (4 studies)	Step count	SMD 1.27 (0.51, 2.04) I^2=82%	NR
	Liu et al. 2020[27]	83 (2 studies)	MVPA	SMD 1.23 (0.75, 1.70) I^2 =0	
WAT-based interventions vs an ACG (a pedometer)	Liu et al. 2020[27]	201 (3 studies)	Step count	SMD 0.22 (-0.62, 1.06) I^2=88%	
Electronic health-supported home exercise interventions	Schafer et al. 2018[46]	516 (3 studies)	Pain (3MFU)	SMD -0.55 (-0.81, -0.28) I^2=55%	NR for mHealth sub group analysis
	Schafer et al. 2018[46]	280 (2 studies)	Pain (9-12MFU)	SMD -0.34 (-0.72, -0.03) I^2=60%	
	Schafer et al. 2018[46]	333 (2 studies)	Physical performance (3MFU)	SMD 0.66 (0.18, 1.13) I^2=76	
	Schafer et al. 2018[46]	280 (2 studies)	Physical performance (9-12MFU)	SMD 0.46 (0.08, 0.84) I^2=61%	
	Schafer et al. 2018[46]	304 (2 studies)	QoL (3MFU)	SMD 0.27 (0.04, 0.49) I^2=0%	
	Schafer et al. 2018[46]	279 (2 studies)	QoL (9-12MFU)	SMD 0.24 (-0.10, 0.57) I^2=52%	
	Srikesavan et al. 2019[47]	93 (1 study)	Pain (short term)	MD -0.5 (-1.44, 0.44)	Very Low
	Srikesavan et al. 2019[47]	88 (1 study)	Pain (medium term)	MD -0.2 (-1.27, 0.87)	Very Low

Web-based rehabilitation vs waiting list	Srikesavan et al. 2019[47]	93 (1 study)	QoL (short term)	MD -3.5 (-0.85, 8.85)	Very Low
	Srikesavan et al. 2019[47]	88 (1 study)	QoL (medium term)	MD 4.9 (-0.96, 10.76)	Very Low
Web-based rehabilitation vs usual care	Srikesavan et al. 2019[47]	144 (1 study)	Pain (long term)	MD -0.45 (-1.20, 0.31)	Very Low
	Srikesavan et al. 2019[47]	144 (1 study)	Physical performance (long term)	MD -0.03 (-0.15, 0.09)	Very Low
Web-based rehabilitation (Individualised physical activity) vs general information on exercise & physical activity)	Srikesavan et al. 2019[47]	155 (1 study)	Physical performance (short term)	MD 0.03 (-0.04, 0.10)	Very Low
	Srikesavan et al. 2019[47]	155 (1 study)	Physical performance medium term)	MD -0.02 (-0.09, 0.05)	Very Low
	Srikesavan et al. 2019[47]	108 (1 study)	Physical performance (long term)	MD -0.01 (-0.11, 0.09)	Very Low
	Srikesavan et al. 2019[47]	155 (1 study)	QoL (short term)	MD -0.7 (-1.59, 0.19)	Very Low
	Srikesavan et al. 2019[47]	152 (1 study)	QoL (medium term)	MD -1.7 (-2.62, -0.78)	Very Low
	Srikesavan et al. 2019[47]	108 (1 study)	QoL (long term)	MD -1.5 (-2.71, -0.29)	Very Low
	Srikesavan et al. 2019[47]	152 (1 study)	Proportion of participants moderately active (medium term)	RR 3.62 (1.67, 7.83)	Very Low
	Srikesavan et al. 2019[47]	108 (1 study)	Proportion of participants moderately active (long term)	RR 0.77 (0.37, 1.6)	Very Low
	Srikesavan et al. 2019[47]	155 (1 study)	Proportion of participants moderately active (short term)	RR 1.58 (0.93, 2.69)	Very Low
	Srikesavan et al. 2019[47]	152 (1 study)	Proportion of participants vigorously active (medium term)	RR 1.28 (0.82, 2.69)	Very Low
	Srikesavan et al. 2019[47]	108 (1 study)	Proportion of participants vigorously active (long term)	RR 4 (0.46, 2.02)	Very Low

Web-based rehabilitation (Information) vs no access to website	Srikesavan et al. 2019[47]	69 (1 study)	Physical activity: average time spent on exercise (short term)	MD -10.76 (-22.36, 0.84)	Very Low
	Srikesavan et al. 2019[47]	68 (1 study)	Physical activity: average time spent on exercise (medium term)	MD -14.76 (-24.81, -4.71)	Very Low
Web-based rehabilitation (Information & social support) vs no access to website	Srikesavan et al. 2019[47]	69 (1 study)	Physical activity: average time spent on exercise (short term)	MD -16.02 (-28.58, -3.46)	Very Low
Web-based rehabilitation (Information & social support) vs no access to website	Srikesavan et al. 2019[47]	63 (1 study)	Physical activity: average time spent on exercise (medium term)	MD -10.54 (-24.53, 3.45)	Very Low
Web-based rehabilitation (Information & gamification features) vs no access to website	Srikesavan et al. 2019[47]	68 (1 study)	Physical activity: average time spent on exercise (short term)	MD -10.82 (-24.44, 2.80)	Very Low
Web-based rehabilitation (Information & gamification features) vs no access to website	Srikesavan et al. 2019[47]	66 (1 study)	Physical activity: average time spent on exercise (medium term)	MD -7.97 (-22.61, 6.65)	Very Low
Web-based rehabilitation (Information, social support, gamification features) vs no access to website	Srikesavan et al. 2019[47]	68 (1 study)	Physical activity: average time spent on exercise (short term)	MD -15.91 (-27.91, -3.91)	Very Low
Web-based rehabilitation (Information, social support, gamification features) vs no access to website	Srikesavan et al. 2019[47]	66 (1 study)	Physical activity: average time spent on exercise (medium term)	MD -13.75 (-26.22, -1.28)	Very Low

Key: GRADE: Grading of Recommendations Assessment, Development and Evaluation; MD: mean difference; MFU: months follow up; MVPA: moderate to vigorous physical activity; NR: not reported; RR: risk ratio; SMD: standardised mean difference

Table 3: Interventions for remote rehabilitation assessed by the included systematic reviews (narrative synthesis)

Interventions	Systematic Reviews	Number of Participants (studies)	Outcomes	Effect
WAT-based interventions vs a PCG	Liu et al. 2020[26]	32 (1 study)	Step count	*Between group comparison* The IG significantly increased their daily steps over the CG by 3,376 (p<0.001)
	Liu et al. 2020[26]	32 (1 study)	MVPA	*Between group comparison* The IG increased their total activity time by 21 min/day (23% increase) and aerobic time by 13 min/day (160 % increase) which was highly statistically significant compared to the CG [a]
	Liu et al. 2020[26]	235[b] (1 study)	MVPA: wrist worn pedometer MVPA: ankle worn pedometer	*Within-group comparison* The IG significantly increased their daily PA by 11%[a] *Between group comparison* No significant difference between IG and CG (p=0.11) *Between group comparison* The IG increased their daily PA by 46% which was significant compared to the CG (p<0.001) which correspond to a 11 minute increase in MVPA
	Liu et al. 2020[26]	263 (1 study)	Step count	*Between group comparison* The IG walked significantly more steps than the CG at 2 months (adjusted mean 4,041 vs. 3,499 steps/day,

WAT-based interventions vs an ACG (a pedometer)				p=0.01), but this effect waned by 12 months (3,861 vs. 3,383, p=0.09)
	Liu et al. 2020[26]	51 (1 study)	Step count	*Within-group comparison* The IG significantly increased their steps count[a] *Between group comparison* No significant difference between IG and CG [a]
	Liu et al. 2020[26]	51 (1 study)	MVPA	*Within-group comparison* The IG significantly increase the time spent on MVPA [a] *Between group comparison* No significant difference between IG and CG [a]
	Liu et al. 2020[26]	32 (1 study)	MVPA	*Between group comparison* The IG significantly increased their total activity time by 21 min/day (23% increase) and aerobic time by 13 min/day (160 % increase) compared to the ACG [a]
	Liu et al. 2020[26]	48 (1 study)	Step count	*Between group comparison* The IG significantly increased their daily steps over the CG by 2,534 (p<0.001)
	Liu et al. 2020[26]	49 (1 study)	MVPA	*Between group comparison* No significant differences at 6 or 12 months between the IG and CG[a]
	Liu et al. 2020[26]	15 (1 study)	Finger Function	*Within-group comparison* Improvement on the mean scores on the 9PHT (12 out of 15 participants)[a]

Mobile based apps vs no control group	Zhou et al. 2018[27]	6 (1 study)	Range of motion	*Within-group comparison* Improvement in mean scores on the AART, PROM and AROM[a] Statistically significant changes were not obtained with this pilot study.
	Zhou et al. 2018[27]	30 (1 study)	Degree of disability	*Within-group comparison* Significant improvement in mean scores on the MRS ($p<0.00001$)
	Zhou et al. 2018[27]	30 (1 study)	Activities of daily living	*Within-group comparison* CAHAI; AM-PAC scores were not reported Significant improvement in mean scores on the BI ($p<0.00001$)
Mobile based apps vs PCG	Zhou et al. 2018[27]	24 (1 study)	Step count	*Between group comparison* The IG walked significantly more steps than the CG ($p=0.005$)
	Zhou et al. 2018[27]	24 (1 study)	Walking time	*Between group comparison* The IG spent significantly more time walking than those in the CG ($p=0.002$)
	Zhou et al. 2018[27]	24 (1 study)	Sedentary behaviour	*Between group comparison* No significant reductions in sedentary time ($p>0.05$) or upright time ($p>0.05$) between the IG and CG
	Zhou et al. 2018[27]	24 (1 study)	Activities of daily living	Not reported
	Zhou et al. 2018[27]	24 (1 study)	Balance/Gait	Not reported
	Zhou et al. 2018[27]	21 (1 study)	QoL	Not reported
	Zhou et al. 2018[27]	24 (1 study)	Muscle strength	*Between group comparison* Significant improvements in mean scores on the MMT ($p<0.05$) between the IG and the CG

	Zhou et al. 2018[27]	21 (1 study)	Finger function	*Between group comparison* Significant improvements in mean scores on the MFT ($p<0.05$) and PPT($p<0.05$) between the IG and the CG
Computer-based activities vs no CG	Zhou et al. 2018[27]	21 (1 study)	Cognitive function	*Within-group comparison* Significant improvements in mean scores on the ACE-R, WAIS and MMS (all $p<0.05$)
Computer-based activities vs standard care	Zhou et al. 2018[27]	43 (1 study)	QoL	*Between group comparison* No significant improvements in mean score for the SSQoL ($p>0.05$) between the IG and CG
	Zhou et al. 2018[27]	43 (1 study)	Cognitive function	*Between group comparison* Significant improvements in mean scores on the MMSE ($p=0.01$), FAB ($p=0.02$), CDT ($p=0.05$, Schulte's test ($p=0.01$, MOCA ($p=0.07$) between the IG and CG
Home-based non immersive VR telerehabilitation vs clinic-based conventional therapy	Schroder et al. 2018[48]	90 (4 studies)	Balance/Gait	*Within-group comparison* Significant improvement in mean scores ($p<0.05$) in both IG and CG on the BBS (4 studies all $p<0.05$) *Between group comparison* No significant differences in mean scores between the IG and the CG for the BBS (4 studies) [a]
	Schroder et al. 2018[48]	30 (1 study)	Balance/Gait	*Within-group comparison* Significant improvement in mean scores ($p<0.05$) in both IG and CG on the POMA-B ($p=0.06$): POMA-G ($p=0.01$)

				Between group comparison No significant differences in mean scores between the IG and the CG on POMA-B, POMA-G [a]
	Schroder et al. 2018[48]	46 (3 studies)	Balance/Gait	*Between group comparison* No significant differences in mean scores between IG and CG on the 10mWT [a]
	Schroder et al. 2018[48]	46 (3 studies)	Balance/Gait	*Between group comparison* No significant differences in mean scores between IG and CG for the TUG [a]
	Schroder et al. 2018[48]	12 (1 study)	Balance/Gait	A general positive effects of VR-based exercise interventions. Due to small sample sizes, outcome on effectiveness of this study was not reported in detail
Home-based non-immersive VR telerehabilitation vs no control group	Schroder et al. 2018[48]	2 (2 studies)	Balance/Gait	A general positive effects of VR-based exercise interventions. Due to small sample sizes and lack of a CG, outcome on effectiveness of these studies were not reported in detail

[a] further details of statistical analysis including p values were not reported in the systematic review
[b] total number of participants reported only

Key: 10mWT: 10 minute walk test; 9PHT: Nine Hole Peg Test; ARAT: Action Research Arm Test; ACE-R: Addenbrooke's Cognitive Examination; ACG: active control group; AM-PAC: short-form version of the Activity Measure for Post-Acute Care; AROM: active range of motion; BBS: Berg Balance Scale; BI: Barthel Index; CAHAI: Chedoke Arm and Hand Activity Inventory; CDT: Clock drawing test; FAB: Frontal assessment battery; MFT: The Manual Function Test; MMSE: Mini Mental Status Exam; MMT: The Manual Muscle Test; MoCA: Montreal Cognitive Assessment; mRS: Modified Rankin Scale; MVPA: moderate to vigorous physical activity; PCG: passive control group; POMA-B: performance-oriented mobility assessment-balance subscale; POMA-G: performance-oriented mobility assessment-gait; PPT: Purdue Pegboard Test; PROM: passive range of motion; QoL: quality of life; SMD: standardised mean difference; SS-QoL: Stroke Specific Quality of Life Scale; TUG: Timed Up and Go test; VR: virtual reality; WAIS: Wechsler Adult Intelligence Scale; WAT: wearable activity tracker

Table 4: Summary of evidence for studies where meta-analysis was conducted

Interventions	Included systematic reviews	Outcomes							
		PF	FP	Pain	Step Count	MVPA	QoL	Balance Gait	CF
WAT vs PCG for older adults with deconditioning	Liu et al. 2020[27]								
WAT vs ACG for older adults with deconditioning	Liu et al. 2020[27]								
E health-supported home exercise interventions (web-based or app-based) for OAK/H	Schafer et al. 2018[46]								

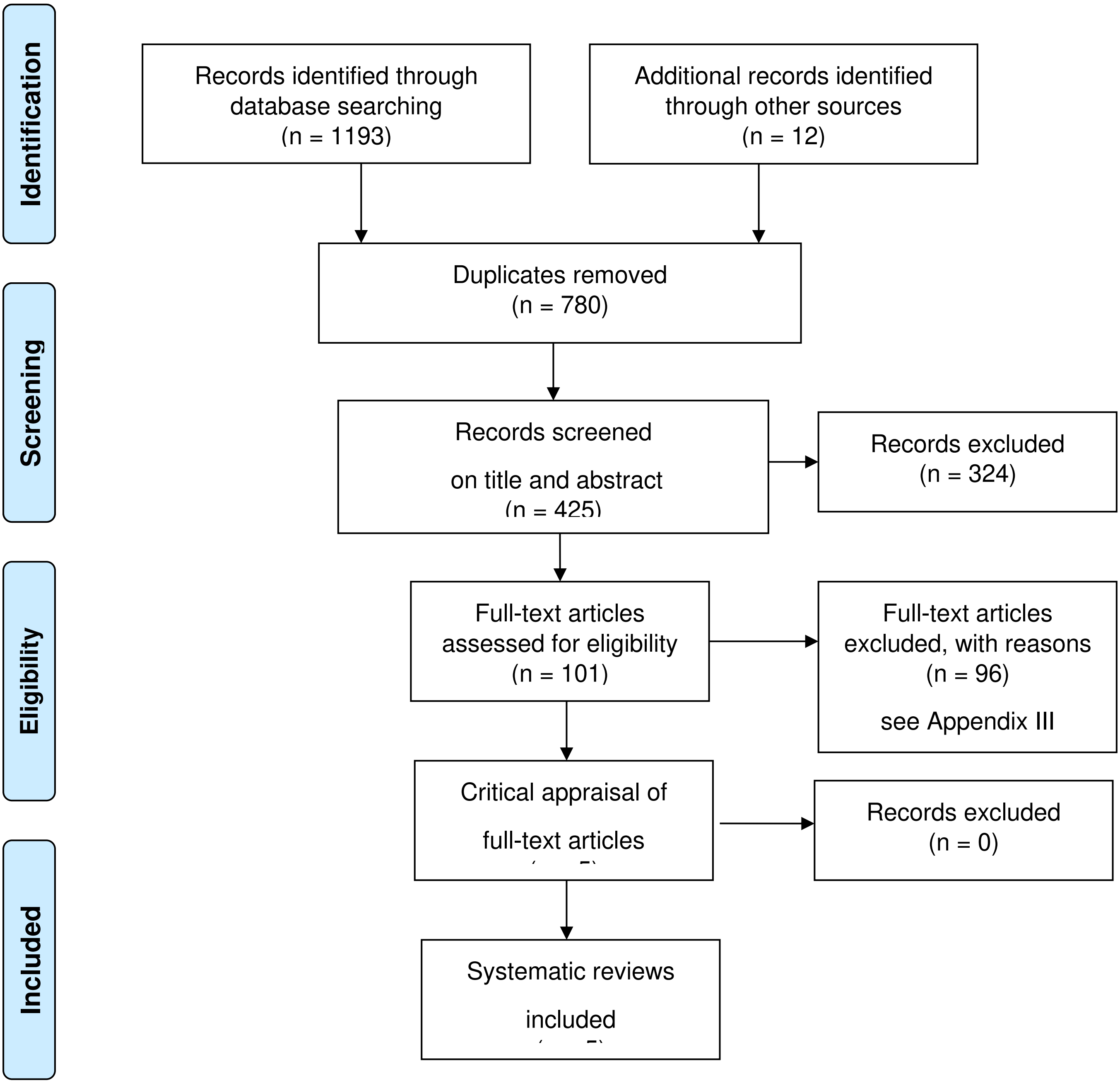
Key: ACG: active control group; CF: cognitive function; E Health: electronic health; FP: functional performance; MVPA: moderate to vigorous physical activity; OAK/H: osteoarthritis in the knee or hip; PCG: passive control group; PF: physical function; WAT: wearable activity tracker

An effective intervention

No effect or difference compared to a control treatment

Not reported

Figure 1: PRISMA flowchart of study selection and inclusion process



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Appendix I: Search strategies

Ovid MEDLINE(R) ALL: searched 8th January 2021

1. *accelerometry/ or *actigraphy/
2. *Fitness Trackers/
3. ((wearable or remote or portable or mobile) adj5 (system* or device* or monitor* or tech* or track* or measur* or captur* or detect* or monitor*)).ti.
4. (accelerometer* or gyroscope* or actigraph* or acceleromet*).ti,ab.
5. (fitbit or garmin or apple or Misfit or Polar or Samsung Gear or TomTom or Lumoalexa or google or sensor*).ti.
6. *Mobile Applications/
7. cell phones/
8. smartphone/
9. computers, handheld/
10. ((hand or wrist or cell* or smart* or mobile* or android) adj3 (comput* or device* or app or apps or application*)).ti,ab.
11. (tablet* or ipad*or iphone* or i-phone*).ti,ab.
12. ((internet* or web* or online*) adj3 (comput* or device* or app or apps or application* or program* or intervention*)).ti,ab.
13. (ehealth or e-health or electronic health or mhealth or m-health or "mobile health" or etool).ti,ab.
14. (digital adj3 (health or intervention* or technolo* or program* or device*)).ti,ab.
15. exp video game/
16. (Game* or gaming or gamification or videogam* or video-gam* or video-based or computer-based or computer gam* or exergame* or exer-game or "exer game" or wii*or xbox or Kinect or play-station or "play station" or playstation or nintendo or switch or "dance dance revolution" or virtual* or VR or smart*).tw.
17. Exp Virtual Reality/
18. *telemedicine/
19. *telerehabilitation/
20. *remote consultation/
21. *telemetry/
22. tele*.ti.
23. or/1-22
24. exp Stroke Rehabilitation/ or exp Neurological Rehabilitation/ or exp Rehabilitation/
25. (Rehabilit* or recover*).ti,ab.
26. 24 or 25
27. (home or homes or in-home* or communit* or remote* or distance*).ti,ab.
28. exp Meta-Analysis/ or exp "Systematic Review"/
29. (review* or meta-analy* or metanaly* or metaanaly* or "meta analy* or meta-synthesis" or metasynthesis or "meta synthesis" or synthesis or overview* or umbrella*).ti.
30. 28 or 29
31. 23 and 26 and 27 and 30
32. limit 31 to english language
33. limit 32 to yr="2016 -Current"

Ovid EMBASE: searched 8th January 2021

1. *accelerometry/ or *actigraphy/
2. *Fitness Trackers/
3. ((wearable or remote or portable or mobile) adj5 (system* or device* or monitor* or tech* or track* or measur* or captur* or detect* or monitor*)).ti.
4. (accelerometer* or gyroscope* or actigraph* or acceleromet*).ti,ab.
5. (fitbit or garmin or apple or Misfit or Polar or Samsung Gear or TomTom or Lumoalexa or google or sensor*).ti.
6. *Mobile Applications/
7. cell phones/
8. smartphone/
9. computers, handheld/

10. ((hand or wrist or cell* or smart* or mobile* or android) adj3 (comput* or device* or app or apps or application*)).ti,ab.
11. (tablet* or ipad*or iphone* or i-phone*).ti,ab.
12. ((internet* or web* or online*) adj3 (comput* or device* or app or apps or application* or program* or intervention*)).ti,ab.
13. (ehealth or e-health or electronic health or mhealth or m-health or "mobile health" or etool).ti,ab.
14. (digital adj3 (health or intervention* or technolo* or program* or device*)).ti,ab
15. exp video game/
16. (Game* or gaming or gamification or videogam* or video-gam* or video-based or computer-based or computer gam* or exergame* or exer-game or "exer game" or wii*or xbox or Kinect or play-station or "play station" or playstation or nintendo or switch or "dance dance revolution" or virtual* or VR or smart*).tw.
17. Exp Virtual Reality/
18. *telemedicine/
19. *telerehabilitation/
20. *remote consultation/
21. *telemetry/
22. tele*.ti.
23. or/1-22
24. exp Stroke Rehabilitation/ or exp Neurological Rehabilitation/ or exp Rehabilitation/
25. (Rehabilit* or recover*).ti,ab.
26. 24 or 25
27. (home or homes or in-home* or communit* or remote* or distance*).ti,ab.
28. exp Meta-Analysis/ or exp "Systematic Review"/
29. (review* or meta-analy* or metanaly* or metaanaly* or "meta analy* or meta-synthesis" or metasynthesis or "meta synthesis" or synthesis or overview* or umbrella*).ti.
30. 28 or 29
31. 23 and 26 and 27 and 30
32. limit 31 to english language
33. limit 32 to yr="2016 -Current"

Ovid PsycINFO: searched 8th January 2021

1. *accelerometry/ or *actigraphy/
2. ((wearable or remote or portable or mobile) adj5 (system* or device* or monitor* or tech* or track* or measur* or captur* or detect* or monitor*)).ti.
3. (accelerometer* or gyroscope* or actigraph* or acceleromet*).ti,ab.
4. (fitbit or garmin or apple or Misfit or Polar or Samsung Gear or TomTom or Lumoalexa or google or sensor*).ti.
5. *Mobile Applications/
6. cell phones/
7. ((hand or wrist or cell* or smart* or mobile* or android) adj3 (comput* or device* or app or apps or application*)).ti,ab.
8. (tablet* or ipad*or iphone* or i-phone*).ti,ab.
9. ((internet* or web* or online*) adj3 (comput* or device* or app or apps or application* or program* or intervention*)).ti,ab.
10. (ehealth or e-health or electronic health or mhealth or m-health or "mobile health" or etool).ti,ab.
11. (digital adj3 (health or intervention* or technolo* or program* or device*)).ti,ab.
12. exp video game/
13. (Game* or gaming or gamification or videogam* or video-gam* or video-based or computer-based or computer gam* or exergame* or exer-game or "exer game" or wii*or xbox or Kinect or play-station or "play station" or playstation or nintendo or switch or "dance dance revolution" or virtual* or VR or smart*).tw.
14. Exp Virtual Reality/
15. *telemedicine/
16. *telerehabilitation/
17. *remote consultation/
18. *telemetry/
19. tele*.ti.

20. or/1-19
21. exp Stroke Rehabilitation/ or exp Neurological Rehabilitation/ or exp Rehabilitation/
22. (Rehabilit* or recover*).ti,ab.
23. 21 or 22
24. (home or homes or in-home* or communit* or remote* or distance*).ti,ab.
25. exp Meta-Analysis/ or exp "Systematic Review"/
26. (review* or meta-analy* or metanaly* or metaanaly* or "meta analy* or meta-synthesis" or metasynthesis or "meta synthesis" or synthesis or overview* or umbrella*).ti.
27. 25 or 26
28. 20 and 23 and 24 and 27
29. limit 28 to english language
30. limit 30 to yr="2016 -Current"

CINAHL: searched 15th January 2021

S1 (TI (fitbit or garmin or apple or Misfit or Polar or Samsung Gear or TomTom or Lumoalexa or google)) OR (AB (fitbit or garmin or apple or Misfit or Polar or Samsung Gear or TomTom or Lumoalexa or google))
S2 (TI (accelerometer* or gyroscope* or actigraph* or acceleromet*)) OR (AB (accelerometer* or gyroscope* or actigraph* or acceleromet*))
S3 TI (wearable or remote or portable or mobile) N5 (system* or device* or monitor* or tech* or track* or measur* or captur* or detect* or monitor*)
S4 MH "Accelerometry")
S5 (MM "Actigraphy")
S6 (MM "Fitness Trackers")
S7 (MM "Wearable Sensors")
S8 (MM "Mobile Applications")
S9 (MM "Cellular Phone")
S10 (MM "Smartphone)
S11 (MM "Computers, Hand-Held+")
S12 (TI ((hand or wrist or cell* or smart* or mobile* or android) N3 (comput* or device* or app or apps or application*))) OR (AB ((hand or wrist or cell* or smart* or mobile* or android) N3 (comput* or device* or app or apps or application*))
S13 (TI (tablet* or ipad*or iphone* or i-phone*)) OR (AB (tablet* or ipad*or iphone* or i-phone*)
S14 (TI ((internet* or web* or online*) N3 (comput* or device* or app or apps or application* or program* or intervention*))) OR (AB ((internet* or web* or online*) N3 (comput* or device* or app or apps or application* or program* or intervention*)))
S15 (TI ((digital N3 (health or intervention* or technolo* or program* or device*))) AND (AB (digital N3 (health or intervention* or technolo* or program* or device*)))
S16 (Ti (Game* or gaming or gamification or videogam* or video-gam* or video-based or computer-based or computer gam* or exergame* or exer-game or "exer game" or wii*or xbox or Kinect or play-station or play station or playstation or nintendo or switch or dance dance revolution)) OR (AB (Game* or gaming or gamification or videogam* or video-gam* or video-based or computer-based or computer gam* or exergame* or exer-game or "exer game" or wii*or xbox or Kinect or play-station or play station or playstation or nintendo or switch or dance dance revolution))
S17 (MM "Video Games") OR (MM "Exergames")
S18 TI (virtual*) or AB (virtual*)
S19 (MM "Virtual Reality")
S20 Ti smart
S21 Ti tele*
S22 (MM "Telehealth")
S23 (MM "Telerehabilitation")
S24 (MM "Telemedicine")
S25 (MM "Remote Consultation")

S26 S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25
S27 (MM "Meta Synthesis")
S28 Ti (review* or meta-analy* or metanaly* or metaanaly* or "meta analy* or meta-synthesis" or metasynthesis or "meta synthesis" or synthesis or overview* or umbrella*)
S29 (MM "Systematic Review")
S30 (MM "Meta Analysis")
S31 S27 OR S28 or S29 and S30
S32 (TI (home or homes or in-home* or communiti* or remote*)) OR (AB (home or homes or in-home* or communiti* or remote*))
S33 (MH "Rehabilitation Patients") OR (MM "Home Rehabilitation") OR (MM "Rehabilitation, Psychosocial") OR (MM "Rehabilitation, Geriatric") OR (MM "Rehabilitation, Cognitive") OR (MM "Telerehabilitation")
S34 (Ti (Rehabilit* or recover*) OR (AB (Rehabilit* or recover*)
S35 S33 OR S34
S36 S26 AND S31 AND S32 AND S35
S37 S26 AND S31 AND S32 AND S35 (English language)
S38 S26 AND S31 AND S32 AND S35 (2016-current)

PEDro: searched 15th January 2021

Fitness Tracker OR Acceleromet* OR actigrap* OR wearables OR gyroscope* OR fitbit OR garmin OR apple OR sensor* OR Technolog* OR Mobile OR Device* OR Applications OR App OR Apps OR Tablet OR Web* OR Internet* OR Digital OR Ehealth OR Etool* OR Mhealth OR Gam* OR Wii OR Virtual OR Smart OR Tele*

Appendix II: Studies excluded from the review with reasons

Author	Reason for exclusion
Aguiar LT, Nadeau S, Martins JC, Teixeira-Salmela LF, Britto RR, Faria CDCM. Efficacy of interventions aimed at improving physical activity in individuals with stroke: A systematic review. Disabil Rehabil 2020;42:902–17.	A mixture of interventions including robotics and not all interventions conducted remotely, some took place before discharge
Amorim P, Santos BS, Dias P, Silva S, Martins H. Serious games for stroke telerehabilitation of upper limb - A review for future research. Int J Telerehabilitation 2020;12:65–76.	A mixture of technologies including robotic assistance and a pooled analysis across all studies was conducted
Bahadori S, Collard S, Williams JM, Swain I. A review of current use of commercial wearable technology and smartphone apps with application in monitoring individuals following total hip replacement surgery. J Med Eng Technol 2020;44:324–33.	No outcomes of interest
Bahadori S, Wainwright TW, Ahmed OH. Smartphone apps for total hip replacement and total knee replacement surgery patients: A systematic review. Disabil Rehabil 2020;42:983–8.	No outcomes of interest
Berton A, Longo UG, Candela V, Fioravanti S, Giannone L, Arcangeli V, et al. Virtual reality, augmented reality, gamification, and telerehabilitation: Psychological impact on orthopedic patients' rehabilitation. J Clin Med 2020;9:1–13.	No outcomes of interest
Betts S, Feichter L, Kleinig Z, O'Connell-Debais A, Thai H, Wong C, et al. telerehabilitation versus standard care for improving cognitive function and quality of life for adults with traumatic brain injury: A systematic review. Internet J Allied Health Sci Pract 2018;16:1–16.	Wrong intervention: a mixture of therapist delivered telerehabilitation technologies delivered through phone, radio, videoconferencing, or online computer messaging programs
Bonnechere B, Jansen B, Omelina L, Van Sint Jan S. The use of commercial video games in rehabilitation: A systematic review. Int J Rehabil Res 2016;39:277–90.	Focuses on how much activity was performed by individuals with across a range of neurological conditions
Brickwood KJ, Watson G, O'Brien J, Williams AD. Consumer-based wearable activity trackers increase physical activity participation: Systematic review and meta-analysis. JMIR MHealth UHealth 2019;7:e11819.	No risk of bias assessment
Brickwood KJ, Watson G, O'Brien J, Williams AD. Consumer-based wearable activity trackers increase physical activity participation: Systematic review and meta-analysis. JMIR MHealth UHealth 2019;7:e11819.	Focuses on impact on behaviour measured by rate of participation, not condition related
Byra J, Czernicki K. The effectiveness of virtual reality rehabilitation in patients with knee and hip osteoarthritis. J Clin Med 2020;9:	A mixture of immersive and non-immersive technologies and a pooled analysis across all studies was conducted
Cano Porras D, Siemonsma P, Inzelberg R, Zeilig G, Plotnik M. Advantages of virtual reality in the rehabilitation of balance and gait: Systematic review. Neurology 2018;90:1017–25.	A mixture of settings and a pooled analysis across all studies was conducted
Chen L, Lo WLA, Mao YR, Ding MH, Lin Q, Li H, et al. Effect of virtual reality on postural and balance control in patients with stroke: A systematic literature review. BioMed Res Int 2016;2016:7309272.	A mixture of immersive and non-immersive technologies and a pooled analysis across all studies was conducted
Chen Y, Abel KT, Janecek JT, Chen Y, Zheng K, Cramer SC. Home-based technologies for stroke rehabilitation: A systematic review. Int J Med Inf 2019;123:11–22.	No risk of bias assessment
Christopher E, Alsaffarini KW, Jamjoom AA. Mobile health for traumatic brain injury: a systematic review of the literature and mobile application market. *Cureus* 2019;11:e5120.	No risk of bias assessment
Cooper C, Gross A, Brinkman C, Pope R, Allen K, Hastings S, et al. The impact of wearable motion sensing technology on physical activity in older adults. Exp Gerontol 2018;112:9–19.	Wrong population: conducted across older adults of all ages with a range of long-term health conditions and a pooled analysis across all studies was conducted
Corregidor-Sanchez AI, Segura-Fragoso A, Criado-Alvarez JJ, Rodriguez-Hernandez M, Mohedano-Moriano A, Polonio-Lopez	A mixture of settings and a pooled analysis across all studies was conducted

B. Effectiveness of virtual reality systems to improve the activities of daily life in older people. Int J Environ Res Public Health Electron Resour 2020;17:28.	
Cottrell MA, Galea OA, O'Leary SP, Hill AJ, Russell TG. Real-time telerehabilitation for the treatment of musculoskeletal conditions is effective and comparable to standard practice: a systematic review and meta-analysis. Clin Rehabil 2017;31:625–38.	Wrong intervention: a mixture of therapist delivered telerehabilitation approaches including telehealth via telephone or video
de Amorim JSC, Leite RC, Brizola R, Yonamine CY. Virtual reality therapy for rehabilitation of balance in the elderly: A systematic review and meta-analysis. Adv Rheumatol 2018;58.	Wrong population: conducted across older adults of all ages with a range of long-term health conditions and a pooled analysis across all studies was conducted
Davergne T, Pallot A, Dechartres A, Fautrel B, Gossec L. Use of wearable activity trackers to improve physical activity behavior in patients with rheumatic and musculoskeletal diseases: A systematic review and meta-analysis. Arthritis Care Res 2019;71:758–67.	Wrong population: included a study with adolescents with juvenile arthritis and a pooled analysis across all studies was conducted
de Rooij IJM, van de Port IGL, Meijer JW. Effect of virtual reality training on balance and gait ability in patients with stroke: systematic review and meta-analysis. Phys Ther 2016;96:1905–18.	A mixture of immersive and non-immersive technologies and a pooled analysis across all studies was conducted
Desplenter T, Zhou Y, Edmonds BP, Lidka M, Goldman A, Trejos AL. Rehabilitative and assistive wearable mechatronic upper-limb devices: A review. J Rehabil Assist Technol Eng 2020;7:2055668320917870.	Not a systematic review
Direito A, Carraca E, Rawstorn J, Whittaker R, Maddison R. mHealth technologies to influence physical activity and sedentary behaviors: behavior change techniques, systematic review and meta-analysis of randomized controlled trials. Ann Behav Med 2017;51:226–39	A mixture of 'mHealth' technology including mobile phones (texting), across adults of all ages and a pooled analysis across all studies was conducted
Donath L, Rossler R, Faude O. Effects of virtual reality training (exergaming) compared to alternative exercise training and passive control on standing balance and functional mobility in healthy community-dwelling seniors:: A meta-analytical review. Sports Med 2016;46:1293–309	A mixture of settings and a pooled analysis across all studies was conducted
Elavsky S, Knapova L, Klocek A, Smahel D. Mobile health interventions for physical activity, sedentary behavior, and sleep in adults aged 50 years and older: A systematic literature review. J Aging Phys Act 2019;27:565–93.	A mixture of mobile interventions to improve physical activity including text messaging and a pooled analysis across all studies was conducted
Ferreira V, Carvas N, Artilheiro MC, Pompeu JE, Hassan SA, Kasawara KT. Interactive video gaming improves functional balance in poststroke individuals: Meta-analysis of randomized controlled trials. Eval Health Prof 2020;43:23–32	A mixture of settings and a pooled analysis across all studies was conducted
Gandhi D, Sterba A, Kate M, Khatter H, Pandian J. Computer game based therapy for post-stroke upper limb impairments: A meta analysis. Eur Stroke J 2019;4 (Supplement 1):33.	A mixture of immersive and non-immersive technologies and a pooled analysis across all studies was conducted
Goode AP, Hall KS, Batch BC, Huffman KM, Hastings SN, Allen KD, et al. The impact of interventions that integrate accelerometers on physical activity and weight loss: A systematic review. Ann Behav Med 2017;51:79–93.	Focuses on increasing physical activity or achieving weight loss
Gordt K, Gerhardy T, Najafi B, Schwenk M. Effects of wearable sensor-based balance and gait training on balance, gait, and functional performance in healthy and patient populations: A systematic review and meta-analysis of randomized controlled trials. Gerontology 2018;64:74–89	A mixture of neurological conditions including stroke, MS, PD and a pooled analysis across all studies was conducted
Gumaa M, Youssef AR. Is virtual reality effective in orthopedic rehabilitation? A systematic review and meta-analysis. Phys Ther 2019;99:10	A mixture of immersive and non-immersive technologies and a mixture of settings and

	a pooled analysis across all studies was conducted
Hakala S, Rintala A, Immonen J, Karvanen J, Heinonen A, Sjogren T. Effectiveness of technology-based distance interventions promoting physical activity: systematic review, meta-analysis and meta-regression. J Rehabil Med 2017;49:97–105.	Wrong population: conducted across younger and older adults of all ages and a pooled analysis across all studies was conducted
Hakala S, Rintala A, Immonen J, Karvanen J, Heinonen A, Sjogren T. Effectiveness of physical activity promoting technology-based distance interventions compared to usual care. Systematic review, meta-analysis and meta-regression. Eur J Phys Rehabil Med 2017;53:953–67	Wrong population: conducted across younger and older adults of all ages and a pooled analysis across all studies was conducted
Hamel R. Review of viatherapy mobile application for upper extremity stroke rehabilitation. *Phys Ther Rev* 2018;23:298–9.	Not a systematic review
Hosseiniravandi M, Kahlaee AH, Karim H, Ghamkhar L, Safdari R. Home-based telerehabilitation software systems for remote supervising: A systematic review. Int J Technol Assess Health Care 2020;36:113–25	No risk of bias assessment
Howes SC, Charles DK, Marley J, Pedlow K, McDonough SM. Gaming for health: systematic review and meta-analysis of the physical and cognitive effects of active computer gaming in older adults. Phys Ther 2017;97:1122–37.	A mixture of settings and a pooled analysis across all studies was conducted
Hung KG, Fong KNK. Effects of telerehabilitation in occupational therapy practice: A systematic review. Hong Kong J Occup Ther 2019;32:3–21.	A mixture of diseases and health conditions and a pooled analysis across all studies was conducted
Jahangiry L, Farhangi MA, Shab-Bidar S, Rezaei F, Pashaei T. Web-based physical activity interventions: A systematic review and meta-analysis of randomized controlled trials. Public Health 2017;152:36–46.	Wrong population: conducted across younger and older adults of all ages and a pooled analysis across all studies was conducted
Jansson MM, Rantala A, Miettunen J, Puhto AP, Pikkarainen M. The effects and safety of telerehabilitation in patients with lower-limb joint replacement: A systematic review and narrative synthesis. J Telemed Telecare 2020;2020 Apr 21:Epub ahead of print:	A mixture of telerehabilitation interventions including video conferencing and a pooled analysis across all studies was conducted
Jonkman NH, van Schooten KS, Maier AB, Pijnappels M. eHealth interventions to promote objectively measured physical activity in community-dwelling older people. Maturitas 2018;113:32–9.	Not a systematic review
Joseph RP, Royse KE, Benitez TJ. A systematic review of electronic and mobile health (e- and m-Health) physical activity interventions for African American and Hispanic women. J Phys Act Health 2019;16:230–9.	Focused on web-based physical activity interventions across adults of all ages and a pooled analysis across all studies was conducted
Kang M, Park E, Cho BH, Lee KS. Recent patient health monitoring platforms incorporating Internet of Things-enabled smart devices. Int Neurourol J 2018;22:S76–82.	Not a systematic review
Karamians R, Proffitt R, Kline D, Gauthier LV. Effectiveness of virtual reality- and gaming-based interventions for upper extremity rehabilitation post-stroke: A meta-analysis. Arch Phys Med Rehabil 2020;101:885–96	A mixture of telerehabilitation technologies including immersive VR and gamification and a pooled analysis across all studies was conducted
Kettlewell J, das Nair R, Radford K. A systematic review of personal smart technologies used to improve outcomes in adults with acquired brain injuries. Clin Rehabil 2019;33:1705–12.	Wrong setting: therapist delivered interventions in 5 studies and only 3 then asked whether they would be continued at home and a pooled analysis across all studies was conducted
Knepley KD, Mao JZ, Wieczorek P, Okoye FO, Jain AP, Harel NY. Impact of telerehabilitation for stroke-related deficits. Telemed J E Health 2020;Apr 23. Online ahead of print:	A mixture of telerehabilitation interventions including robotics and a pooled analysis across all studies was conducted
Larsen RT, Christensen J, Juhl. C. B, Andersen HB, Langberg H. Physical activity monitors to enhance amount of physical	Wrong population: conducted across healthy older adults and those with a range

activity in older adults - A systematic review and meta-analysis. Eur Rev Aging Phys Act 2019;16:7	of chronic conditions and a pooled analysis across all studies was conducted
Laver KE, Lange B, George S, Deutsch JE, Saposnik G, Crotty M. Virtual reality for stroke rehabilitation. Cochrane Database Syst Rev 2017;11	A mixture of immersive and non-immersive technologies and a pooled analysis across all studies was conducted
Laver KE, Adey-Wakeling Z, Crotty M, Lannin NA, George S, Sherrington C. Telerehabilitation services for stroke. Cochrane Database Syst Rev 2020;1	Mixed telerehabilitation interventions and a pooled analysis across all studies was conducted
Lenouvel E, Novak L, Nef T, Kloppel S. Advances in sensor monitoring effectiveness and applicability: A systematic review and update. Gerontologist 2020;60:e299–308	A mixture of settings and a pooled analysis across all studies was conducted
Li Z, Han XG, Sheng J, Ma SJ. Virtual reality for improving balance in patients after stroke: A systematic review and meta-analysis. Clin Rehabil 2016;30:432–40.	A mixture of home based and inpatient settings and a pooled analysis across all studies was conducted
Lynch EA, Jones TM, Simpson DB, Fini NA, Kuys SS, Borschmann K, et al. Activity monitors for increasing physical activity in adult stroke survivors. Cochrane Database Syst Rev 2018;7	A mixture of settings including inpatients, laboratory settings and community and a pooled analysis across all studies was conducted
Lynch C, Bird S, Lythgo N, Selva-Raj I. Changing the physical activity behavior of adults with fitness trackers: A systematic review and meta-analysis. Am J Health Promot 2020;34:418–30	Wrong population: conducted across younger and older adults of all ages and a pooled analysis across all studies was conducted
Maier M, Rubio Ballester B, Duff A, Duarte Oller E, Verschure PFMJ. Effect of specific over nonspecific VR-based rehabilitation on poststroke motor recovery: A systematic meta-analysis. Neurorehabil Neural Repair 2019;33:112–29.	A mixture of settings and a pooled analysis across all studies was conducted
Manivannan S, Al-Amri M, Postans M, Westacott LJ, Gray W, Zaben M. The Effectiveness of Virtual Reality Interventions for Improvement of Neurocognitive Performance After Traumatic Brain Injury: A Systematic Review. J Head Trauma Rehabil 2019;34:E52–65	A mixture of immersive and non-immersive technologies and a pooled analysis across all studies was conducted
Manlapaz DG, Sole G, Jayakaran P, Chapple CM. A narrative synthesis of nintendo wii fit gaming protocol in addressing balance among healthy older adults: What system works? Games Health J 2017;6:65–74.	Not a systematic review
Maresca G, Maggio MG, De Luca R, Manuli A, Tonin P, Pignolo L, et al. Tele-neuro-rehabilitation in italy: State of the art and future perspectives. Front Neurol 2020;11:563375	No risk of bias assessment and mixed sample of children and adults and a pooled analysis across all studies was conducted
Massetti T, da Silva TD, Crocetta TB, Guarnieri R, de Freitas BL, Bianchi Lopes P, *et al.* The clinical utility of virtual reality in neurorehabilitation: A systematic review. *J Cent Nerv Syst Dis* 2018;10:1179573518813541.	No risk of bias assessment
Matamala-Gomez M, Maisto M, Montana JI, Mavrodiev PA, Baglio F, Rossetto F, et al. The role of engagement in teleneurorehabilitation: A systematic review. Front Neurol 2020;11:354	A mixture of telerehabilitation interventions across a range of neurological conditions and a pooled analysis across all studies was conducted
Mat Rosly M, Mat Rosly H, Davis Oam GM, Husain R, Hasnan N. Exergaming for individuals with neurological disability: A systematic review. Disabil Rehabil 2017;39:727–35	A mixture of disease and health conditions and mixed samples of children and adults and a pooled analysis across all studies was conducted
Mohammadi R, Semnani AV, Mirmohammadkhani M, Grampurohit N. Effects of virtual reality compared to conventional therapy on balance poststroke: A systematic review and meta-analysis. J Stroke Cerebrovasc Dis 2019;28:7	A mixture of settings and a pooled analysis across all studies was conducted
Moral-Munoz JA, Zhang W, Cobo MJ, Herrera-Viedma E, Kaber DB. Smartphone-based systems for physical rehabilitation applications: A systematic review. Assist Technol 2019:1–14.	No risk of bias assessment

Mubin O, Alnajjar F, Jishtu N, Alsinglawi B, Al Mahmud A. Exoskeletons with virtual reality, augmented reality, and gamification for stroke patients' rehabilitation: Systematic review. JMIR Rehabil Assist Technol 2019;6:e12010.	A mixture of technologies including exoskeleton robotics and gamification and a pooled analysis across all studies was conducted
Mura G, Carta MG, Sancassiani F, Machado S, Prosperini L. Active exergames to improve cognitive functioning in neurological disabilities: a systematic review and meta-analysis. Eur J Phys Rehabil Med 2018;54:450–62.	A mixture of neurological conditions including MS, PD, post-stroke hemiparesis, dementia, dyslexia, Down syndrome and a pooled analysis across all studies was conducted
Nascimento L, Bonfati LV, Freitas MB, Mendes Junior JJA, Siqueira HV, Stevan SL. Sensors and systems for physical rehabilitation and health monitoring: A review. Sensors 2020;20:22.	No risk of bias assessment
Neri SG, Cardoso JR, Cruz L, Lima RM, de Oliveira RJ, Iversen MD, et al. Do virtual reality games improve mobility skills and balance measurements in community-dwelling older adults? Systematic review and meta-analysis. Clin Rehabil 2017;31:1292–304	A mixture of settings and a pooled analysis across all studies was conducted
Nussbaum R, Kelly C, Quinby E, Mac A, Parmanto B, Dicianno BE. Systematic review of mobile health applications in rehabilitation. Arch Phys Med Rehabil 2019;100:115–27	No risk of bias assessment
Palma GCS, Freitas TB, Bonuzzi GMG, Soares MAA, Leite PHW, Mazzini NA, et al. Effects of virtual reality for stroke individuals based on the International Classification of Functioning and Health: A systematic review. Top Stroke Rehabil 2017;24:269–78	A mixture of immersive and non-immersive technologies and a pooled analysis across all studies was conducted
Parker J, Powell L, Mawson S. Effectiveness of upper limb wearable technology for improving activity and participation in adult stroke survivors: Systematic review. J Med Internet Res 2020;22:e15981.	A mixture of settings and a pooled analysis across all studies was conducted
Perrochon A, Borel B, Istrate D, Compagnat M, Daviet JC. Exercise-based games interventions at home in individuals with a neurological disease: A systematic review and meta-analysis. Ann Phys Rehabil Med 2019;62:366–78	A mixture of neurological conditions including stroke, MS, PD and a pooled analysis across all studies was conducted
Pastora-Bernal J, Martin-Valero R, Baron-Lopez FJ, Estebanez-Perez MJ. Evidence of benefit of telerehabilitation after orthopedic surgery: A systematic review. J Med Internet Res 2017;19:e142.	No outcomes of interest
Piga M, Cangemi I, Mathieu A, Cauli A. Telemedicine for patients with rheumatic diseases: Systematic review and proposal for research agenda. Semin Arthritis Rheum 2017;47:121–8.	Focus was primarily self-management
Pope Z, Zeng N, Gao Z. The effects of active video games on patients' rehabilitative outcomes: A meta-analysis. Prev Med 2017;95:38–46.	A mixture of settings and a pooled analysis across all studies was conducted
Powell L, Parker J, Martyn St-James M, Mawson S. The effectiveness of lower-limb wearable technology for improving activity and participation in adult stroke survivors: A systematic review. J Med Internet Res 2016;18:e259.	A mixture of settings and a pooled analysis across all studies was conducted
Qi J, Yang P, Waraich A, Deng Z, Zhao Y, Yang YC. Examining sensor-based physical activity recognition and monitoring for healthcare using Internet of Things: A systematic review. J Biomed Inform 2018;87:138–53.	No risk of bias assessment
Ramprasad C, Tamariz L, Garcia-Barcena J, Nemeth Z, Palacio A. The use of tablet technology by older adults in health care settings - is it effective and satisfying? A systematic review and meta analysis. Clin Gerontol 2019;42:17–26	Focus was primarily self-management and not clear if tablet was always used at home as could have been used in clinical setting

Reis E, Postolache G, Teixeira L, Arriaga P, Lima ML, Postolache O. Exergames for motor rehabilitation in older adults: An umbrella review. Phys Ther Rev 2019;24:84–99.	Umbrella review used for back-chaining
Rintala A, Paivarinne V, Hakala S, Paltamaa J, Heinonen A, Karvanen J, et al. Effectiveness of technology-based distance physical rehabilitation interventions for improving physical functioning in stroke: A systematic review and meta-analysis of randomized controlled trials. Arch Phys Med Rehabil 2019;100:1339–58.	A mixture of technologies including wearable device, Internet, telephone calls, smartphone application, video calls and texting and a pooled analysis across all studies was conducted
Romeo A, Edney S, Plotnikoff R, Curtis R, Ryan J, Sanders I, et al. Can smartphone apps increase physical activity? Systematic review and meta-analysis. J Med Internet Res 2019;21:e12053.	Wrong population: smart phone apps for increasing physical activity in younger and older adults of all ages and a pooled analysis across all studies was conducted
Saeed N, Manzoor M, Khosravi P. An exploration of usability issues in telecare monitoring systems and possible solutions: A systematic literature review. Disabil Rehabil Assist Technol 2020;15:271–81.	Understandability, learnability, attractiveness, operability and usability of apps
Sancho-Garcia S, Sanz-de Diego S, Medina-Porqueres I. Apps to prescribe therapeutic exercise among rehabilitating adults: A systematic review. J Sports Med Phys Fitness 2020;60:472–8. https://doi.org/10.23736/S0022-4707.19.09601-4.	Not a systematic review
Sardi L, Idri A, Fernández-Alemán JL. A systematic review of gamification in e-Health. J Biomed Inform 2017;71:31–48	Generic review and not related to a specific conditions
Sarfo FS, Ulasavets U, Opare-Sem OK, Ovbiagele B. Tele-rehabilitation after stroke: an updated systematic review of the literature. J Stroke Cerebrovasc Dis 2018;27:2306–18.	A mixture of telerehabilitation technologies including VR, mobile apps, robotic assisted therapy and a pooled analysis across all studies was conducted
Saywell N, Taylor N, Rodgers E, Skinner L, Boocock M. Play-based interventions improve physical function for people with adult-acquired brain injury: A systematic review and meta-analysis of randomised controlled trials. Clin Rehabil 2017;31:145–57.	A mixture of settings and technologies (including robotic devices) and a pooled analysis across all studies was conducted
Schoeppe S, Alley S, van Lippevelde W, Bray NA, Williams SL, Duncan MJ, et al. Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: A systematic review. Int J Behav Nutr Phys Act 2016;7:127	Focus was on the prevention of non-communicable diseases
Shek AC, Biondi A, Ballard D, Wykes T, Simblett SK. Technology-based interventions for mental health support after stroke: A systematic review of their acceptability and feasibility. Neuropsychol Rehabil 2019:1–21	A mixture of technologies including videoconferencing and robotic assistance and a pooled analysis across all studies was conducted
Shukla H, Nair S, Thakker D. Role of telerehabilitation in patients following total knee arthroplasty: Evidence from a systematic literature review and meta-analysis. J Telemed Telecare 2017;23:339–46.	A mixture of technologies including physiotherapy via videoconferencing and a pooled analysis across all studies was conducted
Silva M, Sao-Joao TM, Brizon VC, Franco DH, Mialhe FL. Impact of implementation intentions on physical activity practice in adults: A systematic review and meta-analysis of randomized clinical trials. PLoS ONE 2018;13:e0206294.	Dance mediated intervention individually, couples or groups across a range of settings
Skjaeret N, Nawaz A, Morat T, Schoene D, Helbostad JL, Vereijken B. Exercise and rehabilitation delivered through exergames in older adults: An integrative review of technologies, safety and efficacy. Int J Med Inf 2016;85:1–16.	A mixture of settings and a pooled analysis across all studies was conducted
Stockwell S, Schofield P, Fisher A, Firth J, Jackson SE, Stubbs B, et al. Digital behavior change interventions to promote physical activity and/or reduce sedentary behavior in older adults: A systematic review and meta-analysis. Exp Gerontol 2019;120:68–87.	A mixture of technologies including text messages and immersive VR pooled analysis across all studies was conducted

Sultana M, Bryant D, Orange JB, Beedie T, Montero-Odasso M. Effect of Wii Fit exercise on balance of older adults with neurocognitive disorders: A meta-analysis. J Alzheimers Dis 2020;75:817–26.	Wrong population: a mixture of neurocognitive disorders including Alzheimer's disease, PD and dementia
Taylor LM, Kerse N, Frakking T, Maddison R. Active video games for improving physical performance measures in older people: A meta-analysis. J Geriatr Phys Ther 2018;41:108–23	A mixture of settings and a pooled analysis across all studies was conducted
Tchero H, Tabue Teguo M, Lannuzel A, Rusch E. Telerehabilitation for stroke survivors: Systematic review and meta-analysis. J Med Internet Res 2018;20:e10867	A mixture of telerehabilitation approaches including telehealth via telephone or video and a pooled analysis across all studies was conducted
Velayati F, Ayatollahi H, Hemmat M. A systematic review of the effectiveness of telerehabilitation interventions for therapeutic purposes in the elderly. Methods Inf Med 2020;59:104–9.	A mixture of telerehabilitation approaches and a pooled analysis across all studies was conducted
Wang Q, Marlopoulos P, Yu B, Chen W, Timmermans A. Interactive wearable systems for upper body rehabilitation: A systematic review. J Neuroengineering Rehabil 2017;14:1–21.	No risk of bias assessment
Wang X, Hunter DJ, Vesentini G, Pozzobon D, Ferreira ML. Technology-assisted rehabilitation following total knee or hip replacement for people with osteoarthritis: a systematic review and meta-analysis. BMC Musculoskelet Disord 2019;3:.	A mixture of telerehabilitation technologies including telehealth via telephone or video and VR and a pooled analysis across all studies was conducted
Yerrakalva D, Yerrakalva D, Hajna S, Griffin S. Effects of mobile health app interventions on sedentary time, physical activity, and fitness in older adults: Systematic review and meta-analysis. J Med Internet Res 2019;21:e14343	A mixture of mHealth interventions and some had additional components or education and/or counselling and a pooled analysis conducted
Xie SH, Wang Q, Wang LQ, Wang L, Song KP, He CQ. Effect of internet-based rehabilitation programs on improvement of pain and physical function in patients with knee osteoarthritis: Systematic review and meta-analysis of randomized controlled trials. J Med Internet Res 2021;23:e21542	A mixture of interventions that include conventional psychotherapy or supervised training and a pooled analysis conduced
Zeng N, Pope Z, Lee JE, Gao Z. A systematic review of active video games on rehabilitative outcomes among older patients. J Sport Health Sci 2017;6:.	A mixture of diseases and health conditions and a pooled analysis across all studies was conducted

Key: CHF: chronic heart failure; COPD: chronic obstructive pulmonary disease; CP: cerebral palsy; MS: Multiple sclerosis; PD: Parkinson Disease; SCI: spinal cord injury; VR: virtual reality

Appendix III: List of relevant primary studies included in systematic reviews

Primary studies Included in Systematic reviews (n=31)	Included systematic reviews (n=5)				
	Liu et al. 2020[27]	Schafer et al. 2018[46]	Srikesavan et al. 2019[47]	Zhou et al. 2018[27]	Schroder et al. 2019[48]
Allam et al. 2015			v		
Ashe et al. 2015	v				
Bennell et al. 2017a		v			
Bickmore et al. 2013	v				
Bossen et al. 2013		v			
Cadmus-Bertram et al. 2015	v				
Cikajilo et al. 2009					v
Flynn et al 2007					v
Hoover and Carney 2014				v	
Jang and Jang 2016				v	
Kizony et al. 2016				v	
Krpic et al. 2013					v
Lawson et al. 2017				v	
Lewis et al. 2017	v				
Lin et al. 2014					v
Llorens et al. 2015					v
Lorig et al. 2008			v		
Lyons et al. 2017	v				
Martin et al. 2015	v				
Mouawad et al. 2011					v
Paul et al. 2016				v	
Prokopenko et al. 2013				v	
Ressner et al. 2014				v	
Rowley et al. 2017	v				
Shigaki et al. 2013			v		
Skrepnik et al. 2017		v			
Suboc et al. 2014	v				
Sureshkumar et al. 2016				v	
Thompson et al. 2014	v				
Van den Berg et al. 2006			v		
Wijsman et al. 2013	v				

Appendix IV: Characteristics of systematic reviews (n=5)

Study Review objectives	Details of interventions Participants	Search details	Characteristics of included primary studies
Liu e al. 2020[26] To evaluate the effectiveness of WAT-based interventions in improving PA levels in sedentary older adults	<u>Interventions</u> WATs <u>Participants</u> Community-dwelling older adults mean age $\geq$ 55 who were following a sedentary lifestyle, regardless of gender and race (n=1035) Mean age 65.5 years / Female 64.4%	Databases (n=8) CENTRAL MEDLINE, EMBASE, CINAHL, PsycINFO, Science Direct Web of Science, PubMed <u>Date restrictions</u> Retrieved from Jan 2008 to Jan 2018 <u>Language restrictions</u> English	<u>Study designs</u> RCTs (n=10) <u>Countries of interventions</u> USA (n=8) Canada (n=1) the Netherlands (n=1) <u>Settings</u> Home-based or nursing homes
Zhou et al. 2018[27] To determine the effectiveness of mobile applications in the rehabilitation of stroke survivors	<u>Interventions</u> Mobile applications <u>Participants</u> Stroke survivors (n=165) Age and gender not reported	Databases (n=4) PubMed, EMBASE Web of Science SCIE CINAHL <u>Date restrictions</u> Retrieved from inception to May 2017 <u>Language restrictions</u> English	<u>Study designs</u> RCTs (n=2) Quasi RCTs (n=10) Total relevant (RCTs n=2; Quasi-experimental (n=5)[b] <u>Countries of interventions</u> USA (n=1), UK (n=2), Russia (n=1), Korea (n=1) Israel (n=1), the Czech Republic (n=1) <u>Settings</u> Home based
Schroder et al. 2019[48] To investigate whether it is feasible to combine virtual reality which allows exercising in game-like environments with tele-rehabilitation in a community dwelling stroke population	<u>Interventions</u> Screen-based non immersive VR <u>Participants</u> Adult stroke survivors (>18 years) (n=120) Mean age 62.6 years Gender not reported	Databases (n=5) PubMed, Web of Science, PEDro Rehab Data, CENTRAL <u>Date restrictions</u> Retrieved from inception to Jan 2018 <u>Language restrictions</u> English, Dutch, German or French	<u>Study designs</u> RCTs (n=4), Case studies (n=2), Case control study (n=1) <u>Countries of interventions</u> Slovenia (n=1), Spain (n=1), Taiwan (n=1) USA (n=1), Australia (n=1) <u>Settings</u> Home based

Schafer et al. 2018[46] To compare the efficacy of eHealth-supported home exercise interventions with no or other interventions regarding pain, physical function, and health-related QoL in patients with OAK	<u>Interventions</u> Electronic health-supported home exercise interventions Web- based or app-based <u>Participants</u> Patients with symptomatic unilateral or bilateral OAK (n=558) Unilateral OAK (n=1) Mixed group with knee OA, hip OA or both (n=1) Chronic knee pain (n=1) Mean age 63 years / Females 56%	Databases (n=4) CENTRAL, PubMed CINAHL, PEDro <u>Date restrictions</u> Retrieved from inception to July 2017 <u>Language restrictions</u> English or German	<u>Study designs</u> RCTs (n=7) Total relevant (n=3)[a] <u>Countries of interventions</u> Australia (n=1) the Netherlands (n=1) USA (n=1) <u>Settings</u> Home-based
Srikesavan et al. 2019[47] To determine the effects of web-based rehabilitation interventions in adults with RA	<u>Interventions</u> Web-based rehabilitation interventions <u>Participants</u> Adults (aged above 18 years) with a clinical diagnosis of RA, osteoarthritis or fibromyalgia (n=567) Mean age 55.2 years (across 2 studies), median age 49 years (n=1), not reported (n=1) Gender not reported	Databases (n=9) EMBASE, AMED, PSYCinfo, SCOPUS, PEDro, CINAHL, Sports Discus, CENTRAL, Google Scholar <u>Date restrictions</u> Retrieved from inception to Feb 2017 <u>Language restrictions</u> English	<u>Study designs</u> RCTs (n=4, across 6 publications) <u>Countries of interventions</u> Switzerland (n=1) the Netherlands (n=1) USA (n=2) <u>Settings</u> Home Based

[a] data for interventions that involved telephone supported counselling to encourage physical activity were not extracted (n=3)

[b] data from studies that were aimed at rehabilitation of language function (n=4) or the management of post stroke vascular risk factors were not extracted

Key: AMED: Alllied and Complementary Medicine Database; CENTRAL: Cochrane Library Central Register of Controlled Trials; CINAHL: Cumulative Index of Nursing and Allied Health Literature Database; DOAJ: Directory of Open Access Journals; EMBASE: Excerpta Medica Database; MEDLINE: Medical Literature Analysis and Retrieval System Online Database; OAK: osteoarthritis of the knee; PA: physical activity; PEDro: Physiotherapy Evidence Database; PsycINFO: Psychological Information Database; PubMed: search engine accessing primarily the MEDLINE database of references and abstracts on life sciences and biomedical topics; RA: rheumatoid arthritis; RCTs: randomised controlled trials; SCIE: Science Citation Index Expanded-Database; WAT: wearable activity tracker; VR: virtual reality

Appendix V: Characteristics of systematic reviews (n=5) continued

Study	Instruments used for bias appraisal	Bias appraisal ratings	Outcomes of interest and outcome measures	Assessments and follow up time points	Methods of analysis
Liu e al. 2020[26]	Cochrane RoB	Unclear risk of selection bias (n=5) High risk detection bias (n=3) High risk of attrition bias (n=3) High risk in selective reporting (n=4) Low RoB (n=2)	PA: Daily step counts or time spent in MVPA measured objectively using an accelerometer or pedometer	Short term 3 weeks (n=1) 6 weeks (n=1) 12 weeks (n=1) Post intervention 5 weeks (n=1) 8 weeks (n=1) 12 weeks (n=4) 13 weeks (n=1) 6 months (n=3) Follow up 12 months (n=2)	Meta-analysis Random effects model Narrative synthesis
Zhou et al. 2018[27]	Criteria published by the Australian Evidence-Based Health Care Center	RCTs [a]High quality (A) (n=2) [a]Medium quality (B) (n=3) Quasi-experimental [a]High quality (A) (n=1) [a]Medium quality (B) (n=1)	PA / SB Step counts or time spent walking or time spent in SB measured objectively using an activity monitor Balance / Gait: 10mWT Physical performance: Muscle strength: MMT Finger function: MFT; PPT; 9PHT Degree of disability: MRS Range of motion: ARAT; AROM, PROM ADL: IADL; CAHAI; AM-PAC; BI	Short term 2 weeks (n=1) Post intervention 2 weeks (n=1) 4 weeks (n=2) 6 weeks (n=2) 12 weeks (n=1) Not reported (n=1)	Narrative synthesis

			QoL: SS-QoL Cognitive function: MMSE; FAB; CDT; MoCA; ACE-R; WAIS Adverse events		
Schroder et al. 2019[48]	RCTs – PEDro scale CCS – Newcastle Ottawa Scale Cases Series - National Heart, Lung and Blood Institute checklist	Score of 8-9 Low RoB (n=1) Score 5-7 Moderate RoB (n=1) Score <4 High RoB (n=2) CCS [a]Moderate RoB (n=2) Case Series [a]High RoB (n=1)	Balance / Gait 10mWT; 6mWT; BBS DGI; FMA balance; POMA-B; POMA-G; SAE; SUE; TUG,	Post treatment 8 weeks (n=1) 4 weeks (n=4) 3 weeks (n=1) 2 weeks (n=1) Follow up 12 weeks (n=1)	Narrative synthesis
Schafer et al. 2018[46]	Cochrane RoB	Low RoB (n=3)	Pain: NRS; VAS; KOOS; WOMAC pain subscale Balance / Gait: 6mWT; Physical Performance WOMAC; KOOS; HOOS; IKHOAM QoL: AQoL; WHO QoL; KOOS; HOOS	Post intervention 3 months (n=3) Follow up 9 months (n=1) 12 months (n=1)	Meta-analysis Random effects model
Srikesavan et al. 2019[47]	Cochrane RoB	High RoB (n=4)	Pain: NRS; (Symptom's component); RADAR Physical performance: HAQ; MACTAR QoL: RA QoL; SF-36; AIMS2-SF; QoL Scale 2 PA: Time spent on PA; EBS Adverse effects		Mean difference 95% Cis Risk ratio 95% CIs Narrative synthesis

[a] classification details for risk of bias / overall quality was not provided

Key: 10mWT: 10 meter walk test; 6 mWT: 6 meter walk test; 9PHT: Nine Hole Peg Test; ARAT: Action Research Arm Test; AAS: Active Australia Survey; ACE-R: Addenbrooke's Cognitive Examination; ADL: Activities of Daily Living; AIMS2-SF: Arthritis Impact Measurement Scales 2 Short Form; AM-PAC: short-form version of the Activity Measure for Post-Acute Care; AQoL: Assessment of Quality of Life instrument; AROM: Active Range of Motion; BBS: Berg Balance Scale; BI: Barthel Index; CAHAI: Chedoke Arm and Hand Activity Inventory; CCS: case control study; CDT: Clock Drawing Test; CI: confidence intervals; DGI: Dynamic Gait Index; EBS: exercise behaviour scale; FAB: Frontal Assessment Battery; FMA: Fugl-Meyer Assessment; HAQ: Health Assessment Questionnaire; HOOS: Hip Osteoarthritis Outcome Score; IADL: The Instrumental Activities of Daily Living Scale; IKHOAM: Ibadan knee/Hip Osteoarthritis Outcome Measure; KOOS: Knee Osteoarthritis Outcome Score; MACTAR: McMaster Toronto Arthritis Patient Preference questionnaire; MFT: The Manual Function Test; MFU: months follow up; MMSE: Mini Mental Status Exam; MMT: The Manual Muscle Test; MoCA: Montreal Cognitive Assessment; mRS: Modified Rankin Scale; MVPA: moderate to vigorous physical activity; NRS: Numerical Rating Scales; PA: physical activity; PACE: Physical Activity Scale for the Elderly; POMA-B: Performance-Oriented Mobility Assessment-balance subscale; POMA-G: Performance-Oriented Mobility Assessment-Gait subscale; PPT: Purdue Pegboard Test; PROM: passive range of motion; QoL: quality of life; RADAR: Rapid Assessment of Disease Activity in Rheumatology Questionnaire; RCT: randomised controlled trail; RoB: risk of bias; SAE: standing affected leg; SB: sedentary behaviour; SF-36: 36-item Short Form Health Survey; SMD: standardised mean difference; SS-QoL: Stroke Specific Quality of Life scale;; SUE: standing unaffected leg; TUG: Timed Up and Go test; VAS: visual analogue scale; WAIS: Wechsler Adult Intelligence Scale; WHO-QoL: World Health Organisation assessment of Quality of Life instrument; WOMAC: Western Ontario and MacMaster Universities Osteoarthritis Index

Appendix VI: Details of interventions

Study	Liu e al. 2020[26]	Zhou et al. 2018[27]	Schroder et al. 2019[48]	Schafer et al. 2018[46]	Srikesavan et al. 2019[47]
Rehabilitation focus	Physical function (n=10)	Physical function (n=5) Cognitive function (n=2)	Physical Function (n=7)	Physical Function (n=3)	Physical Function (n=4)
Technology	Commercial WATs connected to an interactive website (n=7) mobile app (n=2) or to website and a mobile app (n=1) Fitbit One, Fitbug Orb, Digital pedometers (Omron HJ), UP24 Jawbone, Phillips DirectLife activity monitor, unbranded digital pedometer Hip/waist-worn (n=6) Arm/wrist-worn (n=2) Ankle-worn (n=1) Tights-worn (n=1)	Mobile applications Smart phone based (n=3) IPAD or tablet based (n=2) Computer-based activities (n=2)	Commercially available gaming devices (n=3) Wii PlayStation 2 EyeToy Microsoft Kinect Non-commercial systems that support balance training (n=4)	Interactive web sites (n=2) Commercial WAT connected to a mobile app (n=1) Jawbone	Interactive web sites (n=4)
Physical function component/s	Tailored PA prescriptions (n=1) Walking (n=9)	Physical Applications and software targeted the following physical functions Active and passive action of arm and hand (n=1) Activities of daily living (n=1) Numbers of steps and walking time per day, Upper extremity function, and hand function (n=1) Muscle strength and finger function (n=1)	Physical Balance training including repetitive task training in upright postures, for example, weight-shifting during bipedal stance	Physical Lower limb strengthening (n=1) Exercise reinforcement of self-selected activities such as cycling or walking along with home strengthening and stretching exercises (n=1) Walking (daily step goals) (n=1) Gradual increase in patients favourite recreational activity cycling, walking or gardening (n=1)	Physical Muscle strengthening (n=1) Range of motion exercises (n=1) No active exercise component but general PA encouraged (n=1) Tailored exercises (n=1) No exercise component (n=1)

Cognitive function component/s	Not applicable	Use non-verbal tasks such as assembling shapes or figures, getting through a labyrinth, memorizing cards and shapes and planning and strategic thinking tasks (n=1) Training of attention, visual and spatial gnosis by performing some tasks (n=1)	Not applicable	Not applicable	Not applicable
Additional key components	Information / educational material (n=3) Social support (n=2) Virtual exercise coaching (n=2) Personal coach (n=1) Goal setting (n=7) Action planning (n=1) Telephone counselling (n=3)	Not reported	Analysis of outcome measures and adjustment of difficulty by system (n=1) Daily schedules, motor activity diaries, feedback caregiver (n=1) Videoconferencing during balance training (n=4) Not reported (n=1)	Information/Educational material (n=2) Pain and coping skills training (n=1) Hyaloranon injections (n=1) No additional components (n=1)	Information / educational material (n=4) Social support via online forums and/or discussion boards (n=4) Gamification (n=1) Tailored self-management strategies (n=1)
Level of personal contact	No human contact (n=2) Very little contact with interventionists acting a credible source in favor of increased PA (n=3) Full contact with interventionists (n=5) ranging from leading group discussion, overseeing a prescription, planning exercise regime, providing face to face phone consultations or running an online forum with the participants	Very little contact with interventionists providing initial instructions on use of technology PA (n=11) Full contact with interventionists (n=1) which included a one-hour clinic session once a week	No contact (n=1) Full contact with interventionists (n=5) ranging from videoconferencing during balance training to providing education, daily schedules, feedback or weekly conventional physical therapy in clinic	No contact (n=3)	No contact (n=2) Full contact with interventionists (n=2) ranging from one-to-one weekly telephone contacts with the team leader to personalised activity schedules, weekly remote supervision from physiotherapists in addition to an online discussion forum, telephone support, e-newsletters and group meetings once every 3 months
Duration	5 weeks (n=1)	Not specified (n=1)	7 weeks (n=1)	3 months (n=3)	6 weeks (n=1)

	6 months (n=1) 48 weeks (n=1) 12 months (n=1) 12 weeks (n=5) 16 weeks (n-1)	16 hours (n=1) 2 weeks (n=1) 4 weeks (n=2) 6 weeks (n=2) 10 weeks (n=1) 3 months (n=1) 120 days (n=1) 180 days (n=1) 6 months (n=1)	2 weeks (n=2) 3 weeks (n=1) 4- 5 weeks (n=1)		2 months (n=1) 10 weeks (n=1) 52 weeks (n=1)
Frequency	No details provided	Physical rehabilitation (n=5) 31 to 90 mins per session No individual study details provided Cognitive rehabilitation (n=2) 30 mins/day 1.5 hours/week	3 sessions/week 45 mins 3 sessions/week 70 mins 3 session/week 15 mins or 4 sessions/week 20 mins 1 hour per day increasing to 3 hours/day 3 sessions/week 17-20 mins 3 sessions/week time ns 5 sessions/week 20 mins 5 sessions/week 60 mins	No details provided	1 session/week 60 mins 5 sessions/week time ns 3 sessions/week, total 1–2 hours/week Weekly modules time ns
Details of control groups	Active controls (n=4) Passive controls (n=3) Health information (n=1) Wait list control (n=3) Active & passive controls (n=3)	No control (n=4) Passive controls (n=3) Usual care (n=2) No training (n=1)	No control (n=2) Active controls (n=5)	Active controls (n=1) Passive controls (n=2) Wait list control (n=1) Health information (n=1)	Passive controls (n=3) Usual care (n=1) Wait list control (n=1) Information only (n=1) Active & passive controls (n=1)

Key: C: control; I: intervention; NS: not specified; PA: physical activity; VR: virtual reality; WAT: wearable activity tracker