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[Intervention Review]

Telerehabilitation services for stroke

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ABSTRACT

Background

Telerehabilitation is an alternative way of delivering rehabilitation services. Information and communication technologies are used to facilitate communication between the healthcare professional and the patient in a remote location. The use of telerehabilitation is becoming more viable as the speed and sophistication of communication technologies improve. However, it is currently unclear how effective this model of delivery is relative to rehabilitation delivered face-to-face.

Objectives

To determine whether the use of telerehabilitation leads to improved ability to perform activities of daily living amongst stroke survivors when compared with (1) in-person rehabilitation (when the clinician and the patient are at the same physical location and rehabilitation is provided face-to-face); or (2) no rehabilitation. Secondary objectives were to determine whether use of telerehabilitation leads to greater independence in self care and domestic life and improved mobility, health-related quality of life, upper limb function, cognitive function or functional communication when compared with in-person rehabilitation and no rehabilitation. Additionally, we aimed to report on the presence of adverse events, cost-effectiveness, feasibility and levels of user satisfaction associated with telerehabilitation interventions.

Search methods

We searched the Cochrane Stroke Group Trials Register (November 2012), the Cochrane Effective Practice and Organization of Care Group Trials Register (November 2012), the Cochrane Central Register of Controlled Trials (*The Cochrane Library,* Issue 11, 2012), MEDLINE (1950 to November 2012), EMBASE (1980 to November 2012) and eight additional databases. We searched trial registries, conference proceedings and reference lists.

Selection criteria

Randomised controlled trials (RCTs) of telerehabilitation in stroke. We included studies that compared telerehabilitation with in-person rehabilitation or no rehabilitation. In addition, we synthesised and described the results of RCTs that compared two different methods of delivering telerehabilitation services without an alternative group. We included rehabilitation programmes that used a combination of telerehabilitation and in-person rehabilitation provided that the greater proportion of intervention was provided via telerehabilitation.

Data collection and analysis

Two review authors independently identified trials on the basis of prespecified inclusion criteria, extracted data and assessed risk of bias. A third review author moderated any disagreements. The review authors contacted investigators to ask for missing information.

Main results

We included in the review 10 trials involving a total of 933 participants. The studies were generally small, and reporting quality was often inadequate, particularly in relation to blinding of outcome assessors and concealment of allocation. Selective outcome reporting was apparent in several studies. Study interventions and comparisons varied, meaning that in most cases, it was inappropriate to pool studies. Intervention approaches included upper limb training, lower limb and mobility retraining, case management and caregiver support. Most studies were conducted with people in the chronic phase following stroke. Primary outcome: no statistically significant results for independence in activities of daily living (based on two studies with 661 participants) were noted when a case management intervention was evaluated. Secondary outcomes: no statistically significant results for upper limb function (based on two studies with 46 participants) were observed when a computer programme was used to remotely retrain upper limb function. Evidence was insufficient to draw conclusions on the effects of the intervention on mobility, health-related quality of life or participant satisfaction with the intervention. No studies evaluated the cost-effectiveness of telerehabilitation. No studies reported on the occurrence of adverse events within the studies.

Authors' conclusions

We found insufficient evidence to reach conclusions about the effectiveness of telerehabilitation after stroke. Moreover, we were unable to find any randomised trials that included an evaluation of cost-effectiveness. Which intervention approaches are most appropriately adapted to a telerehabilitation approach remain unclear, as does the best way to utilise this approach.

PLAIN LANGUAGE SUMMARY

Telerehabilitation services for stroke

Stroke is a common cause of disability in adults. After a stroke, it is common for the individual to have difficulty managing everyday activities such as walking, showering, dressing and participating in community activities. Many people need rehabilitation after stroke; this is usually provided by healthcare professionals in a hospital or clinic setting. Recent studies have investigated whether it is possible to use technologies such as the telephone or the Internet to help people communicate with healthcare professionals without having to leave their home. This approach, which is called telerehabilitation, may be a more convenient and less expensive way of providing rehabilitation.

This review aimed to gather evidence for the use of telerehabilitation after stroke. We identified 10 studies involving 933 people after stroke. The studies used a wide range of treatments, including therapy programmes designed to improve arm function and ability to walk and programmes designed to provide counselling and support for people upon leaving hospital after stroke. As the studies were very different, it was inappropriate to combine results to determine overall effect. Therefore, at this point, not enough research has been done to show whether telerehabilitation is an effective way to provide rehabilitation. Also, information is lacking as to the cost-effectiveness of providing therapy using telerehabilitation. Further trials are urgently required.

BACKGROUND

Description of the condition

Stroke is one of the most common causes of death and acquired disability worldwide (Donnan 2008). Survivors of stroke commonly experience a range of symptoms affecting motor function, speech, swallowing, vision, sensation and cognition, and recovery can be slow and incomplete (Langhorne 2011). These symptoms

often lead to difficulty managing activities and limited participation in home and community activities. Approximately half of stroke survivors access some form of rehabilitation on discharge from acute services (National Institutes of Health 2012; National Stroke Foundation 2011). Rehabilitation programmes are often lengthy and resource intensive (AROC 2011; Canadian Stroke Network 2011). Therefore, determining the most effective and efficient ways to deliver stroke rehabilitation services is a matter of priority (Langhorne 2002).

Description of the intervention

Telerehabilitation is the provision of rehabilitation services to patients at a remote location using information and communication technologies (Brennan 2009). Communication between the patient and the rehabilitation professional may occur through a variety of technologies such as the telephone, Internet-based videoconferencing and sensors (such as pedometers). Virtual reality programmes may also be used as a medium for therapy; the patient completes therapy tasks within a computer-generated virtual environment, and data are transmitted to the therapist (Rogante 2010). Telerehabilitation consultations may include assessment, diagnosis, goal setting, therapy, education and monitoring (Russell 2009).

Stemming from the broader approach of telehealth, telerehabilitation has been described as an alternative method of delivering conventional rehabilitation services rather than a subspecialty (Winters 2002). The approach is relatively new, with the first related literature published in the late 1990s. Increasing interest in the use of telerehabilitation (Brochard 2010) has prompted professional bodies to draft position statements regarding its use (American Speech-Language-Hearing Association 2005; Wakeford 2005). These statements have emphasised the need to ensure that quality, ethical and legal standards are met when treatment is provided remotely rather than in person.

Many examples in the current literature demonstrate the scope of telerehabilitation. For example, home assessments to determine the need for modifications have been completed remotely by occupational therapists using a combination of still photography, telephone calls and videoconferencing technology (Sanford 2004). Physiotherapists have provided a safe and effective therapy programme for people after total knee replacement using videoconferencing (Russell 2004), and speech pathologists have demonstrated the feasibility of assessing motor speech disorders via the Internet (Hill 2006).

How the intervention might work

Telerehabilitaton has been described simply as an alternative method of providing rehabilitation. Therefore, in theory, the mechanisms leading to recovery should mirror those associated with conventional rehabilitation programmes. It is now well established that organised, interdisciplinary stroke care reduces the likelihood of institutional care and long-term disability and increases independence in activities of daily living (Kalra 2007). Improvements in function after completion of rehabilitation programmes have been attributed to a combination of physiological recovery, neuroplasticity and compensation (Kwakkel 2004).

One of the key advantages of telerehabilitation is that it provides the opportunity for people who are isolated to access rehabilitation services. This feature is particularly beneficial in vast countries such as Canada and Australia, where many people live long distances away from specialised rehabilitation centres. People in rural and remote areas are unlikely to have access to rehabilitation teams with expertise in stroke, and they may not have access to rehabilitation clinicians at all. Eliminating the need for travel to rehabilitation centres may also benefit people with severely restricted mobility who have difficulty travelling or are unable to travel.

Telerehabilitation services may also be used to complement and enhance the quality of current rehabilitation services. Stroke survivors have expressed concern regarding the lack of available long-term support and ongoing unmet rehabilitation needs (McKevitt 2011). It is possible that the use of telerehabilitation may help to address these gaps by supporting patients as they resume life roles on discharge from inpatient facilities.

Furthermore, the use of telerehabilitation may result in cost savings in various ways. Reduced travel time (for clinicians who visit patients in their own home) may mean that clinicians are able to fit more consultations into a single day. In addition, it may be possible to discharge patients from inpatient rehabilitation facilities earlier and offer telerehabilitation as a way of continuing the rehabilitation programme. Furthermore, telerehabilitation may provide a mechanism for increasing the dose of therapy without an increase in face-to-face supervision.

Despite its apparent advantages, the challenges associated with telerehabilitation are well documented (Theodoros 2008). One of the key issues facing clinicians is how to conduct assessments or provide interventions that are typically "hands on", for example, assessment of muscle strength. The inability to conduct hands-on assessment or treatment means that therapists need to modify current techniques, for example, by utilising family members or teaching the patient ways to perform the intervention independently (Russell 2009).

Furthermore, clinicians and patients may not possess the technical expertise to establish systems and to troubleshoot information and communication technologies. It has been recommended that service providers ensure that technical requirements are met (such as having adequate bandwidth), provide access to technical support and provide training to all users (clinicians and patients). Concerns have also been raised about the security of data transfer and how patient confidentiality can be maintained (American Telemedicine Association 2010).

Why it is important to do this review

Changes in the demographics of the population mean that the burden of stroke is projected to increase (Feigin 2003). New approaches that are demonstrated to be clinically sound and cost-effective will be required. Increasing interest in telerehabilitation suggests that this area will continue to grow (Brochard 2010). Furthermore, clinical guidelines for stroke now recommend telerehabilitation for people without access to centre-based rehabilitation services (Canadian Stroke Network 2006). However, establishment of telerehabilitation services may be expensive because of the costs of equipment, training and ongoing technical support. Therefore, it is important to determine whether telerehabilitation services once established may result in the desired outcomes.

Previous systematic reviews have examined the effectiveness of telerehabilitation after stroke (Johansson 2011; Kairy 2009). Kairy et al reviewed the evidence for telerehabilitation for a range of diagnostic groups (Kairy 2009). The literature search was completed in 2007 and included both experimental and observational studies. Four studies involving participants with stroke were included, all of which were observational. The authors reported that despite positive effects reported by some studies, more research was required to obtain definitive information. A more recent review looked specifically at telerehabilitation after stroke and identified nine relevant studies, of which four were RCTs (Johansson 2011). Once again, the review authors reported that although the approach showed promise and was associated with high levels of participant satisfaction, evidence was insufficient to guide practice, and no evidence regarding the cost-effectiveness of telerehabilitation was found. Several limitations were associated with these reviews, including the use of limited search terms and sources. Given the growth of research in this area and the potential for telerehabilitation to improve access to and quality of rehabilitation services while reducing costs, a review using Cochrane methodology was warranted.

OBJECTIVES

To determine whether the use of telerehabilitation leads to improved ability to perform activities of daily living amongst stroke survivors when compared with (1) in-person rehabilitation (when the clinician and the patient are at the same physical location and rehabilitation is provided face-to-face); or (2) no rehabilitation.

Secondary objectives were to determine whether use of telerehabilitation leads to greater independence in self care and domestic life and improved mobility, health-related quality of life, upper limb function, cognitive function or functional communication when compared with in-person rehabilitation and no rehabilitation. Additionally, we aimed to report on the presence of adverse events, cost-effectiveness, feasibility and levels of user satisfaction associated with telerehabilitation interventions.

METHODS

Criteria for considering studies for this review

Types of studies

We included only RCTs. We considered cross-over trials as RCTs in accordance with the guidelines of The Cochrane Collaboration (Higgins 2011). We included studies if they compared telerehabilitation with in-person rehabilitation or no rehabilitation, two different methods of delivering telerehabilitation services, different doses of telerehabilitation or telerehabilitation plus usual care compared with usual care alone.

Types of participants

All study participants had received a clinical diagnosis of stroke as defined by the World Health Organization ("a syndrome of rapidly developing symptoms and signs of focal, and at times global, loss of cerebral function lasting more than 24 hours or leading to death with no apparent cause other than that of vascular origin") (WHO 1989). We included people with all types of stroke, at all levels of severity and at all stages poststroke (acute, subacute or chronic). We also included participants with subarachnoid haemorrhage. We excluded studies with participants of mixed aetiology (e.g. stroke and traumatic brain injury) unless data were available for stroke survivors only. We set no age limits; however, we planned to acknowledge the inclusion of any participants who were younger than 18 years of age.

Types of interventions

We included Interventions if they matched the following definition of telerehabilitation: "the delivery of rehabilitation services via information and communication technologies" (Brennan 2009). Clinically, this term encompasses a range of rehabilitation services that include assessment, prevention, intervention, supervision, education, consultation and counselling (American Telemedicine Association 2010). Programmes must have lasted longer than one session. Interactive and communication technologies included the telephone, the Internet, virtual reality and monitoring via sensors or wearable devices. We included rehabilitation programmes that used "store and forward" methods of communication, or real-time interaction. Interventions were provided by one or more health disciplines (e.g. we planned to include studies involving only physical therapy). We included rehabilitation programmes that used a combination of telerehabilitation and in-person rehabilitation to conduct assessment or intervention, provided that the greater proportion of intervention was provided via telerehabilitation. We did not include the use of telerehabilitation when the purpose was

to provide education or support for healthcare professionals rather than participant care.

Types of outcome measures

Primary outcomes

The primary outcome of interest was independence in activities of daily living. In the review, this encompassed the self care, mobility and domestic life activity and participation domains derived from the International Classification of Functioning, Disability and Health (WHO 2010). Included were assessment tools scored by the healthcare professional, such as the Functional Independence Measure or the Barthel Index, and questionnaires completed by the study participant (e.g. the Nottingham Extended Activities of Daily Living Index).

Secondary outcomes

1. Self care and domestic life.
2. Mobility (e.g. Timed Up and Go test, walking speed, functional ambulation category).
3. Participant satisfaction with the intervention.
4. Self-reported health-related quality of life.
5. Upper limb function (e.g. Action Research Arm Test, Wolf Motor Function Test, Fugl-Meyer Upper Extremity measure).
6. Cognitive function (global measures such as the Mini Mental State Examination, or specific measures such as tests of attention or executive functioning).
7. Functional communication.
8. Cost-effectiveness (as measured by comparing the costs and outcomes of each intervention approach).
9. Adverse events.

We also aimed to provide information on the feasibility of telerehabilitation for use with stroke patients by reporting on participant eligibility criteria and recruitment methods used in the individual studies identified.

Search methods for identification of studies

See the 'Specialized register' section in the Cochrane Stroke Group module. We searched for relevant trials in all languages and planned to arrange translation of trial reports published in languages other than English, if necessary.

Electronic searches

We searched the Cochrane Stroke Group Trials Register, which was searched by the Managing Editor in November 2012 using the intervention code telerehabilitation, and the Cochrane Effective Practice and Organisation of Care (EPOC) Group Trials Register in November 2012 using the terms (stroke or brain infarc or cerebral infarc or brain stem infarc) AND tele* as well as (stroke OR brain infarc OR cerebral infarc OR brain stem infarc) AND telerehab*. In addition, we searched the following electronic bibliographic databases: the Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library*, Issue 11, November 2012), MEDLINE (Ovid, 1950 to November Week 1, 2012) (Appendix 1), EMBASE (Ovid, 1980 to 11 November 2012) (Appendix 2), AMED (Ovid, 1985 to 18 November 2012) (Appendix 3), CINAHL (Ebsco, 1982 to 11 November 2012) (Appendix 4), PsycINFO (Ovid, 1840 to 11 November 2012) (Appendix 5), PsycBITE (Psychological Database for Brain Impairment Treatment Efficacy, www.psycbite.com/ to 8 November 2012), OTseeker (www.otseeker.com to 8 November 2012), Physiotherapy Evidence Database (www.pedro.org.au to 9 November 2012), REHABDATA (www.naric.com/research/rehab/ to 9 November 2012) and the Health Technology Assessment Database (HTA) (www.crd.york.ac.uk/crdweb/ to 9 November 2012). We developed the MEDLINE search strategy with the help of the Cochrane Stroke Group Trials Search Co-ordinator and used a combination of controlled vocabulary and text word terms. We adapted this strategy for use with the other databases. Search words for trial registers and for other Web-based databases included telerehabilitation, telemedicine, telehealth, videoconferencing and stroke.

We also:

1. searched the following ongoing trials registers: Current Controlled Trials (www.controlled-trials.com), National Institutes of Health Clinical Trials Database (www.clinicaltrials.gov), Stroke Trials Registry (www.strokecenter.org/trials/), EU Clinical Trials Register (www.clinicaltrialsregister.eu), WHO International Clinical Trials Registry Platform (www.who.int/ictrp/en/) and Australian New Zealand Clinical Trials Registry (www.anzctr.org.au/) to 11 November 2012;
2. used the Cited Reference Search within Science Citation Index (SCI) and Social Science Citation Index (SSCI) to track relevant references;
3. searched Dissertation Abstracts (to 9 November 2012) and contacted key researchers in the area and international telemedicine organisations;
4. searched the UK Telemedicine and E-health Information Service (www.teis.port.ac.uk/); and
5. searched the grey literature using Open Grey (www.opengrey.eu) and Google Scholar (http://scholar.google.com) on 13 November 2012.

Searching other resources

To identify further published, unpublished and ongoing trials, we:

1. scanned the reference lists of all identified studies and reviews;

2. scanned the abstracts of non-English language studies if they were available in English; and

3. searched the proceedings of the American Telemedicine Association International Meetings (2005 to 2012) and the International Congress on Telehealth and Telecare (2011 to 2012).

Data collection and analysis

Selection of studies

Two review authors (KEL and DS) independently reviewed titles and abstracts of the records identified through searches and excluded obviously irrelevant studies. We obtained the full text of the remaining studies, and two review authors (KEL and DS) selected studies for inclusion based on the inclusion criteria of the review. When unsure regarding inclusion of a particular study, a third review author (MC, SG or CS) made the final decision. We contacted trial authors for further details when required and documented the reasons for exclusion.

Data extraction and management

Two review authors (KEL and DS) independently extracted study data and recorded information on a predesigned data extraction form. We extracted the following study details.

1. Citation details: title, authors, source and year of publication.
2. Participant inclusion and exclusion criteria.
3. Participant details: age, gender, location of stroke, time since onset of stroke and level of disability.
4. Recruitment details: numbers of people screened, eligible, recruited and randomly assigned; withdrawals.
5. Methodological quality: The Cochrane Collaboration's tool for assessing risk of bias.
6. Intervention details: descriptions of procedures, personnel involved, duration, dose and comparison interventions.
7. Outcome measures: measures used, by whom, when they were administered and how they were administered (in person or via information and communication technologies).

We contacted trial authors to ask for missing information when required. We resolved differences by discussion or by consultation with a third review author when necessary.

Assessment of risk of bias in included studies

Two review authors (KEL and DS) independently assessed the risk of bias of included studies using The Cochrane Collaboration's 'Risk of bias' tool (Higgins 2011). This tool allows assessment of the following possible sources of bias: random sequence generation; allocation concealment; blinding of outcome assessors; incomplete outcome data; selective reporting; and any other potential sources of bias. We did not report on whether studies were able to blind participants or personnel because of the difficulties involved in achieving this in rehabilitation trials. We compared each study against the tool and assessed it as "low risk", "high risk" or "unclear risk" of bias, depending on whether it met the criteria for each aspect of the tool. A third review author resolved any disagreements.

Measures of treatment effect

Two review authors (KEL and DS) independently assigned outcome measures to the domain assessed (activities of daily living, participant satisfaction, health-related quality of life, mobility, upper limb function, cognitive function, functional communication). If more than one outcome measure was used in the same domain from the same study, we included the measure most frequently used across included studies.

We intended to conduct separate analyses between short-term (less than three months after intervention) and long-term (three months or longer) outcomes.

We planned to calculate risk ratios (RRs) and 95% confidence intervals (CIs) for dichotomous outcomes and mean differences (MDs), or standardised mean differences (SMDs) and 95% CIs for continuous outcomes, as appropriate.

Unit of analysis issues

The unit of randomisation in these trials was the individual participant. For three-armed trials in which telerehabilitation was compared with in-person or no rehabilitation, we intended to enter half the sample size for the telerehabilitation group. Thus, each alternative intervention would be included in a separate comparison, and the number of participants in the telerehabilitation group would be divided equally between comparisons; the telerehabilitation group mean and standard deviation would remain unchanged.

Dealing with missing data

We contacted trial authors to ask for missing data. We planned to convert available data when possible (e.g. when data are reported as standard error) using the procedures detailed in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011). We intended to deal with missing data as recommended by the *Cochrane Handbook for Systematic Reviews of Interventions*. When dropouts were clearly identified, we used the denominator of participants contributing data at the relevant outcome assessment.

Assessment of heterogeneity

When appropriate, we pooled results to present an estimate of treatment effect using a random-effects model. We assessed heterogeneity by performing visual inspection of the forest plot along with the I^2 statistic (Higgins 2011).

Assessment of reporting biases

We sought to reduce the impact of publication bias by searching clinical trials registers for studies. In addition, we investigated whether selective reporting occurred by comparing study protocols and the methods sections of papers with the results sections. We intended to assess small sample bias by preparing a funnel plot.

Data synthesis

We conducted a meta-analysis based on a random-effects model with 95% CIs using RevMan 5.2 (RevMan 2012). We explored heterogeneity as detailed below.

Subgroup analysis and investigation of heterogeneity

If a sufficient number of comparable studies were identified, we planned to perform subgroup analyses to determine whether outcomes varied according to time since onset of stroke, severity of stroke, frequency of the intervention (occasions of service per week), intensity of the intervention (total hours of intervention), intervention approach selected (e.g. speech therapy, upper limb retraining), mode of delivery (e.g. telephone versus videoconferencing, real-time communication versus "store and forward") and whether the intervention was provided by a multidisciplinary team or by members of a single discipline.

Sensitivity analysis

We intended to perform sensitivity analyses based on the methodological quality of studies (allocation concealment, blinding of outcome assessor, intention-to-treat analysis) to assess the impact of risk of bias in the included studies. We also planned to conduct a sensitivity analysis to identify differences noted when a fixed-effect versus a random-effects model was used.

RESULTS

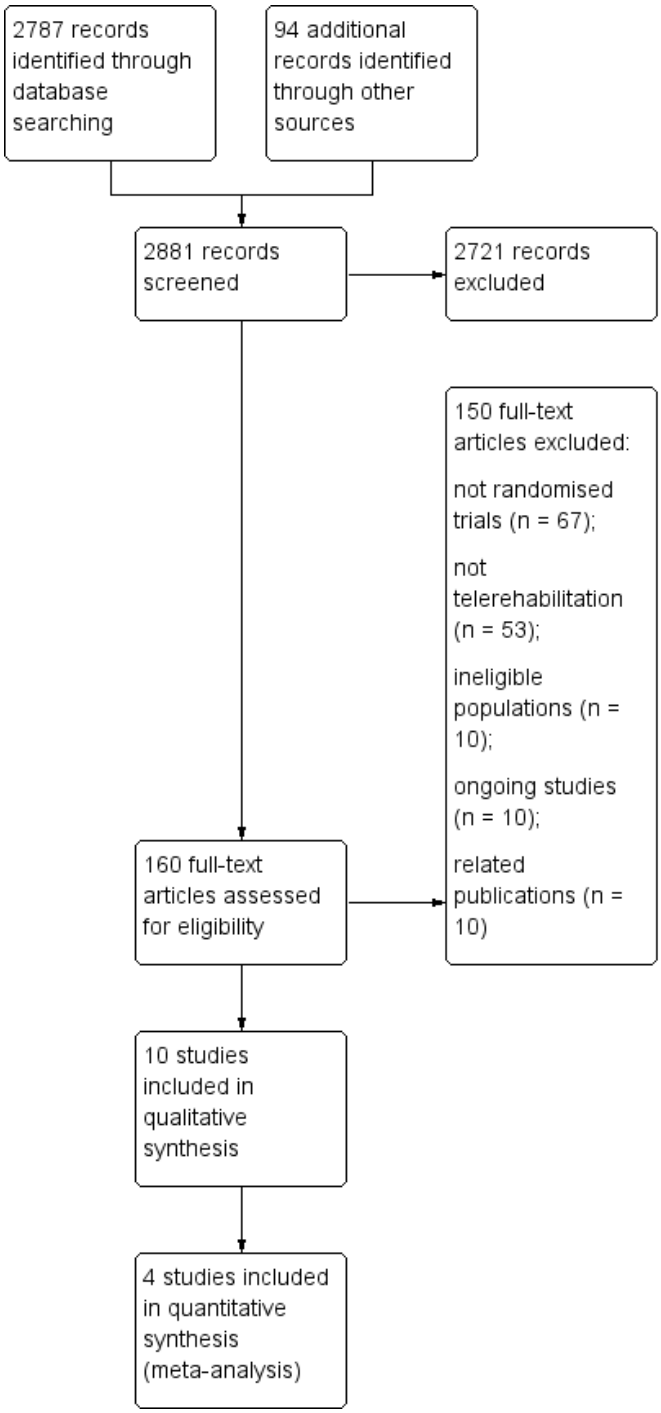
Description of studies

See: Characteristics of included studies; Characteristics of excluded studies; Characteristics of ongoing studies.

Results of the search

We identified 29 studies by searching the Cochrane Stroke Group trials register, 28 studies by searching the Cochrane EPOC Group trials register and 2787 references by searching electronic databases, totaling 2881 references. Of these records, we found 22 on clinical trials registries. We reviewed 160 articles in full text and contacted study authors to request more information when required, excluding articles that did not meet the inclusion criteria. Details of the 16 excluded studies are provided in the 'Characteristics of excluded studies' table. We identified 10 ongoing studies (Characteristics of ongoing studies). Search details are presented in the flow diagram (Figure 1).

Figure 1. Study flow diagram.



Included studies

We included 10 RCTs, with a total of 933 participants, in the review.

Sample characteristics

Included studies were conducted in the United States (n = 5), The Netherlands (n = 2), Italy (n = 2) and Canada (n = 1). All studies were published within the previous 10 years (between 2004 and 2012). Sample sizes ranged from 11 to 536; most studies included fewer than 50 participants (Table 1; Table 2).

Most participants in the included studies were aged in their 50s, 60s and 70s. Similar numbers of male and female participants were included, with the exception of two studies (Chumbler 2012; Smith 2012), for which only male participants were recruited. Two studies recruited participants in the acute stages poststroke (Boter 2004; Mayo 2008), whereas the rest of the studies involved participants in subacute and chronic stages.

Criteria for participant inclusion and exclusion varied amongst studies. Five studies stated that they excluded participants with significant cognitive impairment (Chumbler 2012; Deng 2012; Huijgen 2008; Piron 2008; Piron 2009), although this condition was defined differently between studies; two studies stated that participants needed to have a caregiver available (Forducey 2012; Smith 2012).

As seen in Table 1, among 1427 stroke survivors screened across all studies, 860 were recruited, resulting in a participation rate of 60%. This rate varied widely between studies, ranging from 15% (Carey 2007) to 100% (Chumbler 2012).

Interventions

All interventions were delivered in the participant's own home.

The primary aim of the intervention varied across the studies. Four studies aimed to improve upper limb function through the use of customised computer-based training programmes (Carey 2007; Huijgen 2008; Piron 2008; Piron 2009). Two studies aimed to improve lower limb function and mobility (Chumbler 2012; Deng 2012); one of these studies delivered exercises using a customised computer-based training programme (Deng 2012), whereas the other involved delivery of an exercise programme based on a combination of technologies to enable communication between the participant and the teletherapist. One study used a combination of occupational therapy and physiotherapy to provide rehabilitation that often focused on remediation of impaired limbs (Forducey 2012), two studies aimed to provide support to the person in the home using a case management intervention consisting of home visits and telephone calls (Boter 2004; Mayo 2008) and the remaining study aimed to support the caregivers of stroke survivors by providing them with education and professional and peer support (Smith 2012).

Several different types of information and communication technologies were used to deliver telerehabilitation interventions. These included the telephone (Boter 2004; Mayo 2008), videoconferencing hardware and software (Carey 2007; Deng 2012; Huijgen 2008; Piron 2008; Piron 2009) and desktop videophones (Forducey 2012). Two studies used a combination of technologies: Chumbler 2012 used a combination of telephone calls, an in-home messaging device and video recordings taken by a research assistant to be reviewed by the teletherapist. Smith 2012 used a combination of email, an online chat programme and an online resource room (a virtual online library) established for caregivers of stroke survivors.

Most interventions were conducted entirely by using information and communication technologies (Carey 2007; Deng 2012; Forducey 2012; Huijgen 2008; Piron 2008; Piron 2009). Two studies used a combination of telephone calls and home visits (Boter 2004; Mayo 2008). The remaining study (Chumbler 2012) used "store and forward" methods in which the research assistant video-recorded the participant in his or her home and transmitted the information to the teletherapist for review.

With regard to the comparison interventions used in the studies, two studies compared different models of telerehabilitation (Carey 2007; Deng 2012), five studies compared telerehabilitation with an alternative intervention (Forducey 2012; Huijgen 2008; Piron 2008; Piron 2009; Smith 2012) and the remaining studies (Boter 2004; Chumbler 2012; Mayo 2008) compared telerehabilitation with usual care, when no specific intervention was provided by the trialists.

A wide range of outcome measures were used to assess the effects of the range of intervention approaches. These included measures of physical function, independence in activities of daily living, quality of life and participant satisfaction. All studies assessed outcome measures postintervention. Several studies included follow-up at one month (Piron 2009; Smith 2012), three months (Carey 2007; Chumbler 2012) or six months (Mayo 2008) after completion of the intervention.

Excluded studies

We deemed 16 studies to be ineligible: four because of ineligible populations (e.g. traumatic brain injury or transient ischaemic attack), two because they were not randomised trials and the remaining 10 because the intervention did not meet our definition of telerehabilitation (Characteristics of excluded studies).

Risk of bias in included studies

Refer to Figure 2; Figure 3.

Figure 2. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

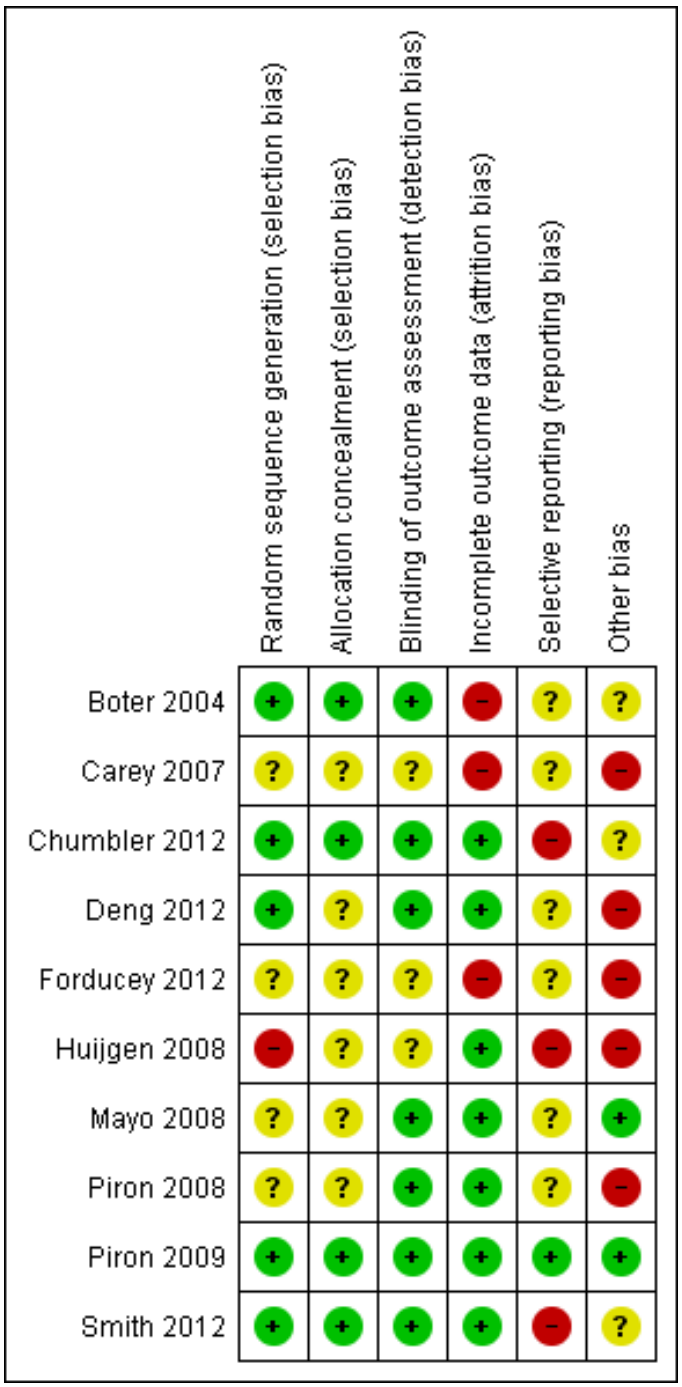
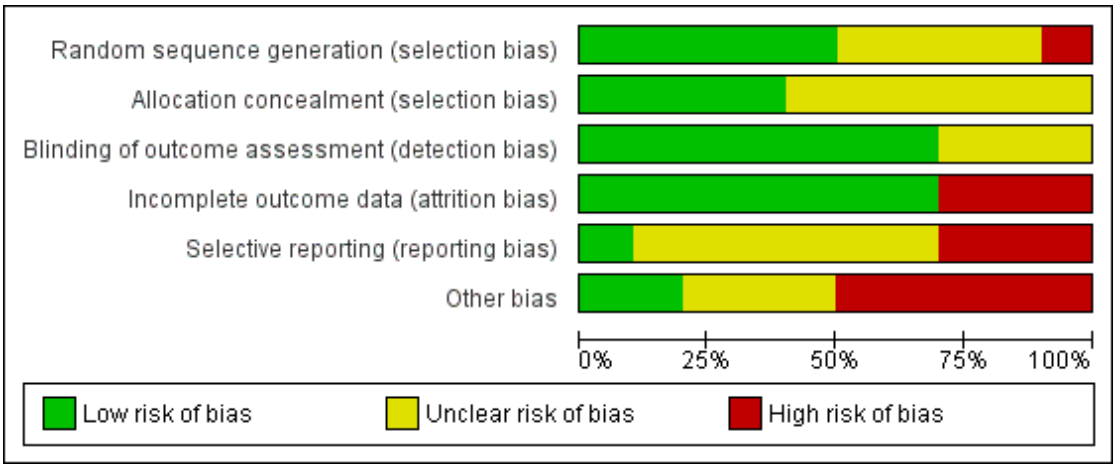


Figure 3. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.



Allocation

Allocation concealment was adequate in four studies (Boter 2004; Chumbler 2012; Piron 2009; Smith 2012) but was unclear in the reports of the remaining studies.

Blinding

Partial blinding of participants and personnel was performed in one of the studies, in which participants were masked to the study objectives because of postponed informed consent procedures (Boter 2004). It was unclear whether the outcome assessor was blinded to intervention group allocation in three studies (Carey 2007; Forducey 2012; Huijgen 2008). The remaining studies clearly stated that the assessor was blinded to allocation.

Incomplete outcome data

Outcome data were incomplete in three studies (Boter 2004; Carey 2007; Forducey 2012). This was deemed adequate in the remaining studies.

Selective reporting

One trialist reported study data to be free of selective reporting (Piron 2009). In three studies, selective reporting was identified (Chumbler 2012; Huijgen 2008; Smith 2012). It was unclear whether selective reporting occurred in the remaining studies.

Other potential sources of bias

Several studies were identified as being at risk of bias because of small sample sizes or differences between groups at baseline, or both (Carey 2007; Deng 2012; Forducey 2012; Huijgen 2008; Piron 2008). It was unclear whether other studies were at risk of other sources of bias.

Effects of interventions

Primary outcome

Four studies presented outcomes for the primary outcome: independence in activities of daily living (Boter 2004; Chumbler 2012; Forducey 2012; Mayo 2008). Significant clinical heterogeneity between studies was noted with regard to the purpose of the intervention and the comparison intervention (described below). Two studies were similar enough to indicate that pooling was appropriate (Boter 2004; Mayo 2008).

Comparison 1.1. Independence in activities of daily living

Two studies (Boter 2004; Mayo 2008) including 661 participants used a case management approach after discharge, provided via a combination of telephone calls and home visits. The control group received usual care, in which the trialists did not provide intervention; however, participants may or may not have received follow-up from other sources. The estimated effect of telerehabilitation on activities of daily living as measured by the Barthel Index was SMD 0.00, 95% CI -0.15 to 0.15 (Analysis 1.1).

One study (Forducey 2012) compared a telerehabilitation intervention delivered by physiotherapists and occupational therapists, in which the primary aim was restoration of physical function, versus a more conventional rehabilitation approach delivered face-to-face. Both groups received the same dose of therapy. Participants

receiving telerehabilitation communicated with the therapist via a desktop videophone connected to a standard home telephone line. The authors reported that both telerehabilitation and control groups showed statistically significant improvement in activities of daily living. No significant differences in improvement were noted between groups.

Another study (Chumbler 2012) compared a combination of technologies (video recordings, in-home messaging and phone calls) in an intervention designed to improve functional mobility versus usual care and reported no statistically significant differences between groups after the intervention was provided.

Secondary outcomes

Mobility

One study, which was designed primarily to provide case management intervention (Mayo 2008), assessed mobility postintervention using the Timed Up and Go test and reported no significant differences between groups postintervention or at follow-up six months after stroke.

Participant satisfaction with the intervention

Three studies reported outcomes related to participant satisfaction with the intervention using different scales (Boter 2004; Huijgen 2008; Piron 2008). Two of these studies (Huijgen 2008; Piron 2008) compared upper limb therapy delivered via customised computer programmes and telerehabilitation versus therapy provided in-person or for self-completion. We were unable to obtain the data required to pool these studies; however, both studies reported that participants in the intervention and control groups had high levels of satisfaction with the intervention. The remaining study (Boter 2004), which compared case management provided for up to six months postdischarge versus usual care, also reported no significant differences in satisfaction with care between intervention and control groups.

Self-reported health-related quality of life

Three studies reported outcomes for health-related quality of life (Boter 2004; Forducey 2012; Mayo 2008). It was inappropriate to pool results because of clinical heterogeneity between studies and the ways in which outcome measures were reported. One of the studies, which provided a case management intervention (Boter 2004), reported that participants in the intervention group had better scores in the domain of 'role limitations due to emotional health' on the Short Form (SF)-36; however, no other significant differences were noted between groups. Another study, which also provided case management intervention (Mayo 2008), reported that people in the intervention group were more likely to respond to one or more of the outcomes within the SF-36 subscales (odds ratio (OR) 1.41, 95% CI 1.11 to 1.79). The remaining study involved a programme of physiotherapy and occupational therapy (Forducey 2012), and investigators reported that although both groups reported improvement in health-related quality of life, no differences between groups were evident after the intervention was provided.

Upper limb function

Comparison 2.1. Upper limb function

We pooled two studies conducted by the same research team (Piron 2008; Piron 2009), which consisted of 46 participants and used a computer software programme to retrain upper limb function. One of the studies compared the intervention versus the same intervention delivered in person (Piron 2008), and the other study (Piron 2009) compared use of a virtual reality programme provided via telerehabilitation versus conventional therapy delivered in person. Participants in both studies were assessed with the Fugl-Meyer Upper Extremity Scale postintervention. The impact of telerehabilitation on upper limb function was not significantly different from the impact of the control intervention: MD 3.65, 95% CI -0.26 to 7.57 (Analysis 2.1).

An additional study, for which we were unable to obtain the data required for pooling (Huijgen 2008), reported that no significant differences were observed between groups on the Action Research Arm Test or the Nine-Hole Peg Test after intervention.

Other secondary outcomes

No studies reported on outcomes in the categories of self care and domestic life, cognitive function, functional communication or cost-effectiveness. No studies reported on the presence of adverse events during completion of the studies.

Studies comparing two different telerehabilitation interventions

Two studies included in the review compared different forms of telerehabilitation (Carey 2007; Deng 2012). Although the main aim of the studies was different, with one study (Carey 2007) aiming to improve finger and wrist movement and the other study (Deng 2012) aiming to improve ankle movement, these studies were similar with regard to the method of intervention and the comparison and were conducted by the same research group. Both studies compared a computer programme that provided feedback on movement and accuracy versus a programme that provided less feedback. Teleconferencing was used in both studies to enable communication with the therapist. Carey 2007 found that both groups improved on measures of hand function after intervention, with no clear difference noted between the groups. The other study (Deng 2012) reported that after intervention, both

groups exhibited an increase in dorsiflexion during gait; this was significantly greater in the group that received more feedback.

DISCUSSION

Summary of main results

We found 10 studies (with 933 participants) that were eligible for inclusion in this review. Because of clinical heterogeneity between studies, it was inappropriate to pool data in most cases.

Independence in activities of daily living

We pooled data from two trials with 661 participants that compared a case management intervention including telephone calls after discharge from hospital versus usual care. Data from these trials showed no evidence of a beneficial effect of telerehabilitation when compared with usual care. However, the strength of the evidence justifies further research in this area.

Two additional studies (Chumbler 2012; Forducey 2012) assessed independence in activities of daily living after telerehabilitation intervention; one compared telerehabilitation versus face-to-face therapy, and the other compared telerehabilitation versus usual care, which may or may not have included any intervention. Both studies failed to find any significant differences in outcomes between the groups postintervention.

Secondary outcomes

We pooled two trials (Piron 2008; Piron 2009) with 46 participants that aimed to retrain upper limb function using a computer programme administered via telerehabilitation. These studies were small; thus evidence was insufficient to allow conclusions on whether the intervention was more effective than the comparison upper limb therapy programme.

It was inappropriate to conduct further analyses because of heterogeneity between studies. Limited information and insufficient evidence prevented conclusions regarding the effects of telerehabilitation on mobility, participant satisfaction and health-related quality of life.

We were unable to find any data related to our other secondary outcomes of self care and domestic life, cognitive function, functional communication and cost-effectiveness.

Overall completeness and applicability of evidence

Despite our extensive search strategy, we were able to find few RCTs that were eligible for inclusion in this review. Furthermore, significant heterogeneity was noted between the included studies with regard to the intervention used, the information and communication technologies involved and the comparison intervention and outcomes assessed. Most studies involved small sample sizes. All studies were published over the past 10 years, demonstrating that this approach is relatively new in rehabilitation. However, our review of the 10 trials provides information about the current state of telerehabilitation research; we also identified 10 ongoing studies, which suggests that research in this area is increasing.

Several studies evaluated interventions involving specialised software and hardware programmes (Carey 2007; Deng 2012; Huijgen 2008; Piron 2008; Piron 2009). Although these studies provide important information regarding the effects of novel technologies, these intervention programmes are not readily accessible to clinicians. Two other studies evaluated interventions that provided case management using a combination of home visits and phone calls (Boter 2004; Mayo 2008). These studies appear to have been designed to evaluate the effectiveness of the case management intervention rather than telerehabilitation per se. However, they met our inclusion criteria and therefore were included in this review. Another study was directed at supporting caregivers of people with stroke using a combination of online resources, online peer support and a facilitator (Smith 2012). Therefore, only the two remaining studies were primarily designed to evaluate the delivery of common rehabilitation interventions to stroke survivors via telerehabilitation (Chumbler 2012; Forducey 2012). More research is required to investigate whether telerehabilitation can be used as an alternative or as a supplement to conventional therapy that is delivered face-to-face. Furthermore, although telerehabilitation is purported to reduce the cost of administering an intervention, none of the studies included in this review reported on cost-effectiveness.

In addition, little information is currently available on the usability of information and communication technologies that are used to deliver telerehabilitation. Most studies used simple telephone or videoconferencing equipment, and few examples were provided of more complex technologies such as wearable sensors or remote monitoring or combinations of technology.

Participants in these studies tended to be aged in their 50s, 60s or 70s, whereas the average age of stroke is one to two decades older. Older people are frequently considered to be less confident in using new technologies and may prefer to participate in face-to-face therapy. Some studies excluded patients with cognitive impairment, which may limit the transferability of this approach. None of the studies reported on participants' level of confidence or familiarity with technologies. Furthermore, more information is needed regarding the support required to administer telerehabilitation: whether a caregiver is required to assist, how much technology support is required and whether the person needs to have a certain infrastructure in place (such as a high-speed Internet connection). Studies rarely reported on these factors or how investigators dealt with issues of privacy and protection of data.

The use of technology to facilitate communication may lead to miscommunication. For example, the healthcare professional may make errors in assessment of the patient, or the patient may misunderstand advice or instructions provided by the healthcare professional. We were unable to identify any information in the included trials regarding harms associated with telerehabilitation.

Quality of the evidence

Many studies involved small sample sizes; larger, more adequately powered studies are required to provide more conclusive evidence. The reporting of many studies was not consistent with the CONSORT guidelines (Schulz 2010), and it was unclear in many cases whether studies were at risk of bias because of poor reporting and lack of clarification from study authors. In particular, in some cases, we were unable to determine whether the outcome assessor was blinded to the intervention, or whether allocation was concealed. Selective outcome reporting was apparent in several studies.

Potential biases in the review process

Our search strategy was comprehensive and included searches of clinical trial registers and the grey literature. However, it is possible that we missed studies. Although we contacted the authors of included and ongoing studies, not all authors responded. Therefore, the methodology of some studies was unclear, and we were unable to obtain some data for analyses.

Agreements and disagreements with other studies or reviews

This review identified a greater number of randomised trials than were described in previous reviews. However, our conclusions are similar: Despite the theoretical advantages of telerehabilitation, evidence is currently insufficient to allow conclusions on its effects.

AUTHORS' CONCLUSIONS

Implications for practice

Evidence is currently insufficient to guide practice.

Implications for research

The potential advantages of telerehabilitation are clear and have the potential to facilitate access to services (thereby improving equity) and reduce costs associated with providing rehabilitation programmes. Therefore, more research in the form of adequately powered high-quality randomised controlled trials (RCTs) is urgently required. In addition, given that several RCTs are under way, we plan to update this review once the results of these trials become available. Researchers in this area should familiarise themselves with the ongoing studies identified within this review and should address the remaining gaps, which are substantial.

Although a growing body of pilot and feasibility studies has been identified, additional RCTs are required to determine the effectiveness of the intervention. Researchers should ensure that studies are adequately powered, are of high methodological quality and are reported in compliance with CONSORT guidelines (Schulz 2010).

Telerehabilitation offers great potential as a replacement for, or as an addition to, current therapies. In the first instance, it is important to understand whether differences have been identified in delivery of the same therapy programme in-person or via information and communication technologies. Therefore, of interest to clinicians are studies that compare telerehabilitation versus conventional therapy, that is, treatment delivered face-to-face, or studies that provide telerehabilitation in addition to conventional therapy.

Evaluation of cost-effectiveness should be prioritised and incorporated into future studies. Furthermore, the use of mixed methods research is valuable in uncovering further information about the usability of telerehabilitation technologies, participant satisfaction with the intervention and challenges associated with recruitment of participants.

It is currently unclear which patient groups are most likely to benefit from telerehabilitation, for example, whether people living in remote areas may benefit and whether people that require enhanced support or rehabilitation on discharge or those many years poststroke would benefit from a short-term programme of rehabilitation.

It is also unclear which types of therapies are best suited to telerehabilitation. Clinicians may find it difficult to adapt their practice to provide services via information and communication technologies, particularly when "hands-on" assessment or treatment is typically involved. It may be that some therapies that do not typically involve "hands-on" assessment (such as speech therapy or counselling) are best suited to this method of delivery.

The studies in this review identified a wide range of outcome measures. It is worth noting that trials do not necessarily have to demonstrate that telerehabilitation services result in superior outcomes in contrast to face-to-face therapy but rather that they result in equal outcomes.

The use of telerehabilitation has only recently emerged and is likely to become increasingly viable as information and communication technologies become more sophisticated and user friendly. It is important that therapists consider how their practice may be adapted so that services can be delivered remotely.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Boter 2004

Methods	RCT
Participants	Recruited from 12 hospitals in The Netherlands Inclusion criteria: Dutch speaking, ≥ 18 years of age, first admission for a stroke, hospitalisation within 72 hours after onset of symptoms, life expectancy > 1 year, independent from or partially dependent on discharge (Rankin grade 0 to 3), discharged home, residence within 40 kilometres of catchment areas served by hospitals Exclusion criteria: failure to meet above criteria Age, years: intervention group median (IQR) = 66 (52 to 76), control group median (IQR) = 63 (51 to 74) Gender: intervention group 49% male, control group 48% male Time poststroke: not reported
Interventions	Telerehabilitation intervention: 3 nurses initiated telephone contacts (1 to 4; 4 to 8; and 18 to 24 weeks after discharge) and visits to participants in their homes (10 to 14 weeks after discharge). Stroke nurses used a standardised checklist of risk factors for stroke, consequences of stroke and unmet needs for services. Nurses supported participants and caregivers according to their individual needs (e.g. by providing information or reassurance) or advised participants to contact their GP when further follow-up was required. Written educational material was provided and discussed. Nurses aimed to support participants and caregivers in solving problems themselves or coping with them rather than solving problems for them Control intervention: standard care
Outcomes	Timing of outcome assessment: baseline and post-intervention (6 months after discharge) Measures: Barthel Index, Rankin Grade, Satisfaction with Stroke Care questionnaire, SF-36, Hospital Anxiety and Depression Scale, health service utilisation (GP), readmissions, therapy, activities of daily living care, rehabilitation, aids, secondary prevention drugs, caregiver questionnaires
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computerised programme
Allocation concealment (selection bias)	Low risk	Central telephone service used
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Outcome assessor was blinded to allocation

Boter 2004 (*Continued*)

Incomplete outcome data (attrition bias) All outcomes	High risk	Additional data collected at 6 months and not reported in the paper
Selective reporting (reporting bias)	Unclear risk	No protocol available
Other bias	Unclear risk	Unable to identify further bias

Carey 2007

Methods	RCT
Participants	Recruited from the community via advertising in a local paper and local stroke support group meetings in the USA Inclusion criteria: more than 12 months poststroke, between 30 and 80 years old, satisfactory corrected vision to recognise the full tracking target and cursor movement, ≥ 90 degrees of passive extension-flexion movement at the index finger metacarpophalangeal joint of the paretic hand (no contracture) and at least 10 degrees of active movement at this joint Exclusion criteria: unable to undergo fMRI, pregnancy or claustrophobia Age, years: intervention group (Track) mean = 65.9 (SD 7.4), intervention group (Move) mean = 67.4 (SD 11.8) Gender: intervention group (Track) 90% male, intervention group (Move) 60% male Time poststroke: intervention group (Track) mean 42.5 months (SD 24.3), intervention group (Move) mean 35.6 months (SD 26.1)
Interventions	Both groups received telerehabilitation. The aim of the intervention was to practice finger and wrist movements. Training was completed on a laptop using customised tracking software without direct supervision by the therapist. Both groups performed 180 tracking trials per day for 10 days. Regular teleconferencing (mobile phone and Webcam operating over the Internet) occurred between therapist and participant Telerehabilitation intervention (Track group): tracking software provided feedback and an accuracy score Telerehabilitation intervention (Move group): tracking software showed a sweeping cursor representing movement, however did not provide the target or response or an accuracy score
Outcomes	Timing of outcome assessment: baseline and post-intervention Measures: Box and Block test, Jebsen Taylor test, finger ROM, finger movement tracking test, fMRI
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Not reported

Carey 2007 (*Continued*)

Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	High risk	Substantial loss of participants at follow-up
Selective reporting (reporting bias)	Unclear risk	No protocol available
Other bias	High risk	Small sample size and considerable differences between groups in mean values on some outcome measures at baseline, although these differences were not statistically significant

Chumbler 2012

Methods	RCT
Participants	Recruited from 3 Veterans Affairs Medical Centres in the USA Inclusion criteria: ischaemic or haemorrhagic stroke within the previous 24 months; participants aged 45 to 90 years, discharged to the community, not cognitively impaired (no more than 4 errors on the Short Portable Mental Status Questionnaire), able to follow a 3-step command, discharge motor Functional Independence Measure score of 18 to 88, approval by participants and physician; signed medical media release form Exclusion criteria: failure to meet above criteria Age, years: intervention group: mean = 67.1 (SD 9.5), control group: mean = 67.7 (SD 10) Gender: intervention group: 96% male; control group: 100% male Time poststroke: intervention group median 26 days, control group median 74 days
Interventions	Telerehabilitation intervention: the purpose of the intervention was to improve the participant's functional mobility. Intervention included 3 televisits, use of an in-home messaging device (IHMD) and 5 telephone calls over a 3-month period. The televisits involved assessment of physical function, goal setting and demonstration of exercises; a research assistant used a camcorder to record the home environment and the participant completing tests of physical and functional performance that were later reviewed by the teletherapist. The therapist asked the participant questions via the IHMD and provided positive encouragement to maximise exercise adherence. Telephone calls were used to problem-solve any barriers to exercise and to review and advance the exercise programmes Control intervention: usual care
Outcomes	Timing of outcome assessment: baseline, post-intervention (3 months) and 6 months Measures: motor subscale of the Functional Independence Measure (telephone version) , Late Life Function and Disability Instrument, stroke-specific participant satisfaction with care questionnaire, Falls Self-Efficacy Scale

Chumbler 2012 (*Continued*)

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computer-generated sequence
Allocation concealment (selection bias)	Low risk	Centralised computer programme
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinded outcome assessors
Incomplete outcome data (attrition bias) All outcomes	Low risk	ITT analyses completed. Small numbers of missing data, which were explained and balanced across groups
Selective reporting (reporting bias)	High risk	The publication does not present the results for all outcome measures listed in the study protocol
Other bias	Unclear risk	Unable to identify further bias

Deng 2012

Methods	RCT
Participants	Recruited from the community. Study conducted in the USA Inclusion criteria: poststroke duration of at least 5 months, at least 10 degrees of active dorsiflexion/plantar flexion at the paretic ankle, ability to understand the tasks, ability to ambulate 30 metres Exclusion criteria: indwelling devices incompatible with MRI Age, years: telerehabilitation (Track) group mean = 51.4 (SD 11.5), telerehabilitation (Move) group mean = 58 (SD 13.4) Gender: track group 38% male; Move group 100% male Time poststroke: track group median 66 months; Move group median 16.5 months
Interventions	Both groups received telerehabilitation. The aim of the intervention was to practice ankle movements. Training was completed on a laptop using customised tracking software without direct supervision by the therapist. Both groups performed 180 repetitions for 20 days. Regular teleconferencing using Skype occurred between the therapist and the participant, and the computer automatically emailed daily records to the laboratory computer to allow monitoring of performance Telerehabilitation intervention (Track group): tracking software provided feedback and an accuracy score Telerehabilitation intervention (Move group): tracking software showed a sweeping cursor representing the movement; however did not provide the target or response or an accuracy score

Deng 2012 (*Continued*)

Outcomes	Timing of outcome assessment: baseline and post-intervention Measures: gait analysis, 10-metre walk test, fMRI
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Electronically generated randomisation list
Allocation concealment (selection bias)	Unclear risk	Not clearly reported
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinded outcome assessors
Incomplete outcome data (attrition bias) All outcomes	Low risk	Attrition reported with reasons and similarities between groups
Selective reporting (reporting bias)	Unclear risk	No access to protocol
Other bias	High risk	Small sample size

Forducey 2012

Methods	RCT
Participants	Recruitment details unclear. Study took place in the USA Inclusion criteria: first time medical diagnosis of acute stroke, onset of stroke was at 6 or fewer months, Medicare or Blue Cross and Blue Shield insurance coverage, moderate deficits in the areas of self care, functional mobility, transfers as documented by the Functional Independence Measure, caregiver present to set up telehealth videophone device Exclusion criteria: aphasia or major depressive disorder, as measured by the Beck Depression Inventory II Age, years: mean age of all participants was 60 Gender: 55% male Time poststroke: not reported
Interventions	Telerehabilitation intervention: 12 treatment sessions (6 occupational therapy and 6 physiotherapy) were provided over approximately 6 weeks. Interventions included education, retraining of self care, functional mobility and posture, home modifications and therapy to improve function in impaired limbs. Communication between therapist and participant occurred via a desktop videophone using standard telephone lines Control intervention: included the same content; however, was delivered in person

Forducey 2012 (*Continued*)

Outcomes	Timing of outcome assessment: baseline and post-intervention Measures: Functional Independence Measure, SF-12
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not reported
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	High risk	Lack of detail in reporting the results
Selective reporting (reporting bias)	Unclear risk	Not able to access protocol
Other bias	High risk	Small sample size

Huijgen 2008

Methods	RCT
Participants	Recruited from a rehabilitation service in The Netherlands Inclusion criteria: age > 18 years; established diagnosis of multiple sclerosis, stroke or traumatic brain injury; taking more than 25 seconds to perform the Nine-Hole Peg Test, ability to move at least 1 peg in 180 seconds during the Nine-Hole Peg Test, sufficient autonomous functioning, Internet connection or telephone line and reachable Internet provider, stable clinical status, living at home Exclusion criteria: disturbed upper limb function not related to multiple sclerosis, traumatic brain injury or stroke; serious cognitive and/or behavioural problems, major visual problems, communication problems, medical complications; other problems, possibly contraindicating autonomous exercise at home Age, years: telerehabilitation group mean = 69 (SD 8), control group mean = 71 (SD 7) Gender: telerehabilitation group 18% males, control group 80% males Time poststroke: telerehabilitation group mean 3 (SD 2) years, control group mean 1.8 (SD 0.8) years
Interventions	Telerehabilitation intervention: 1 month of usual care followed by approximately 4 training sessions with the Home Care Activity Device (HCAD) system in the hospital and intervention using the HCAD for 1 month. The system comprised a hospital-based server and the portable unit installed at the participant's home. The portable unit

Huijgen 2008 (*Continued*)

	consisted of 7 sensorised tools; a key, a light bulb, a book, a jar, writing, checkers and keyboard. The unit also had 2 Webcams that allowed videoconferencing and recording. It was recommended that participants use the HCAD at least 5 days per week for 30 minutes Control intervention: usual care and generic exercises prescribed by the physician
Outcomes	Timing of outcome assessment: baseline and post-intervention Measures: Barthel Index, participant satisfaction assessed using visual analogue scale, SF-36, Action Research Arm Test, Nine-Hole Peg Test, Wolf Motor Function Test, grip strength, Abilhand
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	High risk	Randomisation scheme generated using 2:1 allocation ratio. Participants allocated to the study when the intervention was available
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Low risk	Dropouts were reported and ITT analyses conducted
Selective reporting (reporting bias)	High risk	Some study data not reported in the published paper
Other bias	High risk	Small sample size Differences between groups at baseline

Mayo 2008

Methods	RCT
Participants	Recruited from 5 acute care hospitals in Canada Inclusion criteria: all persons returning home directly from the acute care hospital after a first or recurrent stroke with any of the following criteria indicating a specific need for healthcare supervision postdischarge (lives alone, mobility problem requiring assistive device, physical assistance or supervision, mild cognitive deficit, dysphagia, incontinence, social service consultation during acute hospitalisation, or need for postdischarge medical management for diabetes, congestive heart failure, ischaemic heart disease, arthritis, chronic obstructive pulmonary disease, atrial fibrillation, kidney disease, peripheral vascular disease)

	Exclusion criteria: people discharged to an inpatient rehabilitation facility or to long-term care Age, years: telerehabiltation group = 70 (SD 14.5), control group = 72 (SD 12.95) Gender: telerehabilitation group 67% male, control group 55% male Time poststroke: telerehabilitation group 12 (SD 11.7 days), control group 13 (SD 15. 7 days)
Interventions	Telerehabilitation intervention: received case management (defined as a 'collaborative process of assessment, planning, facilitation and advocacy for options and services to meet an individual's health needs through communication and available resources to promote quality cost-effective outcomes'). Managed through home visits and telephone contacts for a period of 6 weeks. The nurse established contact with the GP and provided 24-hour contact. Interventions included surveillance, information exchange, medication management, health system guidance, active listening, family support, teaching and risk identification Control intervention: participant and family were instructed to make an appointment with their local GP
Outcomes	Timing of outcome assessment: baseline, post-intervention and 6-month follow-up Measures: reintegration to normal living index, Barthel Index, gait speed, Timed Up and Go test, SF-36, EQ5D, Geriatric Depression Scale, health service utilisation
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Not reported
Allocation concealment (selection bias)	Unclear risk	Reported that 'sealed envelopes' were used
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinded outcome assessor
Incomplete outcome data (attrition bias) All outcomes	Low risk	Few instances of missing data. Balanced attrition across groups. ITT analyses conducted. Multiple imputation used for missing data
Selective reporting (reporting bias)	Unclear risk	Not able to access protocol
Other bias	Low risk	None apparent

Piron 2008

Methods	RCT
Participants	Study took place in Italy Inclusion criteria: mild to intermediate arm motor impairment due to ischaemic stroke in the area of the middle cerebral artery; without cognitive problems that could interfere with comprehension Exclusion criteria: failure to meet above criteria Age, years: telerehabilitation group = 53 (SD 15) years, control group = 65 (SD 11) years Gender: telerehabilitation group 40% male, control group 60% male Time poststroke: telerehabilitation group 10 months (SD 3), control group 13 months (SD 2)
Interventions	Telerehabilitation intervention: the purpose of the intervention was to improve upper limb function using a virtual reality programme. Patient-therapist interaction facilitated by a videoconferencing unit beside the telerehabilitation equipment. 1 computer was at the hospital and 1 at the participant's home Control intervention: virtual reality workstation with a 3D motion tracking system that recorded the participant's arm movements. The participant's movement was represented in the virtual environment. The therapist created a sequence of virtual tasks for the participant to complete with the affected arm. Participants could see their own trajectory and the ideal/desired trajectory
Outcomes	Timing of outcome assessment: baseline and post-intervention Measures: participant satisfaction questionnaire, Fugl-Meyer Upper Extremity Scale
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Described as 'simple randomisation'
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinded outcome assessor
Incomplete outcome data (attrition bias) All outcomes	Low risk	No missing outcome data
Selective reporting (reporting bias)	Unclear risk	Not able to access protocol
Other bias	High risk	Small sample size

Piron 2009

Methods	RCT
Participants	Study took place in Italy Inclusion criteria: single ischaemic stroke in the middle cerebral artery region with mild to intermediate arm motor impairment (Fugl-Meyer Upper Extremity Scale score 30 to 55) Exclusion criteria: clinical evidence of cognitive impairment, apraxia (< 62 points on the 'De Renzi' test), neglect or language disturbance interfering with verbal comprehension (> 40 errors on the Token test) Age, years: telerehabilitation group mean = 66 (SD 8), control group mean = 64 (SD 8) years Gender: 58% males Timing post stroke: intervention group mean (SD) 15 (7) months, control group 12 (4) months
Interventions	Telerehabilitation intervention: the virtual reality telerehabilitation programme used 1 computer workstation at the participant's home and 1 at the rehabilitation hospital. The system used a 3D motion tracking system to record arm movements through a magnetic receiver into a virtual image. The participant moved a real object by following the trajectory of a virtual object displayed on the screen in accordance with the requested virtual task. 5 virtual tasks comprising simple arm movements were devised for training Control intervention: specific exercises for the upper limb with progressive complexity. Started with control of isolated movements without postural control, then postural control including touching different targets and manipulating objects Sessions were 60 minutes, 5 times per week for 4 weeks (20 hours total)
Outcomes	Timing of outcome assessment: baseline, post-intervention and at 1 month Measures: Fugl-Meyer Upper Extremity Scale, Abilhand Scale, modified Ashworth Scale
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Personal correspondence with study authors reports the use of a simple computer-generated sequence
Allocation concealment (selection bias)	Low risk	Opaque sequentially numbered envelopes
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinded outcome assessor
Incomplete outcome data (attrition bias) All outcomes	Low risk	No missing data
Selective reporting (reporting bias)	Low risk	No other outcomes collected

Piron 2009 (*Continued*)

Other bias	Low risk	None apparent

Smith 2012

Methods	RCT
Participants	Study took place in the USA Inclusion criteria: female caregiver providing care at home to husband after a stroke; either stroke survivor or caregiver scored 5 or greater on the PHQ-9 (at least mild depression), neither stroke survivor nor caregiver were medically unstable or terminally ill and both were cognitively able to participate Exclusion criteria: failure to meet above criteria Age, years: telerehabilitation group mean = 59.9 (SD 8.2), control group mean = 59.1 (SD 13.6) Gender: 100% male Time since onset of stroke: details not reported
Interventions	Telerehabilitation intervention: consisted of 5 components designed to support the caregiver and provide caregiver with knowledge, resources and skills to assist him or her in reducing 'personal distress' and providing optimal emotional care to the stroke survivor. The 5 components included: 1. a professional guide to facilitate the intervention and provide email support; 2. educational videos; 3. online chat sessions; 4. email and message board; and 5. Resource Room (a virtual online library). Intervention took place over 11 weeks Control group: had access to the Resource Room only
Outcomes	Timing of outcome assessment: baseline, post-intervention and at 1 month Measures: CES-D, PHQ9, parts of the Mastery Scale, 10-item self-esteem scale, parts of the MOS Social Support Survey, ratings of treatment credibility, reported effort and perceived benefit
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Computer-generated design
Allocation concealment (selection bias)	Low risk	Sealed opaque envelopes
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinded outcome assessor

Smith 2012 (*Continued*)

Incomplete outcome data (attrition bias) All outcomes	Low risk	ITT analyses conducted. Few dropouts, all accounted for and balanced across groups
Selective reporting (reporting bias)	High risk	Additional outcomes assessed that were not reported in the paper
Other bias	Unclear risk	No other sources of bias identified

fMRI: functional magnetic resonance imaging
GP: general practitioner
IQR: interquartile range
ITT: intention-to-treat
MRI: magnetic resonance imaging
RCT: randomised controlled trial
ROM: range of movement
SD: standard deviation

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Adie 2010	Included participants with TIA
Bergquist 2012	Included participants with diagnoses other than stroke
Burton 2005	Intervention did not match our definition of telerehabilitation
Eide 2012	Included participants with diagnoses other than stroke and intervention did not meet our criteria
Gillham 2010	Included participants with TIA
Hoffman 2010	Intervention did not match our definition of telerehabilitation
Huijbregts 2010	Not an RCT
Jackson 2010	Intervention did not match our definition of telerehabilitation
Joubert 2006	Intervention did not match our definition of telerehabilitation
Joubert 2009	Intervention did not match our definition of telerehabilitation
Kerry 2010	Intervention did not match our definition of telerehabilitation
Mclaughlin 2010	Not an RCT

(*Continued*)

Palmer 2011	Intervention did not match our definition of telerehabilitation
Redzuan 2012	Intervention did not match our definition of telerehabilitation
Song 2010	Intervention did not match our definition of telerehabilitation
Zucconi 2012	Intervention did not match our definition of telerehabilitation

RCT: randomised controlled trial
TIA: transient ischaemic attack

Characteristics of ongoing studies *[ordered by study ID]*

Eames 2011

Trial name or title	RCT of a postdischarge education and support package for clients with stroke and their carers
Methods	RCT
Participants	Stroke patients
Interventions	Intervention group: stroke education and support package with tailored written and verbal information provided face-to-face before discharge and via telephone after discharge
Outcomes	Stroke knowledge, self-efficacy, mood, quality of life, satisfaction and caregiver burden
Starting date	2008
Contact information	Sally Eames s.eames@uq.edu.au
Notes	

Graven 2012

Trial name or title	Does a focus on participation and personal goal achievement have an impact on depression in the first year after stroke?
Methods	RCT
Participants	Stroke patients
Interventions	Intervention group: collaborative goal setting and review of goal achievement levels, written information provision and further referral to relevant health services as required. Interventions were delivered both as home visits and as telephone contacts

Graven 2012 (*Continued*)

	Control group: usual care
Outcomes	Depression
Starting date	Unknown
Contact information	Unavailable
Notes	

Miller 2010

Trial name or title	Reduction in poststroke depressive symptoms among patients and caregivers: the FITT study
Methods	RCT
Participants	Stroke patients
Interventions	Intervention group: FITT treatment consisted of a series of brief (15 to 20 minutes) telephone contacts from a FITT therapist to the stroke patient and caregiver over a 6-month period after the stroke Control group: usual care
Outcomes	Depression
Starting date	Unknown
Contact information	Unavailable
Notes	

NCT01144715

Trial name or title	Rehabilitation of the stroke hand at home (HAAPI)
Methods	RCT
Participants	Stroke patients
Interventions	Intervention group: robotic and telerehabilitation system Control group: home therapy programme
Outcomes	Action Research Arm Test, Wolf Motor Function Test, Fugl-Meyer Upper Extremity Scale, Stroke Impact Scale
Starting date	June 2010
Contact information	James Koeneman jkoeneman@kineticmuscles.com

NCT01144715 (*Continued*)

Notes	

NCT01157195

Trial name or title	Home-based automated therapy of arm function after stroke via telerehabilitation
Methods	RCT
Participants	Stroke patients
Interventions	Intervention group: remotely administered form of constraint-induced movement therapy Control group: constraint-induced movement therapy
Outcomes	Motor Activity Log, Wolf Motor Function Test
Starting date	June 2010
Contact information	Staci McKay stacemc@uab.edu
Notes	

NCT01350453

Trial name or title	Development and pilot evaluation of a Web-supported programme of constraint-induced therapy following stroke (LifeCIT)
Methods	RCT
Participants	Stroke patients
Interventions	Intervention group: participants will be asked to aim to wear the C-MIT for 9 hours a day for 5 days/week, including 4 to 6 hours of structured activities per day: 2 × 30- to 60-minute sessions of Web-based activities and 3 to 4 hours of practicing everyday activities Control group: usual care
Outcomes	Motor Activity Log, Wolf Motor Function Test, Fugl-Meyer Upper Extremity Scale, Stroke Impact Scale, Canadian Occupational Performance Measure, EQ5D, service utilisation
Starting date	May 2011
Contact information	Claire Meagher cm3v08@soton.ac.uk
Notes	

NCT01655264

Trial name or title	Evaluation of the Gertner Tele-Motion Rehabilitation System for stroke rehabilitation
Methods	RCT
Participants	Stroke patients
Interventions	Intervention group: upper extremity training using the Gertner Tele-Motion Rehabilitation System. This system is implemented via Microsoft Kinect camera-based gesture recognition technology Control group: self-training exercises using a conventional approach to upper extremity training
Outcomes	Range of motion, Chedoke Arm and Hand Activity Inventory, Motor Activity Log, Functional Reach Test, Lawton's index, Fugl-Meyer Upper Extremity Scale, visual analogue scale for pain, Functional Indpenendence Measure, Stroke Impact Scale
Starting date	July 2012
Contact information	Patrice Weiss plweiss@gmail.com
Notes	

Nguyen 2011

Trial name or title	Pharmacist telephone interventions improve adherence to stroke preventative medications and reduce stroke risk factors: an RCT
Methods	RCT
Participants	Stroke patients
Interventions	Intervention group: received telephone follow-up calls at 3 months and 6 months from time of randomisation. Telephone follow-up call included evaluation of medication adherence based on pharmacy refill history, as well as continuing stroke education and reassessment of stroke prevention goals with the participant. Recommendations for medication therapy and relevant clinical studies or laboratories were communicated to the primary care provider and/or stroke provider when appropriate Control group: usual care
Outcomes	Adherence to medication, achievement of stroke prevention goals
Starting date	Unknown
Contact information	Unavailable
Notes	

Rochette 2010

Trial name or title	YOU CALL-WE CALL TRIAL
Methods	RCT
Participants	Stroke
Interventions	Intervention group: multimodal support intervention comprising information, education and telephone support Control group: provided with name and telephone number of a resource person to contact if individuals felt the need
Outcomes	Health service utilisation, EQ5D, Quality of Life Index, participation (LIFE-H), depression (Beck Depression Inventory II)
Starting date	Unknown
Contact information	Annie Rochette annie.rochette@umontreal.ca
Notes	

Taylor 2012

Trial name or title	Telerehabilitation to improve outcomes for people with stroke: the ACTIV trial
Methods	RCT
Participants	Stroke patients
Interventions	Intervention group: a 6-month intervention comprising 4 face-to-face physiotherapy sessions (consisting of exercises working towards a specific goal), 5 telephone calls and 1 to 2 text messages per week, to encourage continuation of the prescribed exercise plan Control group: usual care
Outcomes	Physical function (as measured by the physical component of the Stroke Impact Scale), Step Test, grip strength, stroke self efficacy questionnaire, Stroke Impact Scale, service utilisation, costs, participant satisfaction
Starting date	April 2012
Contact information	Denise Taylor detaylor@aut.ac.nz
Notes	

DATA AND ANALYSES

Comparison 1. Independence in activities of daily living: postintervention

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Independence in activities of daily living	2	661	Std. Mean Difference (IV, Random, 95% CI)	-.00 [-0.15, 0.15]

Comparison 2. Upper limb function: postintervention

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Upper limb function	2	46	Mean Difference (IV, Random, 95% CI)	3.65 [-0.26, 7.57]

Analysis 1.1. Comparison 1 Independence in activities of daily living: postintervention, Outcome 1 Independence in activities of daily living.

Review: Telerehabilitation services for stroke

Comparison: 1 Independence in activities of daily living: postintervention

Outcome: 1 Independence in activities of daily living

Study or subgroup	Telerehabilitation N	Mean(SD)	Usual care N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
Boter 2004	236	19.34 (2.2)	252	19.31 (1.75)		73.8 %	0.02 [-0.16, 0.19]
Mayo 2008	89	91.85 (19.72)	84	92.62 (13.45)		26.2 %	-0.05 [-0.34, 0.25]
Total (95% CI)	**325**		**336**			**100.0 %**	**0.00 [-0.15, 0.15]**

Heterogeneity: Tau² = 0.0; Chi² = 0.12, df = 1 (P = 0.73); I² =0.0%

Test for overall effect: Z = 0.01 (P = 0.99)

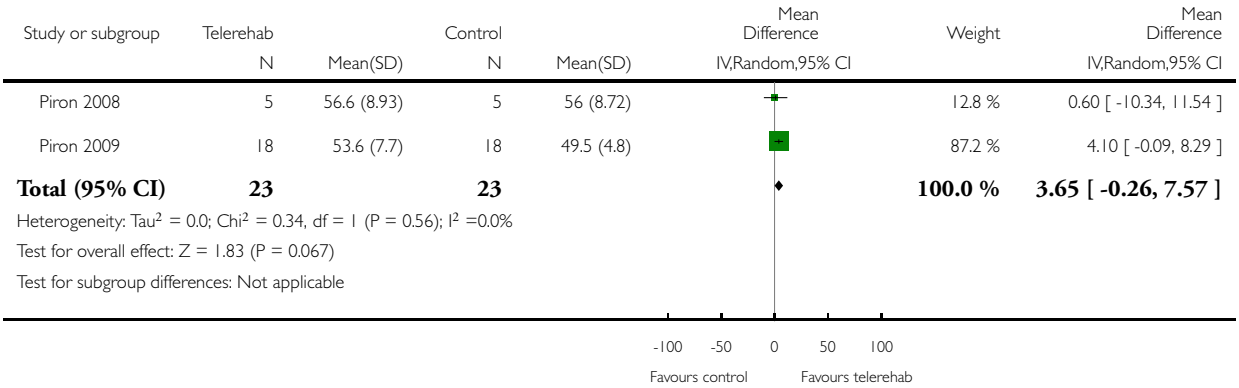
Test for subgroup differences: Not applicable

Analysis 2.1. Comparison 2 Upper limb function: postintervention, Outcome 1 Upper limb function.

Review: Telerehabilitation services for stroke

Comparison: 2 Upper limb function: postintervention

Outcome: 1 Upper limb function



ADDITIONAL TABLES

Table 1. Numbers of participants screened, recruited and followed up

Study	Screened	Randomised	Allocated to intervention group	Allocated to control group	Assessed at follow-up
Boter 2004	691	536	263	273	486
Carey 2007	167	25	13	12	20
Chumbler 2012	52	52	27	25	44
Deng 2012	62	19	9	10	16
Forducey 2012	Not reported	11	Not reported	Not reported	9
Huijgen 2008	Not reported	16	Not reported	Not reported	Not reported
Mayo 2008	294	190	96	94	157
Piron 2008	Not reported	10	5	5	10
Piron 2009	Not reported	36	18	18	36

Table 1. Numbers of participants screened, recruited and followed up *(Continued)*

Smith 2012	161	38	19	19	32

Table 2. Comparison of characteristics of studies included within the review

Study	Intervention	Comparison	Time after stroke	Country of study
Boter 2004	Case management via 3 telephone calls and a home visit up to 24 weeks after discharge from an acute hospital following stroke	Usual care	Not reported; however, intervention was provided on discharge from acute facility	The Netherlands
Carey 2007	Upper limb therapy targeting finger and wrist movements provided via a computerised programme in which explicit feedback on performance was provided. Regular teleconferencing occurred between participant and therapist	Upper limb therapy targeting finger and wrist movements provided via a computerised programme whereby explicit feedback on performance was not provided. Regular teleconferencing occurred between participant and therapist	Chronic phase	USA
Chumbler 2012	A programme designed to improve the person's functional mobility administered via televisits, use of an in-home messaging device and 5 telephone calls over a 3-month period	Usual care	Subacute phase	USA
Deng 2012	Lower limb therapy targeting ankle movements provided via a computerised programme in which explicit feedback on performance was provided. Teleconferencing was used regularly, and performance data were emailed to the therapist	Lower limb therapy targeting ankle movements provided via a computerised programme whereby explicit feedback on performance was not provided. Teleconferencing was used regularly, and performance data were emailed to the therapist	Chronic phase	USA
Forducey 2012	A total of 12 therapy sessions (occupational therapy and physiotherapy) were conducted via a desktop videophone. Interven-	The same intervention programme was delivered face-to-face	Not reported	USA

Table 2. Comparison of characteristics of studies included within the review (*Continued*)

	tions included education, retraining of self care, functional mobility and posture, home modifications and therapy to improve function in impaired limbs			
Huijgen 2008	Upper limb therapy using the Home Care Activity Device (computer-based programme) for 1 month	Usual care and generic exercises were provided by a physician	Chronic phase	The Netherlands
Mayo 2008	Case management intervention provided via home visits and telephone calls for 6 weeks following discharge from acute care	Participants were instructed to make an appointment with their general practitioner	Acute phase	Canada
Piron 2008	Upper limb therapy that was delivered using a virtual reality programme at home and supplemented by videoconferencing	Upper limb therapy that was delivered using a virtual reality programme and conducted in the clinic setting	Chronic phase	Italy
Piron 2009	Upper limb therapy that was delivered using a virtual reality telerehabilitation programme and that took place in the home	A programme of conventional upper limb exercises	Chronic phase	Italy
Smith 2012	An intervention to support the caregivers of stroke survivors by enhancing knowledge, skills and coping. Delivered via email, online chat sessions and online resources	Participants had access to some of the online resources	Not reported	USA

APPENDICES

Appendix 1. MEDLINE (Ovid) search strategy

1. cerebrovascular disorders/ or exp basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp intracranial arterial diseases/ or exp intracranial arteriovenous malformations/ or exp "intracranial embolism and thrombosis"/ or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/
2. brain injuries/ or brain injury, chronic/
3. (stroke$ or cva or poststroke or post-stroke or cerebrovasc$ or cerebral vascular).tw
4. ((cerebral or cerebellar or brain$ or vertebrobasilar) adj5 (infarct$ or isch?emi$ or thrombo$ or emboli$ or apoplexy)).tw.
5. ((cerebral or brain or subarachnoid) adj5 (haemorrhage or hemorrhage or haematoma or hematoma or bleed$)).tw.
6. exp hemiplegia/ or exp paresis/
7. (hempar$ or hemipleg$ or paresis or paretic or brain injur$).tw.
8. Gait Disorders, Neurologic/
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10. telemedicine/ or telemetry/ or exp videoconferencing/ or telecommunications/ or computer communication networks/ or remote consultation/ or remote sensing technology/ or exp telephone/ or electronic mail/ or internet/
11. (telemedicine or telemetry or telerehabilitation or tele-rehabilitation or telerehab or telehealth or tele-health or telehomecare or tele-homecare or telecoaching or tele-coaching or telecommunication$ or videoconference$ or video-conferenc$ or videoconsultation or video-consultation or telestroke or teleconference$ or tele-conference$ or teleconsultation or tele-consultation or telecare or ehealth or e-health).tw
12. (telespeech or tele-speech or teleOT or tele-OT or telepractice or teletherap$).tw.
13. ((rehabilitation or therap$ or treatment or communication or consultation) adj5 (telephone$ or phone$ or video$ or internet$ or computer$ or sensor$ or modem or webcam or website$ or email)).tw.
14. ((remote$ or distance$ or distant) adj5 (rehabilitation or therap$ or treatment or physio$ or occupational therap$ or communication or consultation or care or specialist$ or monitor$ or virtual reality or virtual environment$ or technolog$)).tw.
15. (tele adj3 (game$ or game$ or exergame$ or virtual reality$)).tw.
16. 10 or 11 or 12 or 13 or 14 or 15
17. Randomized Controlled Trials as Topic/
18. random allocation/
19. Controlled Clinical Trials as Topic/
20. control groups/
21. clinical trials as topic/
22. double-blind method/ or single-blind method/
23. Placebos/
24. placebo effect/
25. cross-over studies/
26. Multicenter Studies as Topic/
27. Therapies, Investigational/
28. Research Design/
29. Program Evaluation/
30. evaluation studies as topic/
31. randomized controlled trial.pt.
32. controlled clinical trial.pt.
33. clinical trial.pt.
34. multicenter study.pt.
35. (evaluation studies or comparative study).pt.
36. random$.tw.
37. (controlled adj5 (trial$ or stud$)).tw.
38. (clinical$ adj5 trial$).tw.
39. ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.
40. (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.
41. ((multicenter or multicentre or therapeutic) adj5 (trial$ or stud$)).tw.

42. ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.
43. ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.
44. (coin adj5 (flip or flipped or toss$)).tw.
45. latin square.tw.
46. versus.tw.
47. (cross-over or cross over or crossover).tw.
48. placebo$.tw.
49. sham.tw.
50. (assign$ or alternate or allocat$ or counterbalance$ or multiple baseline).tw.
51. controls.tw.
52. (treatment$ adj6 order).tw.
53. or/17-52
54. 9 and 16 and 53
55. exp animals/ not humans.sh
56 54 not 55

Appendix 2. EMBASE (Ovid) search strategy

1. exp brain ischemia/ or exp carotid artery diseases/ or exp intracranial arterial diseases/ or exp intracranial arteriovenous malformations/ or exp intracranial embolism/) and thrombosis/) or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/
2 brain injuries/ or brain injury, chronic/
3 (stroke$ or cva or poststroke or post-stroke or cerebrovasc$ or cerebral vascular).tw.
4 ((cerebral or cerebellar or brain$ or vertebrobasilar) adj5 (infarct$ or isch?emi$
or thrombo$ or emboli$ or apoplexy)).tw.
5 ((cerebral or brain or subarachnoid) adj5 (haemorrhage or hemorrhage or haematoma or hematoma or bleed$)).tw.
6 exp hemiplegia/ or exp paresis/
7 (hempar$ or hemipleg$ or paresis or paretic or brain injur$).tw.
8 Gait Disorders, Neurologic/
9 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10 telemedicine/ or telemetry/ or exp videoconferencing/ or telecommunications/ or computer communication networks/ or remote consultation/ or remote sensing technology/ or exp telephone/ or electronic mail/ or internet/
11 (telemedicine or telemetry or telerehabilitation or tele-rehabilitation or telerehab or telehealth or tele-health or telehomecare or tele-homecare or telecoaching or telecoaching or telecommunication$ or videoconference$ or video-conferenc$ or videoconsultation or video-consultation or telestroke or teleconference$ or teleconference$ or teleconsultation or tele-consultation or telecare or ehealth or ehealth).tw.
12 (telespeech or tele-speech or teleOT or tele-OT or telepractice or teletherap$).tw.
13 ((rehabilitation or therap$ or treatment or communication or consultation) adj5 (telephone$ or phone$ or video$ or internet$ or computer$ or sensor$ or modem or webcam or website$ or email)).tw.
14 ((remote$ or distance$ or distant) adj5 (rehabilitation or therap$ or treatment or physio$ or occupational therap$ or communication or consultation or care or specialist$ or monitor$ or virtual reality or virtual environment$ or technolog$)).tw.
15 (tele adj3 (game$ or game$ or exergame$ or virtual reality$)).tw.
16 10 or 11 or 12 or 13 or 14 or 15
17 Randomized Controlled Trials as Topic/
18 random allocation/
19 Controlled Clinical Trials as Topic/
20 control groups/
21 clinical trials as topic/
22 double-blind method/ or single-blind method/
23 Placebos/
24 placebo effect/
25 cross-over studies/
26 Multicenter studies as Topic/

27 Therapies, Investigational/
28 Research Design/
29 Program Evaluation/
30 evaluation studies as topic/
31 random$.tw.
32 (controlled adj5 (trial$ or stud$)).tw.
33 (clinical$ adj5 trial$).tw.
34 ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.
35 (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.
36 ((multicenter or multicentre or therapeutic) adj5 (trial$ or stud$)).tw.
37 ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.
38 ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.
39 (coin adj5 (flip or flipped or toss$)).tw.
40 latin square.tw.
41 versus.tw.
42 (cross-over or cross over or crossover).tw.
43 placebo$.tw.
44 sham.tw.
45 (assign$ or alternate or allocat$ or counterbalance$ or multiple baseline).tw.
46 controls.tw.
47 (treatment$ adj6 order).tw.
48 or/17-47
49 9 and 16 and 48
50 exp animals/ not humans.sh.
51 49 not 50

Appendix 3. AMED search strategy

1 ((cerebrovascular disorders/ or exp basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp intracranial arterial diseases/ or exp intracranial arteriovenous malformations/ or exp intracranial embolism/) and thrombosis/) or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/
2 brain injuries/ or brain injury, chronic/
3 (stroke$ or cva or poststroke or post-stroke or cerebrovasc$ or cerebral vascular).tw.
4 ((cerebral or cerebellar or brain$ or vertebrobasilar) adj5 (infarct$ or isch?emi$ or thrombo$ or emboli$ or apoplexy)).tw.
5 ((cerebral or brain or subarachnoid) adj5 (haemorrhage or hemorrhage or haematoma or hematoma or bleed$)).tw.
6 exp hemiplegia/ or exp paresis/
7 (hempar$ or hemipleg$ or paresis or paretic or brain injur$).tw.
8 Gait Disorders, Neurologic/
9 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10 telemedicine/ or telemetry/ or exp videoconferencing/ or telecommunications/ or computer communication networks/ or remote consultation/ or remote sensing technology/ or exp telephone/ or electronic mail/ or internet/
11 (telemedicine or telemetry or telerehabilitation or tele-rehabilitation or telerehab or telehealth or tele-health or telehomecare or tele-homecare or telecoaching or tele-coaching or telecommunication$ or videoconference$ or video-conferenc$ or videoconsultation or video-consultation or telestroke or teleconference$ or tele-conference$ or teleconsultation or tele-consultation or telecare or ehealth or e-health).tw.
12 (telespeech or tele-speech or teleOT or tele-OT or telepractice or teletherap$).tw.
13 ((rehabilitation or therap$ or treatment or communication or consultation) adj5 (telephone$ or phone$ or video$ or internet$ or computer$ or sensor$ or modem or webcam or website$ or email)).tw.
14 ((remote$ or distance$ or distant) adj5 (rehabilitation or therap$ or treatment or physio$ or occupational therap$ or communication or consultation or care or specialist$ or monitor$ or virtual reality or virtual environment$ or technolog$)).tw.
15 (tele adj3 (game$ or game$ or exergame$ or virtual reality$)).tw.
16 10 or 11 or 12 or 13 or 14 or 15

17 random allocation/
18 double-blind method/ or single-blind method/
19 Placebos/
20 Research Design/
21 Program Evaluation/
22 randomized controlled trial.pt.
23 controlled clinical trial.pt.
24 clinical trial.pt.
25 multicenter study.pt.
26 (evaluation studies or comparative study).pt.
27 random$.tw.
28 (controlled adj5 (trial$ or stud$)).tw.
29 (clinical$ adj5 trial$).tw.
30 ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.
31 (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.
32 ((multicenter or multicentre or therapeutic) adj5 (trial$ or stud$)).tw.
33 ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.
34 ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.
35 (coin adj5 (flip or flipped or toss$)).tw.
36 latin square.tw.
37 versus.tw.
38 (cross-over or cross over or crossover).tw.
39 placebo$.tw.
40 sham.tw.
41 (assign$ or alternate or allocat$ or counterbalance$ or multiple baseline).tw.
42 controls.tw.
43 (treatment$ adj6 order).tw.
44 or/17-43
45 9 and 16 and 44
46 exp animals/ not humans.sh.
47 45 not 46

Appendix 4. CINAHL search strategy

1. MH Cerebrovascular disorders
2. MH Basal Ganglia Cerebrovascular Disease
3. MH Cerebral ischemia
4. MH Carotid Artery Diseases
5. MH Intracranial Arterial Diseases
6. MH Arteriovenous Malformations
7. MH Intracranial Embolism and Thrombosis
8. MH Intracranial Hemorrhage
9. MH Stroke
10. AB brain infarction
11. MH Brain Injuries
12. MH Brain Damage, Chronic
13. TX stroke$ OR TX cva OR TX poststroke OR TX post-stroke
14. TX cerebrovasc$ OR TX cerebral vascular
15. TX cerebral OR TX cerebellar OR TX brain$ OR TX verterbrobasilar
16. TX infarct$ OR TX isch?emi$ OR TX thrombo$ OR TX emboli$ OR TX apoplexy
17. S15 and S16
18. TX cerebral OR TX brain OR TX subarachnoid

19. TX haemorrhage OR TX hemorrhage OR TX haematoma OR TX hematoma OR TX bleed
20. S18 and S19
21. MH hemiplegia
22. TX paresis
23. TX hemipar$ OR TX hemipleg$ OR TX paresis OR TX paretic AND TX brain injur$
24. MH Gait Disorders, Neurologic
25. 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
26. MH telemedicine
27. MH telehealth
28. MH videoconferencing OR MH teleconferencing
29. MH remote consultation
30. TX telemedicine OR TX telerehabilitation OR TX tele-rehabilitation OR TX tele-rehab OR TX telehealth OR TX tele-health
31. TX tele-coaching OR TX telecoaching OR TX telecommunication$ OR tele-consultation
32. TX telespeech OR TX tele-speech OR TX teleOT OR TX tele-OT OR TX telepractice OR TX teletherap$
33. S26 or S27 or S28 or S29 or S30 or S31 or S32
34. S25 and S33
35. MH randomized controlled trials
36. AB random allocation
37. AB control group$
38. MH Clinical trials
39. TX double-blind OR TX single-blind
40. TX placebo OR TX cross-over OR TX crossover
41. MH Program evaluation
42. PT randomized controlled trial
43. TX random OR TX (controlled N5 trial$) OR (controlled N5 stud$)
44. S35 or S36 or S37 or S38 or S39 or S40 or S41 or S42 or S43
45. S34 and S44

Appendix 5. PsycINFO search strategy

1 ((cerebrovascular disorders/ or exp basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp intracranial arterial diseases/ or exp intracranial arteriovenous malformations/ or exp intracranial embolism/) and thrombosis/) or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/
2 brain injuries/ or brain injury, chronic/
3 (stroke$ or cva or poststroke or post-stroke or cerebrovasc$ or cerebral vascular).tw.
4 ((cerebral or cerebellar or brain$ or vertebrobasilar) adj5 (infarct$ or isch?emi$ or thrombo$ or emboli$ or apoplexy)).tw.
5 ((cerebral or brain or subarachnoid) adj5 (haemorrhage or hemorrhage or haematoma or hematoma or bleed$)).tw.
6 exp hemiplegia/ or exp paresis/
7 (hempar$ or hemipleg$ or paresis or paretic or brain injur$).tw.
8 Gait Disorders, Neurologic/
9 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 (41110)
10 telemedicine/ or telemetry/ or exp videoconferencing/ or telecommunications/ or computer communication networks/ or remote consultation/ or remote sensing technology/ or exp telephone/ or electronic mail/ or internet/
11 (telemedicine or telemetry or telerehabilitation or tele-rehabilitation or telerehab or telehealth or tele-health or telehomecare or tele-homecare or telecoaching or tele-coaching or telecommunication$ or videoconference$ or video-conferenc$ or videoconsultation or video-consultation or telestroke or teleconference$ or tele-conference$ or teleconsultation or tele-consultation or telecare or ehealth or e-health).tw.
12 (telespeech or tele-speech or teleOT or tele-OT or telepractice or teletherap$).tw.
13 ((rehabilitation or therap$ or treatment or communication or consultation) adj5 (telephone$ or phone$ or video$ or internet$ or computer$ or sensor$ or modem or webcam or website$ or email)).tw.

14 ((remote$ or distance$ or distant) adj5 (rehabilitation or therap$ or treatment or physio$ or occupational therap$ or communication or consultation or care or specialist$ or monitor$ or virtual reality or virtual environment$ or technolog$)).tw.
15 (tele adj3 (game$ or game$ or exergame$ or virtual reality$)).tw.
16 10 or 11 or 12 or 13 or 14 or 15
17 control groups/
18 clinical trials.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
19 cross-over studies.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
20 Research Design/
21 Program Evaluation/
22 (evaluation studies or comparative study).pt.
23 random$.tw.
24 (controlled adj5 (trial$ or stud$)).tw.
25 (clinical$ adj5 trial$).tw.
26 ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.
27 (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.
28 ((multicenter or multicentre or therapeutic) adj5 (trial$ or stud$)).tw.
29 ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.
30 ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.
31 (coin adj5 (flip or flipped or toss$)).tw.
32 latin square.tw.
33 versus.tw.
34 (cross-over or cross over or crossover).tw.
35 placebo$.tw.
36 sham.tw.
37 (assign$ or alternate or allocat$ or counterbalance$ or multiple baseline).tw.
38 controls.tw.
39 (treatment$ adj6 order).tw.
40 or/17-39
41 9 and 16 and 40
42 exp animals/ not humans.sh.
43 41 not 42

CONTRIBUTIONS OF AUTHORS

Kate E Laver is the guarantor of the review. Contributions included co-ordinating the review, drafting the protocol, developing the search strategy, searching for trials, obtaining copies of the trials, selecting which trials to include, extracting data from the trials, entering data, carrying out the analysis, interpreting the analysis and drafting the final review.

Daniel Schoene was involved in drafting the protocol, searching for trials, selecting which trials to include, extracting data from trials, interpreting the analysis and drafting the final review.

Maria Crotty was involved in drafting the protocol, selecting which trials to include (arbiter), interpreting the analysis and drafting the final review.

Stacey George was involved in drafting the protocol, selecting which trials to include (arbiter), interpreting the analysis and drafting the final review.

Natasha A Lannin was involved in drafting the protocol, carrying out the analysis, interpreting the analysis and drafting the final review.

Catherine Sherrington was involved in drafting the protocol, guiding and interpreting the analysis and drafting the final review.

All authors will be responsible for updating the review.

DECLARATIONS OF INTEREST

None known.

INDEX TERMS

Medical Subject Headings (MeSH)

*Stroke Rehabilitation; *Telemedicine; Activities of Daily Living; Randomized Controlled Trials as Topic

MeSH check words

Humans