Telerehabilitation and recovery of motor function: a systematic review and meta-analysis.

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TITLE

Telerehabilitation and recovery of motor function: a systematic review and meta-analysis.

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Disclosure Policy

The authors declare that there is no conflict of interests regarding the publication of this article.

The authors, Agostini Michela and Andrea Turolla, declare that they are the co-authors in the two studies included in this Systematic Review (i.e. Piron 2008 e 2009) [4-9]

Abstract

Recent advances in telecommunication technologies have boosted the possibility to deliver rehabilitation via the internet (i.e. telerehabilitation). Several studies have shown that telerehabilitation is effective to improve clinical outcomes in disabling conditions. The aim of this review was to determine whether telerehabilitation was more effective than other modes of delivering rehabilitation to regain motor function, in different populations of patients.

We searched PubMed, Embase and the Cochrane library retrieving 2360 records.

Twelve studies were included involving different populations (i.e. neurological, total knee arthroplasty (TKA), cardiac) of patients. Inconclusive finding were found on the effect of telerehabilitation for neurological patients (SMD = 0.08, CI 95% = -0.13, 0.29), while both for cardiac (SMD = 0.24, CI 95% = 0.04, 0.43) and TKA patients

(Timed Up and Go test: MD = -5.17, CI 95% = -9.79, -0.55) the results were in favour of telerehabilitation.

Conclusive evidence on the efficacy of telerehabilitation for treatment of motor function, regardless of pathology, was not reached. Nevertheless, a strong positive effect was found for patients following orthopaedic surgery, suggesting that the increased intensity provided by telerehabilitation is a promising option to be offered to patients. More and higher quality research is needed in this field especially with neurological patients.

Background

The increasing availability of low cost internet and communication technologies (ICT) (e.g. ADSL, HDSL, fiber connection) has boosted the opportunity to apply technology-based solutions to provide health services during hospitalisation and after discharge from hospital. This approach, broadly referred to as telemedicine, may guarantee better continuity of care from hospital to patients' home, as well as patients' monitoring and counselling [1]. ICTs has become a valuable option also for rehabilitation supporting the birth of a new branch of telemedicine, called telerehabilitation [2, 3].

Telerehabilitation involves the remote delivery of different rehabilitation services via telecommunications technology [4]. It can provide interventions such as physiotherapy, speech therapy, occupational therapy, patient telemonitoring and teleconsultation, thus providing assistance to homebound patients without the physical presence of a therapists or other health professionals [5]. Benefits of telerehabilitation include the delivery of prolonged therapies tailored on patients' needs while at the same time making significant savings on costs. A number of trials have been published to test the feasibility of telerehabilitation approaches and to compare their effectiveness with standard rehabilitation practice. Recent small randomized trials (RCTs) of rehabilitation of motor function after surgery demonstrated that treatment delivered via telerehabilitation achieved similar results to therapy delivered via standard care [6, 7]. Functional magnetic resonance imaging (fMRI) showed that rehabilitative treatments provided via telerehabilitation activate the same cortical regions as conventional treatment [8]. Previous studies of telerehabilitation for the treatment of upper limb motor function after stroke confirmed these data [4]. Several authors observed that the use of telerehabilitation leads to high levels of satisfaction as reported by patients [9, 10], reinforcing the hypothesis that the delivery of rehabilitative services at a distance is a feasible alternative to routine care. The conclusions from the above evidence suggest that telerehabilitation offers an opportunity for equitable access to rehabilitation services for individuals living in remote areas or unable to reach local health providers because of physical impairments [10]. Furthermore, telerehabilitation would limit unnecessary hospital admissions or delays in discharging patients at home.

Despite satisfactory scientific results and recommendations from national health plans to reduce costs by shortening hospital stays, telerehabilitation is still not widely disseminated. One of the reason explaining the current gap between scientific evidence and clinical deployment of telerehabilitation services relies on the technical requirements needed for settling a therapeutic environment at a distance. First, the flexibility of devices is fundamental to provide the different therapeutic modalities needed in the wide range of impairments. Second, a broad connectivity coverage is needed to reach most users at home. To date, reviews of the scientific literature on telerehabilitation are qualitative syntheses mainly addressing issues related to neurological rehabilitation [11-14]. Recently, Laver and colleagues published the first systematic review with meta-analysis of telerehabilitation services for stroke [15]. The authors concluded that insufficient evidence is available about the effectiveness of telerehabilitation after stroke, moreover no data on cost-effectiveness were found. On this basis, it is still difficult to argue the efficacy of telerehabilitation treatments provided at a distance, when compared to standard rehabilitation care provided in person.

Objectives

The aim of this review was to compare the effectiveness of telerehabilitation programmes with standard rehabilitation treatments (i.e. provided in the presence of health professionals) in terms of recovery of motor function across diseases.

Methods

Search strategy

We searched PubMed (1946-January 2014), Embase (1974-January 2014), the Cochrane Central Register of Controlled Trials (CENTRAL, January 2014) for publications written in English and Italian. We identified published, unpublished and ongoing trials, by hand searching the reference lists from relevant articles and by contacting investigators known to be involved in this research area. Details of search terms and strategies are available in appendix 1.

Selection criteria:

Studies were eligible for inclusion if testing telerehabilitation for the recovery of the motor function (measured by means of different scales), in patients affected by any type of impairment or disease. In the context of this systematic review, telerehabilitation is considered as:

- provided by means of any kind of technological device allowing healthcare professional/patient interaction both on-line or off-line;
- provided by healthcare professionals or caregivers through remote supervision;
- including at least one specific intervention targeted to rehabilitation (e.g. remotely controlled virtual reality motor training, occupational exercises at home through sensorized devices).

Telerehabilitation could be compared to (1) intervention; (2) rehabilitation therapies provided face-to-face independently of setting of delivery (home, hospital, ambulatory); (3) usual care.

We included RCTs or quasi-RCTs and controlled clinical trial (CCT) with or without blinding of assessor(s). In cross-over trials, we included only the first phase of studies to exclude any carry-over or learning effects.

Data collection and analysis

Two authors (MA and AT) independently screened the title and abstract of the records retrieved from the search strategy, applying the selection criteria previously described. The full text of the possible eligible records were retrieved and analysed for final inclusion in this systematic review. Any disagreement was resolved through discussion and contacting a third author (LM), if needed. Two authors (MA and AT) independently extracted the data from the included studies, using a standard form and summarised them in Table 1. The items extracted were: details of the participants (i.e. age, gender, type of disease); inclusion/exclusion criteria for patients' eligibility; duration, intensity and frequency of interventions and controls; description of telerehabilitation programme; outcomes assessed.

Both the experimental and control treatments provided to participants were reported with as many details as possible. If needed, the trials' author was contacted to ask for clarification and to obtain missing data.

Data on motor function scores were extracted and pooled in a meta-analysis using the Cochrane Collaboration's Review Manager software (RevMan 5.0). Whenever available, the results from intention-to-treat (ITT) analyses were extracted and pooled. As motor function is widely assessed through scores on different continuous scales, we pooled the data using the standardised mean difference (SMD) and 95% confidence intervals (CI). In those cases when the same outcome was used in different trials the mean difference (MD) and 95% CI were used for meta-analysis. We analysed the studies according to the type of population included (e.g. neurological, surgical, cardiac patients). Heterogeneity was determined using the I-squared (I^2) statistic (I^2 greater than 50% was considered as substantial heterogeneity). When heterogeneity was present, data were pooled using a random-effect model and potential causes explored through subgroup analysis.

Quality assessment

Two authors (MA and AT) independently evaluated the methodological quality of the included studies, using a standardised critical appraisal assessment form. Quality assessment of studies was focused on areas of bias which might overestimate the effectiveness of interventions. The following domains were considered as relevant: random sequence generation; allocation concealment; baseline comparison between groups; blinding of outcome assessment; incomplete outcome data (attrition and ITT analysis). The results are summarised in the risk of bias table (Table 2).

Results

Studies selection

The literature search retrieved 2360 records (i.e. Pubmed = 1674; Embase = 510; CENTRAL = 176). With regard to crucial keywords such as, “telemonitored rehabilitation” and “telemonitored exercise training”, independent searches retrieved 8 and 3 records, respectively. Nevertheless, all that records contained “telemedicine” as MeSH descriptor that has been included in our search strategy.

After the removal of duplicates, we screened the title and abstract of 2150 references and selected 76 papers (1 full text was not retrieved [16]) for which we assessed the full text for final inclusion. Among these 64 papers were excluded for the following reasons: 35 because the ICTs used were not aimed to rehabilitation purposes [17-51]; eight papers were protocols of ongoing studies and results were not available [52-59]; seven studies did not have a control group [60-66]; five because the intervention setting was the same in the two groups [8, 67-70]; five were pilot studies [71-75]; two were secondary analysis of RCTs already included [76, 77]; two studies were excluded because the poor reporting precluded any possible assessment of its eligibility [78, 79]. Finally, 12 RCTs for a total of 1047 participants were included in the review (Figure 1).

Characteristics of the included studies

The main characteristics of RCTs included are described in Table 1. Ten studies compared telerehabilitation with usual care provided at home or hospital [9, 80-88], while two studies compared the same intervention provided via telerehabilitation or face-to-face by therapists [4, 7]. The best outcome measure assessing motor function was extracted, regardless of its definition as primary outcome. In all the studies motor function was assessed before and after all treatments. Five trials also reported later follow-up assessments at 1 [9, 89], 3 [87] and 6 months [81, 86] after the end of treatment. We did not consider longer follow-up in the meta-analysis. With regard to the populations involved, seven studies focused on patients affected by neurological diseases [9, 81, 83, 84, 86, 88, 89], three on patients following total knee arthroplasty (TKA) surgery [7, 87, 90] and two enrolled cardiac patients [80, 82].

Risk of bias assessment

Table 2 summaries the assessment of the methodological quality of the included studies. There were only RCTs and all but three [80, 87, 88] were at low risk of selection bias due to an adequate random sequence generation and allocation of the randomisation sequence. Baseline characteristics between groups were comparable in all the included trials. Blinding of outcome assessment was judged not adequate in four trials [4, 80, 83, 84]. Attrition bias was absent only in three trials [9, 86, 90] in which no patients were lost at follow up and consequently ITT and per-protocol analysis were coincident.

Effects of interventions

Overall the meta-analyses included 543 participants receiving telerehabilitation compared with 520 participants receiving control treatments. No significant difference between the groups was found (SMD = -0.08, CI 95% = -0.43, 0.27). Moreover, a high level of heterogeneity (I^2 = 85%) affected the meta-analysis which depended on the broad difference of populations enrolled. To take this into account, three different meta-analyses were run grouping the studies with the same populations. The effect of telerehabilitation on motor function is displayed in figures 2 to 4 for neurological, TKA and cardiac populations, respectively. Dallolio et al. reported no overall data but split the results in three subgroups.

Telerehabilitation was more effective than control treatments for regaining motor function, when provided to patients following TKA surgery (Timed Up and Go test: MD = -5.17, CI 95% = -9.79, -0.55). This result was mostly driven by the highly positive study by Piqueras and colleagues, which was judged at high risk of selection and attrition biases. In patients with cardiac diseases, there was a more plausible small effect favouring telerehabilitation (SMD = 0.24, CI 95% = 0.04, 0.43). However, these data are based on two trials only. Similarly to Laver and collegues, no significant different effects were found between telerehabilitation and other interventions when used for the treatment of neurological diseases (SMD = 0.10, CI 95% = -0.24, 0.43). All the meta-analyses were displayed sorted by incremental effect sizes. The visual inspection of forest plots showed that direction of efficacy was influenced by magnitude of effect size, being the studies with biggest effect sizes in favour of telerehabilitation. Nevertheless, none of the studies, except one [87], resulted as statistically significant by itself.

Studies of cardiac patients were homogeneous while heterogeneity was high among neurological (I^2 = 54%) and TKA (I^2 = 84%) studies, thus results from random effects models are displayed in figures 2 and 3. Nevertheless, neither random effects models explained such heterogeneity, thus the reasons were explored through subgroup analysis, finding that it dropped down to 0% removing the studies affected by higher risk of biases, both in neurological [83, 84, 88] and TKA [87] meta-analyses. Nevertheless, the removal of low quality studies did not change the results of the meta-analyses both for neurological (6 studies: SMD = 0.16, CI 95% = -0.12, 0.44) and TKA (Timed Up and Go test, 2 studies: MD = -2.72, CI 95% = -5.39, -0.06) populations.

Discussion

In this study the scientific literature was systematically reviewed to retrieve controlled trials comparing telerehabilitation with other treatments. The aim of the systematic review was to determine whether telerehabilitation was more effective than other rehabilitation modalities to regain motor function, in different populations of patients. It has to be acknowledged that we chose to distinguish telerehabilitation from other telemedicine applications (e.g. telemonitoring, teleradiology) because of the possibility of providing therapeutic interventions, remotely controlled by healthcare professionals, with a rehabilitation purpose. In our definition the aim of telerehabilitation is to augment the intensity and the providing of rehabilitation care after discharge, to guarantee continuity of care from hospital to patient's home and to reduce costs. With this definition, the variety of populations included in this review could be intended as joined by common needs typical of chronic conditions (i.e. reductions of: physical activity, coping, clinical outcomes; increase of: hospital stay, hospital readmission rate, mortality) [91].

The picture depicted by this systematic analysis indicates that the most extensive application for telerehabilitation was developed and tested with survivors from traumatic, degenerative and vascular diseases of the central nervous system (CNS), like: spinal cord injury, traumatic brain injury, multiple sclerosis and stroke.

An interesting finding from our meta-analysis is the significant positive effect of telerehabilitation in the post TKA surgery population. When measured by TUG test a researcher would expect patients treated by telerehabilitation to improve 6.5 seconds more than patients treated routinely, on average. Although a minimally clinically important difference for TUG test in post TKA surgery patients was not established in this study, our result is bigger than the standard error of measurements reported for other populations, thus reducing the chance that the same result was just due to an intrinsic variability of the outcome. A possible explanation for our finding could be due to the follow up time between 2 and 8 weeks for all the TKA studies, that represents a more homogeneous comparison than the follow up range reported for the neurological population (i.e. between 4 and 24 weeks) and a feasible time for recovery after knee surgery. Moreover, telerehabilitation provides a concrete opportunity to increase the amount and intensity of rehabilitation experienced by patients, a factor that is known to be a positive predictor of recovery after surgery.

Overall, our results were influenced by the chosen inclusion criteria deliberately set to exclude all telemedicine applications not devoted to therapy and not provided by healthcare professionals. These criteria determined the difference between the studies included in our study than the ones included by the Cochrane stroke group in its recently published review of telerehabilitation services for stroke [15]. Another difference between the two reviews is related to the choice of outcomes. Whilst Laver and co-workers focused their work on a broad range of clinical outcomes (i.e. ADLs, independence, mobility, QoL, upper limb function, cognitive function, communication), our choice was to detail the effect of telerehabilitation on recovery of motor function amongst different populations. Nevertheless, in both reviews the studies retrieved were small and frequently biased by lack of outcome assessor blinding and lack of allocation concealment.

Limitations

Several limitations of this review should be acknowledged. Despite the most extensive application for telerehabilitation was developed and tested with survivors from traumatic, degenerative and vascular diseases of the central nervous system (CNS), most of the studies in the neurorehabilitation field are marked by small sample sizes, large variability of results and consistent presence of biases representing the main source of heterogeneity in this meta-analysis. Despite the literature on neurorehabilitation represents the largest in terms of studies retrieved (n = 7), the patients enrolled overall (n = 385) were less than the patients enrolled in the 2 studies retrieved for the cardiac population (n = 414). The limit of small samples is common in the neurorehabilitation literature [92], because of the difficulties in predicting prognosis, the broad range of disability experienced by patients, the burden of care on caregivers and the long time needed to observe meaningful changes of clinical outcomes [93]. As a consequence, the enrolment of patients is more challenging for researcher in the neurorehabilitation field, than in other specialties related to rehabilitation.

Another finding from this review was the paucity of eligible trials on telerehabilitation for cardiac patients. The literature on telemedicine for heart failure survivors is wide and has been consolidated for many years. Nevertheless, the major part of clinical trials in this field aimed to improve: reliability of monitoring at a distance, adherence to lifelong therapeutic programs, levels of physical activity, with the aim to reduce risk factors and mortality. Only a minority of trials aimed to study active rehabilitation therapies for cardiac patients. Another limitation for cardiac patients was the selection of questionnaires instead of tests for the assessment of motor function. The choice was based on two main reasons: firstly, in Barnason et al. only for SF-36 data were available for all the patients, thus reducing the attrition bias related to reporting per-protocol analysis; secondly, exist available evidence that telemonitoring is effective in cardiac patients to increase the motor activity and function, as measured by tests. Given these limitations, our final choice was to assess whether the objective improvement of motor function was subjectively perceived with self-reported outcome measures (fully reported in both papers). Indeed, only motor components of questionnaires were considered for meta-analysis. Our choice was also based on the evidence that meta-analysis for homogeneous outcome measures (i.e. minutes of physical activity) has been run confirming the result in favour of telerehabilitation (SMD = 0.25 [0.05-0.45]), but with moderate heterogeneity ($I2$ = 37%) and presumably affected by attrition bias in primary studies. In conclusion we chose to stay conservative reporting a more robust meta-analysis based on new findings not present in the literature.

In the end, the most popular electronic databases were searched for this review, but telerehabilitation is emerging as a transversal topic throughout healthcare professionals, thus other databases specific for different disciplines could have been included to achieve a broader coverage (e.g. CINAHL, psycINFO, PEDro) of the literature. Moreover, only trials reported in English and in Italian were included, restricting the raw dataset of records used for screening.

Conclusion

Our meta-analysis was not conclusive and did not provide final evidence on the efficacy of telerehabilitation in motor function recovery. Several position statements have been published about telerehabilitation in the last few years [94, 95], highlighting the need for standardization of procedures, aims and targets characterizing this therapeutic modality. Considering the growing burden of care within national health systems and the need to guarantee adequate and continue services to chronic conditions, telerehabilitation is becoming an interesting model of care, whose potential deployment needs to be studied. To understand whether the growing dissemination of ICTs infrastructures may be adequate for the deployment of innovative rehabilitation services based on the internet, robust trials have to be designed and carried out, to avoid waste of resources and the risk of inconclusive findings from primary research. Moreover, future trials on telerehabilitation should include costs accountability and cost-effectiveness analyses, associated with clinical findings. The main potentiality of telerehabilitation is the possibility to increase the frequency and intensity of care provided to patients and consequently to motivate clients in their own home environment. The current data are encouraging and support continuity of rehabilitation care through ICTs, but the quality of primary research has to be improved dramatically to have a clearer picture of benefits and risks associated with assisting patients at a distance, once discharged at home.

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Figures

Figure 1. Literature flowchart.

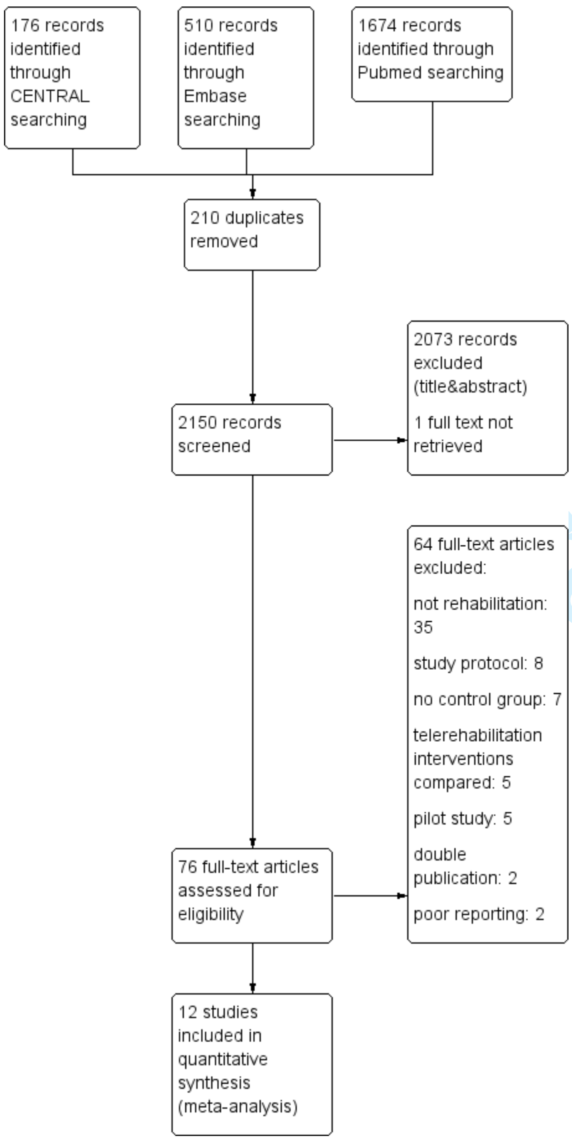
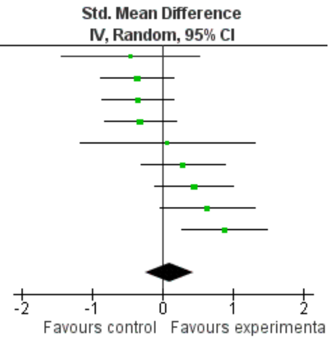


Figure 2. Effect of telerehabilitation on motor function for neurological patients.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Dallolio, 2008b	48.71	30.83	7	62.6	27.28	10	7.3%	-0.46 [-1.44, 0.52]
Dallolio, 2008a	49.13	22.94	30	58.03	25.94	29	13.3%	-0.36 [-0.87, 0.16]
Huijgen, 2008	45.5	14.9	47	50.2	8.2	22	13.3%	-0.35 [-0.86, 0.16]
Hermens, 2007	46.1	14.2	46	50.2	8.2	22	13.3%	-0.32 [-0.83, 0.19]
Piron, 2008	56.6	8.93	5	56	8.72	5	5.3%	0.06 [-1.18, 1.30]
Chumbler, 2012	82.7	9.7	22	79	15	22	12.0%	0.29 [-0.31, 0.88]
Dallolio, 2008c	58.7	24.32	25	46.96	27.35	26	12.6%	0.45 [-0.11, 1.00]
Piron, 2009	53.6	7.7	18	49.5	4.8	18	10.9%	0.62 [-0.05, 1.30]
Gutierrez, 2013	89.47	6.69	24	81.9	10.09	23	11.9%	0.87 [0.27, 1.47]
Total (95% CI)			**224**			**177**	**100.0%**	**0.10 [-0.24, 0.43]**

Heterogeneity: Tau² = 0.15; Chi² = 20.44, df = 8 (P = 0.009); I² = 61%
Test for overall effect: Z = 0.55 (P = 0.58)



The study from Dallolio et al. (2008) was split in three different studies given that reporting of results for the overall groups was missing.

Figure 3. Effect of telerehabilitation on the Timed Up and Go test after total knee arthroplasty.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Piqueras, 2013	-3.36	5.38	72	5.22	6.25	70	38.3%	-8.58 [-10.50, -6.66]
Russell, 2011	-16.33	10.94	31	-12.19	10.12	34	27.2%	-4.14 [-9.28, 1.00]
Tousignant, 2011	-11.7	6.4	21	-9.5	3.4	20	34.5%	-2.20 [-5.32, 0.92]
Total (95% CI)			**124**			**124**	**100.0%**	**-5.17 [-9.79, -0.55]**

Heterogeneity: Tau² = 13.53; Chi² = 12.62, df = 2 (P = 0.002); I² = 84%
Test for overall effect: Z = 2.19 (P = 0.03)

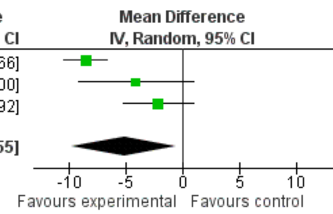


Figure 4. Effect of telerehabilitation on motor function for cardiac patients.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Furber, 2010	4.95	1.2	97	4.65	1.4	107	49.3%	0.23 [-0.05, 0.50]
Barnason, 2009	80	22.1	98	74.3	24.5	112	50.7%	0.24 [-0.03, 0.51]
Total (95% CI)			**195**			**219**	**100.0%**	**0.24 [0.04, 0.43]**

Heterogeneity: Chi² = 0.01, df = 1 (P = 0.94); I² = 0%
Test for overall effect: Z = 2.38 (P = 0.02)

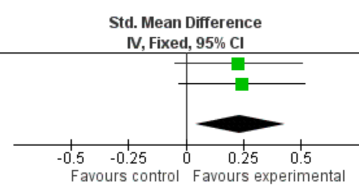


Table 1. Characteristics of the included studies.

Author, year	Population	Patients (exp/ctrl)	Experimental intervention	Control intervention	Motor function outcome	Outcome construct	Other outcomes	Follow-up
Hermens, 2007	Stroke TBI MS	81 (55/26)	30’ daily sessions; 5d/w HCAD	Usual care	ARAT	UE function	NHPT; WMFT	4 weeks
Huijen, 2008	Stroke TBI MS	81 (55/26)	30’ daily sessions; 5d/w HCAD	Usual care	ARAT	UE function	NHPT; VAS satisfaction	4 weeks
Piron, 2008	Stroke	10 (5/5)	1 h daily; 5d/w (20 sessions) Remotely controlled VR	VR at home	F-M UE	UE motor function	Satisfaction	4 weeks
Dallolio, 2008	SCI	137 (62/65)	45’; 8d/w (2 m) + 2d/w (4m) Clinical counselling and OT	Usual care at home	FIM	Independence	SCIM II; Satisfaction	24 weeks
Barnason, 2009	Elderly after CABS	280 (143/137)	7 daily sessions/w (42 sessions) Subjects provided with symptom management strategies	Usual care	MOS SF-36 (physical functioning sub scale)	Motor function, Independence, QoL	Modified 7-Day Activity Interview; RT3 accelerometer; diary (health care use)	6 weeks
Piron, 2009	Stroke	36 (18/18)	1 h daily; 5d/w (20 sessions) Remotely controlled VR	Usual care at home	F-M UE	UE motor function	Ashworth; Abilhand	4 weeks
Furber, 2010	Cardiac parients	222 (109/113)	daily sessions Pedometer, self-monitoring, telephone and mail support	Usual care	Active Australia Questionnaire	Sel-reported physical activity	Kessler 6 scale	6 weeks
Russell, 2011	Total knee arthroplasty	65 (31/34)	45’ daily sessions Exercises programme; education for postoperative management provided by PT	Usual care at the PT department	TUG	Mobility, balance, walking ability	Patient-Specific Functional Scale; WOMAC; Pain Intesity; Knee Flex/Ext; Strength (quadriceps); Limb girth; Gait	6 weeks
Tousignant, 2011	Total knee arthroplasty	48 (24/24)	1 h twice a week Functional exercises programme	Usual care at home	TUG	Mobility, balance, walking ability	ROM; BBS; 30’ Chair-stand Test; WOMAC; Tinetti; SMAF; MOS SF-36	8 weeks
Gutierrez, 2013	MS	47 (24/23)	10w, 4 sessions/w, 20’/session (40 sessions) Xbox360® console with Microsoft® Kinect (i.e. Kinect Sports®, Joy Ride®, Adventures®	40’ twice a week PT (low-loads strength, proprioception, stretching exercises)	BBS	Mobility, balance, walking ability	Tinetti, VAS fatigue, SOT test	10 weeks
Chumbler, 2012	Stroke	48 (25/23)	3 months STeleR: 3 home televisits, daily IHMD, VA.	Usual care (VA) at home.	Motor FONEFIM (telephone version of FIM)	Independence	LLFDI: upper extremity, disability	3 months

Piqueras, 2013	Total knee arthroplasty	181 (90/91)	1h sessions for 10d IVT	Standard rehabilitation	TUG	Mobility, balance, walking ability	ROM; dynamometer; VAS pain; WOMAC	10 days

exp: experimental; ctrl: control; CABS: coronary artery bypass surgery; MOS SF-36: medical outcomes study short form 36; QoL: quality of life; TBI: traumatic brain injury; MS: multiple sclerosis; ARAT: action research arm test; UE: upper extremity; NHPT: nine hole pegboard test; WMFT: Wolf motor function test; PT: physical therapist; WOMAC: Western Ontario and McMaster universities osteoarthritis index; TUG: timed up and go test; VR: virtual reality; F-M: Fugl-Meyer scale; SCI: spinal cord injury; OT: occupational therapy; FIM: functional independence measure; SCIM II: spinal cord independence measure II; ROM: range of movement; BBS: Berg balance scale; SMAF: functional autonomy measurement system; SOT: sensory organization test; IHMD: in-home messaging device; VA: Veteran Affair; LLFDI: Overall Function Component of the Late-Life Function and Disability Instrument; IVT: Interactive Virtual Telerehabilitation.

Table 2. Risk of bias table.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Baseline comparison between groups	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)
Barnason, 2009	−	−	+	−	−
Chumbler, 2012	+	+	+	+	+
Dallolio, 2008a	+	+	+	+	−
Dallolio, 2008b	+	+	+	+	−
Dallolio, 2008c	+	+	+	+	−
Furber, 2010	+	+	+	+	−
Gutierrez, 2013	−	−	+	+	−
Hermens, 2007	+	+	+	−	−
Huijgen, 2008	+	+	+	−	−
Piqueras, 2013	−	−	+	+	−
Piron, 2008	+	+	+	+	+
Piron, 2009	+	+	+	−	−
Russell, 2011	+	+	+	+	+
Tousignant, 2011	+	+	+	+	−

Red = high risk of bias; Green = low risk of bias.

Appendix 1. Electronic searches

MEDLINE search strategy (the search strategy uses MeSH terms unless indicated otherwise):

Set A terms (Combined by OR)

telerehabilitat*

"tele rehabilitation"

Telemedicine (and textword variations)

Telehealth (and textword variations)

"tele health"

Set B terms (Combined by OR)

Telemedicine

Set C (Combined by OR)

"remote consultation"

Telepathology (and textword variations)

Set D (Combined by OR)

random*

"meta analysis"

trial*

MEDLINE Search sets are:

1. (A OR B) OR C. Limits: Humans, Clinical Trial, Meta-Analysis, Randomized Controlled Trial
2. A OR C
3. 2 AND D. Limits: published in the last 60 days
4. 3 AND D

EMBASE search strategy:

1. telemedicine:ab,ti AND [humans]/lim AND [embase]/lim
2. 'telemedicine'/exp AND [humans]/lim AND [embase]/lim AND [medline]/lim
3. 'remote consultation':ab,ti AND [humans]/lim AND [embase]/lim
4. telerehabilitation:ab,ti AND [humans]/lim AND [embase]/lim
5. telehealth:ab,ti AND [humans]/lim AND [embase]/lim
6. telepathology:ab,ti AND [humans]/lim AND [embase]/lim
7. 'tele rehabilitation':ab,ti AND [humans]/lim AND [embase]/lim
8. 'tele health':ab,ti AND [humans]/lim AND [embase]/lim
9. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8
10. 9 AND ([controlled clinical trial]/lim OR [meta analysis]/lim OR [randomized controlled trial]/lim) AND [humans]/lim AND [embase]/lim

THE COCHRANE LIBRARY – CLINICAL TRIALS DATABASE

Set A (Combined by OR)

telerehabilitat*

"tele rehabilitation"

Telemedicine

Telehealth

"tele health"

Set B (Combined by OR)

"remote consultation"

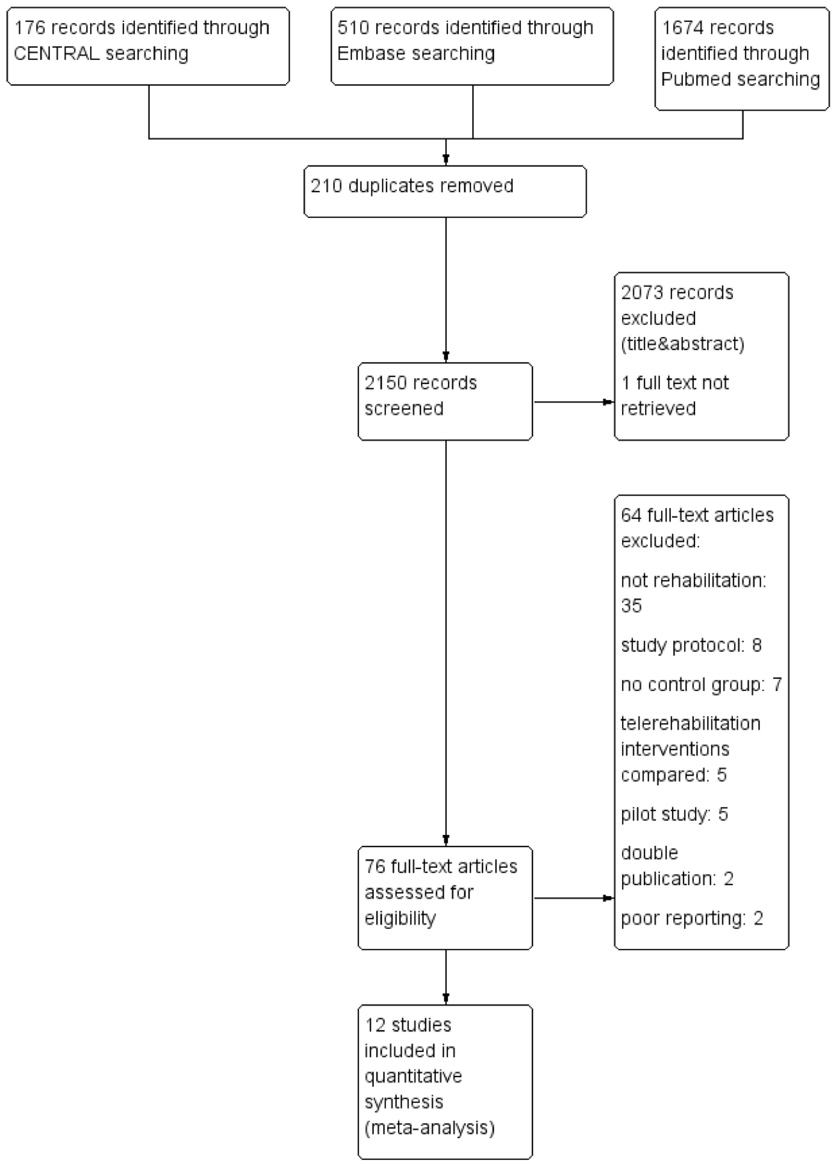
Telepathology

THE COCHRANE LIBRARY – CLINICAL TRIALS DATABASE Search Sets

1. A OR B
2. 1 AND NOT PUBMED
3. 2 AND NOT EMBASE

SEARCHING OTHER RESOURCES

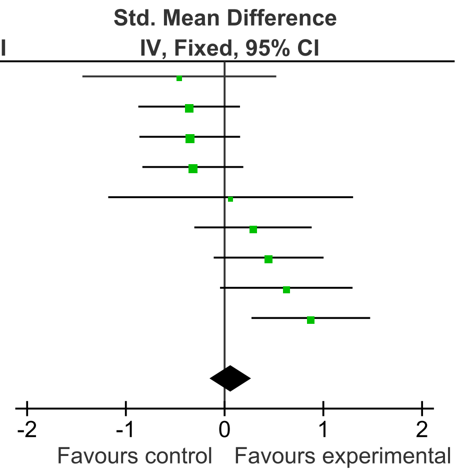
The issues not available online from Journal of Telemedicine and Telecare (from Vol 1, 1995 to Vol 5, 1999) were hand searched. Letters were sent to authors or institutions to request information about studies reported as ongoing at the time of review or in case of poor reporting.



264x362mm (300 x 300 DPI)

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Dallolio, 2008b	48.71	30.83	7	62.6	27.28	10	4.3%	-0.46 [-1.44, 0.52]
Dallolio, 2008a	49.13	22.94	30	58.03	25.94	29	15.6%	-0.36 [-0.87, 0.16]
Huijgen, 2008	45.5	14.9	47	50.2	8.2	22	15.9%	-0.35 [-0.86, 0.16]
Hermens, 2007	46.1	14.2	46	50.2	8.2	22	15.8%	-0.32 [-0.83, 0.19]
Piron, 2008	56.6	8.93	5	56	8.72	5	2.7%	0.06 [-1.18, 1.30]
Chumbler, 2012	82.7	9.7	22	79	15	22	11.7%	0.29 [-0.31, 0.88]
Dallolio, 2008c	58.7	24.32	25	46.96	27.35	26	13.4%	0.45 [-0.11, 1.00]
Piron, 2009	53.6	7.7	18	49.5	4.8	18	9.2%	0.62 [-0.05, 1.30]
Gutierrez, 2013	89.47	6.69	24	81.9	10.09	23	11.4%	0.87 [0.27, 1.47]
Total (95% CI)			**224**			**177**	**100.0%**	**0.07 [-0.13, 0.27]**

Heterogeneity: Chi² = 20.44, df = 8 (P = 0.009); I² = 61%
Test for overall effect: Z = 0.67 (P = 0.50)



	Experimental			Control				Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
Piqueras, 2013	-3.36	5.38	72	5.22	6.25	70	38.3%	-8.58 [-10.50, -6.66]
Russell, 2011	-16.33	10.94	31	-12.19	10.12	34	27.2%	-4.14 [-9.28, 1.00]
Tousignant, 2011	-11.7	6.4	21	-9.5	3.4	20	34.5%	-2.20 [-5.32, 0.92]
Total (95% CI)			**124**			**124**	**100.0%**	**-5.17 [-9.79, -0.55]**

Heterogeneity: Tau² = 13.53; Chi² = 12.62, df = 2 (P = 0.002); I² = 84%
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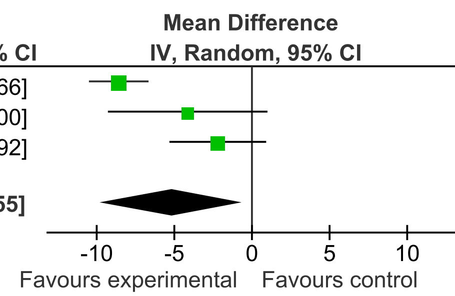

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Barnason, 2009	145.4	118.8	81	126.9	195.7	99	47.1%	0.11 [-0.18, 0.41]
Furber, 2010	366.5	270.8	97	270.9	244.4	107	52.9%	0.37 [0.09, 0.65]
Total (95% CI)			**178**			**206**	**100.0%**	**0.25 [0.05, 0.45]**

Heterogeneity: Chi² = 1.58, df = 1 (P = 0.21); I^2 = 37%
Test for overall effect: Z = 2.41 (P = 0.02)

Std. Mean Difference
IV, Fixed, 95% CI

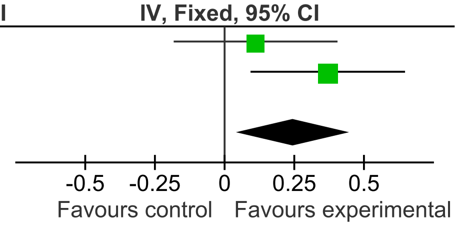

Table 1. Characteristics of the included studies.

Author, year	Population	Patients (exp/ctrl)	Experimental intervention	Control intervention	Motor function outcome	Outcome construct	Other outcomes	Follow-up
Hermens, 2007	Stroke TBI MS	81 (55/26)	30' daily sessions; 5d/w HCAD	Usual care	ARAT	UE function	NHPT; WMFT	4 weeks
Huijen, 2008	Stroke TBI MS	81 (55/26)	30' daily sessions; 5d/w HCAD	Usual care	ARAT	UE function	NHPT; VAS satisfaction	4 weeks
Piron, 2008	Stroke	10 (5/5)	1 h daily; 5d/w (20 sessions) Remotely controlled VR	VR at home	F-M UE	UE motor function	Satisfaction	4 weeks
Dallolio, 2008	SCI	137 (62/65)	45'; 8d/w (2 m) + 2d/w (4m) Clinical counselling and OT	Usual care at home	FIM	Independence	SCIM II; Satisfaction	24 weeks
Barnason, 2009	Elderly after CABS	280 (143/137)	7 daily sessions/w (42 sessions) Subjects provided with symptom management strategies	Usual care	MOS SF-36 (physical functioning sub scale)	Motor function, Independence, QoL	Modified 7-Day Activity Interview; RT3 accelerometer; diary (health care use)	6 weeks
Piron, 2009	Stroke	36 (18/18)	1 h daily; 5d/w (20 sessions) Remotely controlled VR	Usual care at home	F-M UE	UE motor function	Ashworth; Abilhand	4 weeks
Furber, 2010	Cardiac parients	222 (109/113)	daily sessions Pedometer, self-monitoring, telephone and mail support	Usual care	Active Australia Questionnaire	Sel-reported physical activity	Kessler 6 scale	6 weeks
Russell, 2011	Total knee arthroplasty	65 (31/34)	45' daily sessions Exercises programme; education for postoperative management provided by PT	Usual care at the PT department	TUG	Mobility, balance, walking ability	Patient-Specific Functional Scale; WOMAC; Pain Intesity; Knee Flex/Ext; Strength (quadriceps); Limb girth; Gait	6 weeks
Tousignant, 2011	Total knee arthroplasty	48 (24/24)	1 h twice a week Functional exercises programme	Usual care at home	TUG	Mobility, balance, walking ability	ROM; BBS; 30' Chair-stand Test; WOMAC; Tinetti; SMAF; MOS SF-36	8 weeks
Gutierrez, 2013	MS	47 (24/23)	10w, 4 sessions/w, 20'/session (40 sessions) Xbox360® console with Microsoft® Kinect (i.e. Kinect Sports®, Joy Ride®, Adventures®	40' twice a week PT (low-loads strength, proprioception, stretching exercises)	BBS	Mobility, balance, walking ability	Tinetti, VAS fatigue, SOT test	10 weeks

Chumbler, 2012	Stroke	48 (25/23)	3 months STeleR: 3 home televisits, daily IHMD, VA.	Usual care (VA) at home.	Motor FONEFIM (telephone version of FIM)	Independence	LLFDI: upper extremity, disability	3 months
Piqueras, 2013	Total knee arthroplasty	181 (90/91)	1h sessions for 10d IVT	Standard rehabilitation	TUG	Mobility, balance, walking ability	ROM; dynamometer; VAS pain; WOMAC	10 days

exp: experimental; ctrl: control; CABS: coronary artery bypass surgery; MOS SF-36: medical outcomes study short form 36; QoL: quality of life; TBI: traumatic brain injury; MS: multiple sclerosis; ARAT: action research arm test; UE: upper extremity; NHPT: nine hole pegboard test; WMFT: Wolf motor function test; PT: physical therapist; WOMAC: Western Ontario and McMaster universities osteoarthritis index; TUG: timed up and go test; VR: virtual reality; F-M: Fugl-Meyer scale; SCI: spinal cord injury; OT: occupational therapy; FIM: functional independence measure; SCIM II: spinal cord independence measure II; ROM: range of movement; BBS: Berg balance scale; SMAF: functional autonomy measurement system; SOT: sensory organization test; IHMD: in-home messaging device; VA: Veteran Affair; LLFDI: Overall Function Component of the Late-Life Function and Disability Instrument; IVT: Interactive Virtual Telerehabilitation

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Baseline comparison between groups	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)
Barnason, 2009	−	−	+	−	−
Chumbler, 2012	+	+	+	+	+
Dallolio, 2008a	+	+	+	+	−
Dallolio, 2008b	+	+	+	+	−
Dallolio, 2008c	+	+	+	+	−
Furber, 2010	+	+	+	+	−
Gutierrez, 2013	−	−	+	+	−
Hermens, 2007	+	+	+	−	−
Huijgen, 2008	+	+	+	−	−
Piqueras, 2013	−	−	+	+	−
Piron, 2008	+	+	+	+	+
Piron, 2009	+	+	+	−	−
Russell, 2011	+	+	+	+	+
Tousignant, 2011	+	+	+	+	−