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REVIEW

A systematic review of clinical outcomes, clinical process, healthcare utilization and costs associated with telerehabilitation

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Abstract

Purpose. To identify clinical outcomes, clinical process, healthcare utilization and costs associated with telerehabilitation for individuals with physical disabilities.

Method. Relevant databases were searched for articles on telerehabilitation published until February 2007. Reference lists were examined and key journals were hand searched. Studies that included telerehabilitation for individuals with physical impairments and used experimental or observational study designs were included in the analysis, regardless of the specific clientele or location of services. Data was extracted using a form to record methodological aspects and results relating to clinical, process, healthcare utilization and cost outcomes. Study quality of randomized clinical trials was assessed using the PEDro rating scale.

Results. Some 28 articles were analysed. These dealt with rehabilitation of individuals in the community, neurological rehabilitation, cardiac rehabilitation, follow-up of individuals with spinal cord injuries, rehabilitation for speech-language impairments, and rehabilitation for varied clienteles. Clinical outcomes were generally improved following a telerehabilitation intervention and were at least similar to or better than an alternative intervention. Clinical process outcomes, such as attendance and compliance, were high with telerehabilitation although few comparisons are made to alternative interventions. Consultation time tended to be longer with telerehabilitation. Satisfaction with telerehabilitation was consistently high, although it was higher for patients than therapists. Few studies examined healthcare utilization measures and those that did reported mixed findings with respect to adverse events, use of emergency rooms and doctor visits. Only five of the studies examined costs. There is some preliminary evidence of potential cost savings for the healthcare facility.

Conclusions. While evidence is mounting concerning the efficacy and effectiveness of telerehabilitation, high-quality evidence regarding impact on resource allocation and costs is still needed to support clinical and policy decision-making.

Keywords: *Telemedicine, telehealth, telerehabilitation, videoconference, rehabilitation, outcomes, physical therapy, occupational therapy, speech therapy*

Introduction

Current demographic trends, including an ageing population which has tripled over the last 50 years and an increase in chronic diseases, have put increased pressure on healthcare systems worldwide and their ability to provide quality care [1,2]. With healthcare resources already scarce, this has led to a quest for new ways of organizing health services. Telerehabilitation and telemedicine advocates promote the use of communication and information technologies as a way of increasing accessibility and enhancing continuity of care for vulnerable populations such as those with disability [3–5], as well as a potential time and cost-saving strategy [6–10].

Alongside the many branches of telemedicine, the number of telerehabilitation programmes has been steadily increasing. The use of such technologies in rehabilitation clearly has many expected

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and unexpected consequences. In addition, the technologies involved in the provision of telerehabilitation can be quite costly. Prior to implementing new telerehabilitation programmes and in order to ensure sound clinical and policy decisions, it is therefore essential to understand the consequences of its use.

Systematic reviews can help summarize and critically synthesize the available body of literature and be a useful tool for clinical decision-making and programme planning [11], especially in a newer research area, where the quality and scope of studies is very variable. They also help to identify areas in which research is currently lacking [11–13]. Although there is a growing body of literature on telerehabilitation, there are no systematic reviews in this area. Jennett et al. [14] conducted a systematic review of the socio-economic impact of telehealth. However as rehabilitation was one of several areas they examined, they provide only a very brief overview of the types of socio-economic outcomes used in the telerehabilitation studies and the number of studies demonstrating benefits on those outcomes. Van Dijk and Hermens conducted a review of evidence for the use of distance training in restoring motor function [15]. Although their focus was not solely telerehabilitation programmes, their review included several telerehabilitation studies at that time in the preliminary stages of development. As well, a recent report published by the Agence d'évaluation des technologies et des modes d'interventions, a health technology assessment agency in Quebec, Canada, identified clinical and technical guidelines to be applied to telerehabilitation [16]. Its focus however was not the outcomes of telerehabilitation programmes nor did it include telerehabilitation in the patient's home. This article therefore provides a systematic review of the scientific literature in order to evaluate the efficacy, effectiveness and costs of telerehabilitation used for direct patient services. Specifically, this study examined clinical outcomes, clinical process and healthcare utilization measures, as well as costs related to telerehabilitation. These outcomes were selected to reflect a common objective of telerehabilitation programmes, which is to provide access to quality rehabilitation services while maximizing resource allocation and minimizing costs.

Methods

Search strategy

For the present study, telerehabilitation is defined as the use of communication and information technologies to provide clinical rehabilitation services from a distance. The following databases were searched for relevant articles in English or French, starting at the earliest date available for each database and ending in February 2007: Medline, CINHAL, EMBASE, Cochrane database for systematic reviews, ACP Journal Club, DARE, CCTR, Health And Psychosocial Instruments, PsychInfo, PEDro (physiotherapy evidence database), and health technology assessment reports through the Centre for Reviews and Dissemination of the University of York. The keywords telerehabilitation, teletherapy and the combination of telehealth or telemedicine with rehabilitation, were combined with outcome, effectiveness, cost or efficacy. As well, the same searches were repeated by replacing rehabilitation with physiotherapy/physical therapy, occupational therapy and speech-language pathology. Two main journals in telemedicine were also hand searched for additional relevant references (*Journal of Telemedicine and Telecare*, and *Telemedicine Journal and e-Health*). Finally, one relevant article was identified among articles previously retrieved by one of the authors which had not been identified through any of the above searches although it should have been indexed. Therefore the journal in which the article was published was hand searched for additional relevant articles, but no new articles were identified. References from all relevant articles were checked and potentially relevant articles were retrieved.

Selection criteria

Studies published in peer-reviewed journals with a telerehabilitation component in a population with physical deficits were included if: (i) They were designed as an interventional study (experimental or observational) [17], (ii) they used quantitative or qualitative approaches, and (iii) they presented findings related to outcomes or costs. There were no restrictions for age or care setting (e.g., home, community, facility).

Studies were excluded if: (i) They dealt with a population with mental illness only, (ii) they included only telephone interventions (unless telephone intervention was one group of the study, with a video component in the other, or unless other technologies were paired up with the use of the telephone), (iii) the technology was smart home monitoring devices, (iv) they examined telehome care of patients with chronic disease who received only nursing interventions with no rehabilitation objective, (v) they reported only the development phase of the technology (i.e., feasibility of the technology in a lab setting), (vi) they examined only the support for caregivers of patients, (vii) they were programme descriptions or reports not designed as research studies, and (viii) they were redundant

articles which dealt with the same intervention and did not report any new outcomes. Lastly, studies were excluded if they provided insufficient information to allow adequate interpretation of the study design, measures or results or if they were only found in abstract form or in abstracts or posters from conference proceedings as these were felt to provide insufficient detail.

Potential eligibility of the articles was first determined from the title and abstracts identified from the searches. Full-text articles were then retrieved and evaluated for relevance. Articles were excluded at this point if they were not found to meet the above criteria once the full text was examined (for flow chart of article retrieval and reasons for exclusion see Figure 1). A second researcher confirmed the relevance and findings from the selected articles. Twenty-eight articles were retained for analysis using the above search strategies.

Data extraction and outcome measures

The articles were reviewed and a data extraction form was used to include details pertaining to the study quality such as study design, number of subjects, study population, as well as the description of the programme and technology used. Study quality was quantified for randomized clinical trials (RCT) using the PEDro Rating Scale developed by the Centre for Evidence-Based Physiotherapy [18], a commonly used scale in rehabilitation-related systematic reviews and meta-analyses. One point is attributed to each of 10 items relating to internal validity and statistical information, for a maximum score of 10. Based on the Evidence-Based Review of Stroke Rehabilitation [19] scores of 4–5/10 can be regarded as fair, 6–8/10 as good and 9–10/10 as excellent RCTs. Trends and gaps in the available literature were identified; a combined score for the strength of the available evidence was not calculated as there were wide variations in the studies' programmes, populations and measures.

The following types of outcomes reported that were of interest for this review were recorded:

(1) Clinical measures: Outcome measures related to the physical, functional and psychological capacity that are used to determine the effect of an intervention;
(2) Clinical process: Outcomes related to service delivery, such as attendance and adherence to programmes and recommendations, quantity and frequency of contacts with the patient, patient accessibility to the programme, as well as healthcare provider and patient satisfaction with the programme;
(3) Healthcare utilization: Events that occur outside the programme's scope and that the

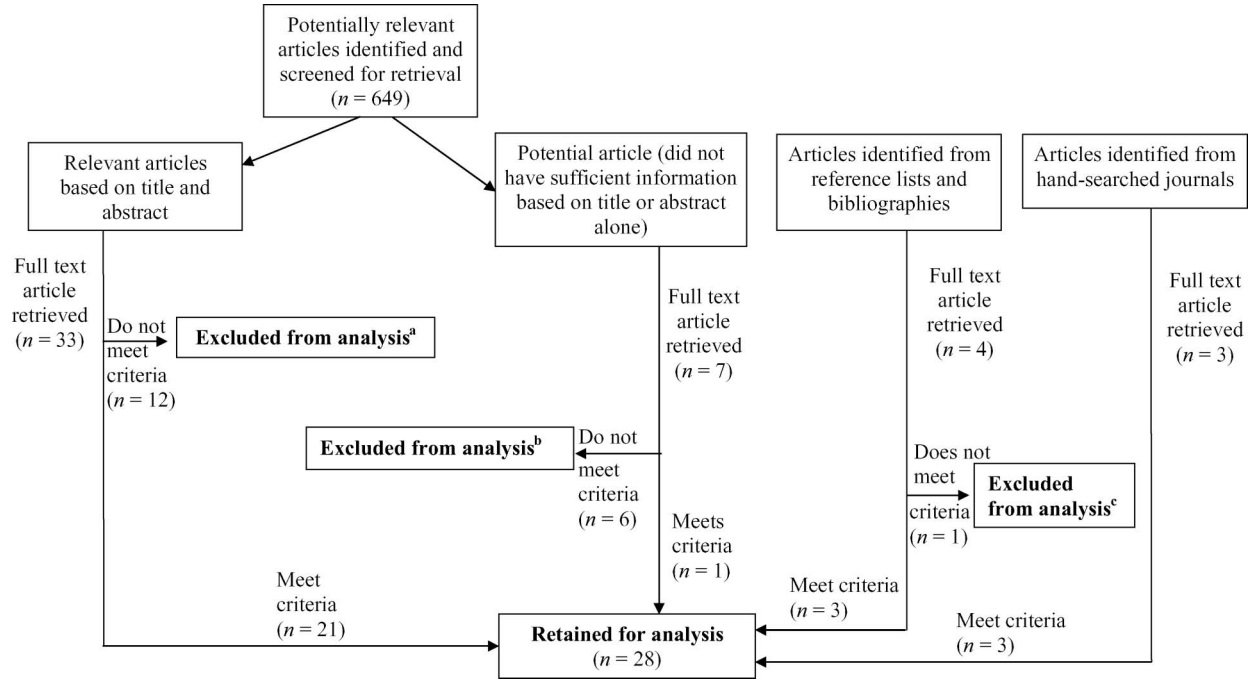

Figure 1. Flow chart of the results from the literature search. (a) Reasons for exclusion: Programme descriptions only ($n = 4$); Review articles ($n = 2$); Feasibility studies ($n = 3$); Prototype testing ($n = 1$); No clinical or cost outcomes ($n = 1$); Descriptive single case study ($n = 1$); (b) Reasons for exclusion: General programme information ($n = 3$); Feasibility studies ($n = 1$); No rehabilitation goals ($n = 1$); Model for cost-analysis only ($n = 1$); (c) Reason for exclusion: Insufficient information to interpret methods, measures and results adequately. ($n =$ number of studies).

programme may aim to reduce or increase, such as hospitalizations, ER admissions and physician visits;

(4) Costs: From the patient's, provider's or organization's perspective, all costs (savings and/or expenses) associated with the use of telerehabilitation.

Studies were then grouped together and outcomes summarized according to the:

(1) Type of telerehabilitation intervention (Table II): Rehabilitation of community-dwelling elderly or disabled population ($n = 9$), follow-up of patients with spinal cord injury ($n = 3$), neurological rehabilitation (motor retraining $n = 3$, other $n = 3$), cardiac rehabilitation ($n = 4$), speech-language impairment rehabilitation ($n = 2$), and consultations for varied clientele ($n = 3$);
(2) Location of telerehabilitation (Table III): Home intervention ($n = 22$, of which five were simulations with the patient and clinician in separate rooms in the same healthcare facility, and three were virtual groups with each patient in their own home), intervention in a group setting in the community ($n = 2$), intervention between healthcare centres ($n = 4$).

Grouping the studies in this way then allowed us to compare outcomes in programmes with similar characteristics, as discussed in further detail in the following section.

Results

As Figure 1 indicates, 22 studies were retained after the initial screening of titles and abstracts and the full-text retrieval of pertinent articles. In addition, six articles were retrieved from hand searches and reference lists, for a total of 28 studies included in this review, 68% (19/28) of which were published after 2003. The search strategy and selection criteria did not limit the type of experimental or observational design. Among the 28 studies, there were eight randomized controlled trials, seven quasi-experimental trials with control groups, nine quasi-experimental pre-post trials without control groups and four trials with post intervention assessments only (see Table I for specific study details).

The results of the clinical outcomes, process outcomes, healthcare utilization and costs reported in the studies are presented in the following sections. These have been summarized in Tables II and III, according to the type of outcome.

Findings relating to clinical outcomes

Of the 28 studies examined, 82% of them reported clinical outcomes, with two studies reporting insufficient information about the outcome measures used and results obtained. Of the studies with a control group which reported clinical outcomes ($n = 8$ randomized and $n = 5$ quasi-experimental studies with control group), seven reported improvements of similar magnitude to a control intervention and six reported greater improvement with telerehabilitation for a variety of clinical outcomes. These included function in activities of daily living ($n = 1$) and return to work ($n = 2$), lower limb range of motion ($n = 1$), gait ($n = 1$), pain ($n = 2$), exercise capacity ($n = 4$), cognitive tasks ($n = 1$), speech quality ($n = 1$), skin integrity ($n = 2$), falls efficacy ($n = 1$), quality of life (QOL; $n = 4$), fatigue ($n = 1$), anxiety ($n = 1$) and depression ($n = 3$). No studies reported worse outcomes with telerehabilitation than in the control group, although two studies reported smaller gains in self-efficacy in the telerehabilitation groups [20,21]. The quasi-experimental studies were well-designed non-randomized studies, which is similar to the type of study design commonly found in other areas of rehabilitation research. All studies with no control group which examined outcomes pre- and post-intervention ($n = 9$) found greater gains following the telerehabilitation intervention in function in activities of daily living, hand function, cognitive tasks, balance, gait, pain, speech quality, skin integrity, falls efficacy, quality of life.

In summary, the studies report positive clinical outcomes, with improvement in physical, functional and psychological measures following a telerehabilitation intervention. The evidence consistently demonstrates that similar outcomes can be obtained using telerehabilitation as compared to a face-to-face or other control intervention.

Findings relating to clinical process

As seen with the clinical outcomes, the process outcomes reported varied between studies. Process outcomes were reported less frequently than clinical measures (68% and 82%, respectively). They were least often reported in studies of patients with neurological deficits ($n = 1$ out of 6 studies) and spinal cord injury ($n = 1$ out of 3 studies). Of the studies that reported these outcomes and that had control groups, four reported similar patient compliance and drop-out rates, as well as duration of consultation and contact time with patients between the telerehabilitation intervention and the control one (three RCTs and one quasi-experimental study with control group) and two found better outcomes (two quasi-experimental studies with control group).

Table I. Study characteristics.

Author (year)	Study design (sample size)	Study quality (PEDro scale/10)	Study population	Description of program Technology used (Tech)	Outcomes and variables reported (Clinical outcomes (CO), Process outcomes (PO), Healthcare utilization measures (HCU), Costs)
Community-dwelling elderly or individuals with disability					
Sanford et al. (2006) [20]	RCT (remote televideo $n=16$; traditional home visit $n=16$; usual care $n=33$)	6	Community-dwelling adults of all ages with prescription for new mobility aid	4 once-weekly in-home multifactorial OT/PT interventions targeting mobility and transfer tasks Control: usual care, no therapy Tech: Mobile wireless televideo system over telephone lines transmits audio and video signal. Have a research assistant in the house to mimic a home health aid.	CO: Modified Falls Efficacy Scale
Hoenig et al. (2006) [24]	Single group post-intervention only ($n=13$)	N/A	Community-dwelling adults of all ages with prescription for new mobility aid	4 once-weekly in-home multifactorial OT/PT interventions targeting mobility and transfer tasks Tech: Mobile wireless televideo system over telephone lines transmits audio and video signal. Have a research assistant in the house to mimic a home health aid.	PO: Adherence to recommendations, compliance with exercise programme, patient and therapist satisfaction
Russell et al. (2004) [50]	Single group post-intervention only ($n=31$)	N/A	Patients with total knee replacement	One 45-minute physiotherapy session per week for 6 weeks Tech: PC-based videoconferencing low-bandwidth using motion-analysis tools (simulation only of home environment).	CO: knee flexion range of motion and others (details not provided, see 2003 study) PO: adherence to programme, compliance with exercise programme, patient and therapist satisfaction
Russell et al. (2003) [27]	RCT (face-to-face $n=11$; telerehabilitation $n=10$)	6	Patients with total knee replacement	One 45-minute physiotherapy session per week for 6 weeks Tech: PC-based videoconferencing low-bandwidth using motion-analysis tools (simulation only of home environment).	CO: active/passive knee flexion, knee extension, limb girth measurements, strength on straight leg raise, pain on visual analog scale, WOMAC osteoarthritis index pain and function subscales, Gait Assessment Rating Scale, Patient Specific Functional Scale, Timed Up and Go PO: patient satisfaction
Tousignant et al. (2006) [35]	Quasi-experimental single group pre-post pilot study ($n=4$)	N/A	Geriatric patients discharged from acute care or geriatric unit discharged home requiring rehabilitation	Physiotherapy programme with exercises for weakness, range of motion, balance, transfers, walking for 4 weeks, 1 hour sessions 3 times a week. A research assistant was present for all sessions Tech: Broadband with video transmission. Audio transmission over hands-free phone. Software used to control cameras and provide e-record.	CO: Functional Autonomy Measurement System, Berg Balance Scale, Timed Up and Go, 30 sec. chair stand test PO: therapist satisfaction HCU: adverse events Costs: mean duration of session, mean hourly salary of physiotherapist, travel time of 20 minutes, cost of internet service without contract and installation

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Table I. (*Continued*).

Author (year)	Study design (sample size)	Study quality (PEDro scale/10)	Study population	Description of program Technology used (Tech)	Outcomes and variables reported (Clinical outcomes (CO), Process outcomes (PO), Healthcare utilization measures (HCU), Costs)
Wong et al. (2005) [51]	Quasi-experimental single group pre-post intervention study ($n = 20$)	N/A	Community-dwelling older adults (>60 yo) with knee pain affecting function	Once-a-week session for 12 weeks: subjects came to one of two community centres and participated in a group exercise and education programme led by physiotherapist though videoconference. A home programme was prescribed. Tech: Broadband, with videoconferencing units at community centre and therapist's site, allowed simultaneous presentation of PowerPoint with DuoVideo.	CO: WOMAC osteoarthritis index for pain, stiffness and function, Berg Balance Scale, Timed Up and Go, quadriceps strength, knee range of motion, SF36, knowledge gained PO: Compliance with home programme, attendance to sessions, patient satisfaction
Lai et al. (2004) [52]	Quasi-experimental single group pre-post intervention study ($n = 19$)	N/A	People who had a stroke at least 6 months previously and attend geriatric day hospital or seniors' community centre	For 8 weeks, once a week for 1.5 hours, seniors come to community centre to participate in group exercise and education programme led by physiotherapist through videoconference. Tech: Broadband, with videoconferencing units at community centre and therapist's site.	CO: Berg Balance Scale, SF-36, State Self-Esteem Scale, stroke knowledge test PO: Attendance, patient satisfaction
Wu et al. (2006) [37]	Quasi-experimental single group pre-post intervention study ($n = 17$)	N/A	Individuals over 65 years old, living and ambulating independently, who have fallen in the past year or have a fear of falling	Group tele-exercise programme given for 4 months, using Tai Chi Quan movements emphasizing balance, strength, flexibility and balance. Given 3 times a week for one hour, over 15 weeks. Tech: Exercise class taught by instructor from a studio, participants in their home, everyone able to communicate with each other through a videoconference system and video camera linked in the homes to TV sets and videoconferencing devices with video camera and microphone, connected through broadband Internet connection.	CO: Timed Up and Go, single leg stance, body sway in quiet stance, SF36, fear of falling PO: Compliance with exercise, attendance, patient satisfaction Costs: Equipment, internet fee, rental of studio and equipment and technical support
Nakamura et al. (1999) [23]	Quasi-experimental pre-post (non-randomized) case-control matching (home care $n = 16$; home telecare $n = 16$)	N/A	Cases who were enrolled to get home care, with varying diagnoses	Home care or home telecare with services predetermined by baseline evaluation: included physician, nurse, PT, OT, speech therapist, social worker and others. Initial visit was done in person for both groups. In video group, there was a combination of face-to-face and telecare. Tech: Videophones over telephone lines, video camera, codec and monitor over ISDN lines.	CO: Functional independence measure (FIM) PO: Person minutes per case, total minutes contact, total minutes with transportation time, number of consultations per week, satisfaction of professionals

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Table I. (*Continued*).

Author (year)	Study design (sample size)	Study quality (PEDro scale/10)	Study population	Description of program Technology used (Tech)	Outcomes and variables reported (Clinical outcomes (CO), Process outcomes (PO), Healthcare utilization measures (HCU), Costs)
Neurological rehabilitation					
Egner et al. (2003) [53]	RCT (video group $n=9$; phone group $n=11$; standard care $n=7$)	6	People with advanced multiple sclerosis (EDSS score ≥ 7) with recent exacerbation and with mobility restrictions	Weekly education sessions (30–40 minutes) by rehabilitation nurse for 5 weeks, then every two weeks for one month Standard care: regular follow-ups offered by rehab facility Tech: Video transmitted over POTS. Phone group used telephone with no image.	CO: Quality of Well-Being Scale, Fatigue Severity Scale, Center for Epidemiologic Stuides Depression Scale (CES-D)
Tam et al. (2003) [54]	Case series quasi-experimental ABA design ($n=3$)	N/A	Traumatic brain injury patients	Cognitive rehabilitation through 6 individualized occupational therapy sessions Tech: Over broadband, PC-based, with software for training and webcams, used NetMeeting to have access to patient's screen	CO: Performance on cognitive tasks and perception of users on their performance such as word recognition, memory tasks (tasks differed according to patient's deficits)
Man et al. (2006) [21]	RCT (computer assisted training group $n=30$; online interactive computer-assisted training $n=29$; therapist administered training $n=30$; control group $n=20$)	9	Patients with traumatic brain injury less than 6 months ago with cognitive deficits	Cognitive rehabilitation for problem-solving skills using 20 weekly 45-minute sessions. Tech: Therapist can have full control of patient's computer with NetMeeting, also used Polycom videoconferencing units for audio and video	CO: Analogy problem-solving skills, Category test for adults, Halstead-Reitan Neuropsychological test battery, Lawton instrumental ADL scale
Lum et al. (2006) [22]	Quasi-experimental single group pre-post intervention study ($n=7$)	N/A	Chronic stroke patients (>12 months)	Upper extremity activity training using AutoCite for 3 hours per day over 10 days in 2 weeks (intensive training protocol) Tech: AutoCite (automated constraint induced trainer), with 2 laptops with video camera. Therapist could also see Autocite monitor and adjust it. High speed ethernet connection (higher than in home setting – done in a lab setting in separate rooms to simulate home)	CO: Hand function tests (Wolf Motor Function Test, Jebsen-Taylor Hand function test, Motor Activity Log) PO: Contact time with patient
Piron et al. (2002) [55]	Quasi-experimental single group pre-post intervention study ($n=5$)	N/A	Chronic stroke patients	One hour of virtual reality teletherapy for arm movement, five days a week for 6 weeks. Training period of 2 weeks at the hospital with virtual reality system prior. Tech: 2 PC workstations linked by ISDN, 3-D motion tracking system on patient's computer to monitor arm movement. Therapist could control patient's console. Also had videoconference equipment for therapist to monitor whole patient.	CO: Subscore of Fugl-Meyer scale for the upper extremity, Functional Independence Measure FIM, velocity of arm movement, arm trajectories

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Table I. (*Continued*).

Author (year)	Study design (sample size)	Study quality (PEDro scale/10)	Study population	Description of program Technology used (Tech)	Outcomes and variables reported (Clinical outcomes (CO), Process outcomes (PO), Healthcare utilization measures (HCU), Costs)
Piron et al. (2004) [56]	Quasi-experimental single group pre-post intervention study ($n=5$)	N/A	Chronic stroke patients	One hour of virtual reality teletherapy for arm movement daily, five days a week for 4 weeks. Training period of a few hours at the hospital with virtual reality system prior. Tech: 2 PC workstations linked by ISDN, 3-D motion tracking system on patient's computer to monitor arm movement. Therapist could control patient's console. Also had videoconference equipment for therapist to monitor whole patient.	CO: Subscore of Fugl-Meyer scale for the upper extremity, Functional Independence Measure FIM, velocity and duration of arm movement, arm trajectories
Cardiac rehabilitation					
Giallauria et al. (2006) [57]	Quasi-experimental pre-post (non-randomized) (control $n=15$; intervention1 $n=15$; intervention2 $n=15$)	N/A	Myocardial infarction in the last 8 days	Control group: 8-week in-hospital cardiac rehab (3X week, exercise was cycling at 75% peak hear rate) Intervention group 1 and 2: patients who could not follow the in-hospital programme for logistic reasons had 8-week home based cardiac rehabilitation. Given same instructions as control group and told to exercise 3 × week on stationary bicycle at 75% peak HR. Had training sessions at predetermined times. Group 1 had telecardiology ECG monitoring. Tech: ECG recording and transmitting device to monitor patients during the home-based exercise programme, connected to call-centre and sent by email to the centre.	CO: Cardiovascular functional capacity (peak exercise HR, exercise duration and peak exercise workload), SF-36, Beck Depression Index State anxiety scales (STAI-Y1) PO: Patients lost at follow-up HCU: Hospitalizations
Ades et al. (2000) [32]	Quasi-experimental pre-post intervention study with control group (intervention $n=83$; control $n=50$)	N/A	Within 3 months of acute myocardial infarction	3-month, 3 times a week exercise and education programme. Intervention group had monitoring by phone and ECG transmitter, patient was in direct contact with nurse and up to 4 other participants during exercise sessions. Trained on stationary bikes. Control group was on site with treadmill training. Tech: ECG transmitted over modem (transtelephonic ECG). Also used a headset and voice transmitter (can monitor 5 patients at one time, all patients can speak to each other)	CO: Hemodynamic data (HR/syst. BP product, body weight, submax VO_2, Peak VO_2, peak workload, Borg scale of perceived exertion, Health Status Questionnaire PO: Dropout rate HCU: sessions cancelled because of symptoms

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Table I. (*Continued*).

Author (year)	Study design (sample size)	Study quality (PEDro scale/10)	Study population	Description of program Technology used (Tech)	Outcomes and variables reported (Clinical outcomes (CO), Process outcomes (PO), Healthcare utilization measures (HCU), Costs)
Sparks et al. (1993) [31]	RCT (control $n = 10$; intervention $= 10$)	5	Cardiac patients 6-weeks post-hospital discharge who were entering a phase II rehabilitation programme	12 week, 3 times a week for one hour, programme of exercise training with education. Control: hospital-based programme Intervention: Home-based programme with monitoring and voice transmission, patient in contact with therapist and up to 4 other patients during training Tech: Transmission of ECG and voice over phone lines (can monitor 5 patients at one time, all patients can speak to each other).	CO: Exercise capacity (workload, maximal oxygen consumption, pressure rate product), return to work PO: Compliance HCU: New arrhythmias
Kortke et al. (2006) [30]	Quasi-experimental pre-post intervention study with control group (control $n = 70$; intervention $n = 100$)	N/A	Patients who just underwent cardiac surgery	Control group was admitted to rehabilitation hospital for 3-week standardized multidisciplinary cardiac rehabilitation (unique to Germany) Intervention group received some training on-site and then continued up to 3 months at home with exercise training on stationary bike 3 times a week, with transtelephonic monitoring and with reassessments onsite to progress the exercise programme at 3, 6, 9 and 12 weeks. Tech: Cardiovascular function during training at home was monitored using mobile telemedicine unit (ECG with heart rate monitor transmitted telephonically to the institute for applied telemedicine).	CO: Body mass index, heart rate, SF36 PO: Number of contacts to institute for assistance HCU: Adverse events Costs: Breakdown for home programme: equipment, setup, consultations, training, transport of equipment, clinical tests, transportation cost for patient, hospital costs based on daily rate.
Follow-up for spinal cord injured patients					
Vesmarovich et al. (1999) [58]	Single group post intervention only ($n = 8$)	N/A	Hospitalized spinal cord injured patients	Weekly telerehabilitation sessions with nurse (initial visit in clinic to assess baseline for signs such as temperature and odour) Tech: Videophones for audio and still images over phone lines.	CO: pressure ulcers that healed and that required surgery PO: number of visits, patient and nurse satisfaction
Phillips et al. (1999) [33]	Quasi-experimental post-intervention only, case-control matching (control $n = 10$; telephone $n = 13$; video $n = 12$)	N/A	Hospitalized spinal cord injury patients	Video and telephone groups: weekly interventions for 10–12 weeks, with counselling sessions for video group for 6–8 weeks followed by telephone only for 4–6 weeks. Telephone group received telephone counselling only throughout.	CO: number of pressure ulcers per year, employed or returned to work PO: Calls to help line HCU: Annual number of ER visits, of hospitalizations, of doctor visits

(*continued*)

Table I. (*Continued*).

Author (year)	Study design (sample size)	Study quality (PEDro scale/10)	Study population	Description of program Technology used (Tech)	Outcomes and variables reported (Clinical outcomes (CO), Process outcomes (PO), Healthcare utilization measures (HCU), Costs)
				Standard care is not described but patients have a scheduled follow-up visit at 2 months, and can contact nurse if issues arise earlier. Tech: Videophones for audio and still images over phone lines.	
Phillips et al. (2001) [34]	RCT (video $n=36$, phone $n=36$, standard care $n=39$)	7	Hospitalized spinal cord injury patients	Video and telephone groups: weekly interventions for 5 weeks, with individual counselling sessions for video group then once every two weeks for 1 month. Standard care group can call help line if help needed in between the regularly scheduled follow-up at 2 months provided for all groups. Tech: Videophones for audio and still images over phone lines.	CO: depression (CES-D), Quality of Well-Being HCU: Annual days of hospitalization, number of patients hospitalized
Rehabilitation for speech-language impairments					
Sicotte et al. (2003) [28]	Quasi-experimental Single-group pre-post intervention ($n=6$)	N/A	Children or adolescents with stuttering problem	Speech-language pathologist from paediatric tertiary care centre provided assessment and treatment services to subjects in remote northern region, for 12–20 weeks, once a week for 1 hour sessions with some follow-up sessions Tech: Videoconferencing units in tertiary care centre in urban area and primary care centre in rural area with one TV monitor, via intranet at 768 kbits/s.	CO: patient/parent perception of stuttering, stuttering frequency PO: Patient attendance, child/parent and therapist satisfaction Costs: Personal costs due to work or home related expenses when having to go to treatment
Mashima et al. (2003) [29]	RCT (conventional vocal rehabilitation $n=28$; videoteleconference vocal rehabilitation $n=23$)	5	Patients with voice disorders, age ranged from 18–85 with different diagnoses (mainly military personnel)	30 minute speech-therapy sessions, over an average of 9 weeks, with an average of 5.7 sessions Tech: Voice therapy was given with therapist in adjacent room (simulation), using video camera and microphone and a speech analysis workstation seen by therapist and patient.	CO: Fiber-optic laryngoscopy by ENT, voice quality, acoustic analysis of voice (jitter, shimmer) PO: Adherence to programme, patient satisfaction
Consultations for varied clienteles					
Lemaire et al. (2001) [59]	Single group post intervention ($n=47$)	N/A	Patients seen at one of the local rural hospitals for communication disorders, foot care, gait	Consultations between one specialized physical rehabilitation hospital and eight community rehabilitation hospital when expertise is not available,	PO: Time spent on-line and off-line for each consultation, patient, remote clinician and specialist satisfaction

(*continued*)

Table I. (*Continued*).

Author (year)	Study design (sample size)	Study quality (PEDro scale/10)	Study population	Description of program Technology used (Tech)	Outcomes and variables reported (Clinical outcomes (CO), Process outcomes (PO), Healthcare utilization measures (HCU), Costs)
			problems, orthotics, prosthetics, arm weakness and wheelchair prescription	consultations result in exercise prescription, assistive devices, equipment adaptation and modification of the client's environment Tech: Both sites equipped with PC, video card, NetMeeting, video capture software, speakerphone, camera, gait analysis software, transmitted over 2 phone lines, low bandwidth	
Guilfoyle et al. (2003) [25]	Single group cross-over design ($n = 12$)	N/A	High care residents of residential aged-care facility	Consultations between metropolitan allied health centres to nursing staff in a residential aged-care facility in rural area. Same clinician did a face-to-face and a videoconference consultation for each patient. Tech: Videoconferencing unit over ISDN lines set up at both sites	PO: Time for consultation, usefulness of videoconference, clinician satisfaction
Hassall et al. (2003) [36]	Single group cross-over design ($n = 12$)	N/A	High care residents of residential aged-care facility	Consultations between metropolitan allied health centres to nursing staff in a residential aged-care facility in rural area. Same clinician did a face-to-face and a videoconference consultation for each patient. Tech: Videoconferencing unit over ISDN lines set up at both sites	Costs: Fixed and variable costs for videoconference sessions and face-to-face sessions (equipment, lines, training, calls, salaries, travel time, accommodations), varied equipment cost and intensity of face-to-face sessions
Appel et al. (2002) [26]	RCT (face to face $n = 9$; speakerphone $n = 9$; closed-circuit TV $n = 9$)	6	Having pain for more than 6 months from various conditions (orthopaedic, peripheral neuropathy, lumbar, cervical)	Behavioural interventions by clinical psychologist aimed at self-regulation (relaxation and guided imagery) Tech: TV monitor and camera at patient and psychologist ends, not done with videoconferencing equipment or over network, set up in the hospital as a simulation	CO: Relaxation Inventory, Behavior Rating Scale, analog pain scale, Subjective Unit of Discomfort Scale PO: Patient satisfaction

*PEDro scale: score of 0–10, 10 indicating better quality, only applicable to RCTs (N/A = not applicable); PEDro items include eligibility criteria, random and concealed allocation, similar baseline between groups, blinding of subjects, therapists and assessors, outcome measure reporting with point estimates and variability, intent to treat analysis, between-group statistical comparisons; *n*: for each study, sample size per group.

Nine of the 11 studies without control groups also reported findings relating to compliance and duration of consultation but they did not provide any basis for comparison. Studies examining telerehabilitation between healthcare facilities found similar or longer times for consultations conducted by telerehabilitation compared to face-to-face, while a home-intervention study reported greater contact time between the patient and the therapist but overall shorter duration of sessions with telerehabilitation

Table II. Main outcomes reported in telerehabilitation studies according to location of intervention.

Location of intervention Outcome	Group intervention in community setting ($n=2$) [51,52]	Home intervention providing group interaction ($n=3$) [31,32,37]	Home intervention one-on-one ($n=19$) [20–24,26,27,29,30,33–35,50,53–58]	Intervention between healthcare centres ($n=4$) [25,28,36,59]
Clinical outcomes	Significant improvement post telerehabilitation in functional (balance, mobility) and psychological outcomes (QOL) and in some physical outcomes (quadriceps strength, not knee range of motion). No control groups or other data available for comparison.	Significant improvement post telerehabilitation in physical (hemodynamic data), functional (exercise capacity, perceived exertion, balance, mobility and return to work) and psychological outcomes (QOL and fear of falling). 2 studies were controlled trials, and had similar improvements in telerehabilitation and hospital-based cardiac rehabilitation programme	Most studies report significant improvement in physical (active/passive ROM, strength, pain, swelling, velocity of movement, body mass index, pressure sores, speech quality) functional (functional autonomy, ADL, gait, mobility, balance, hand motor function, cognitive tasks, exercise capacity, return to work, perception of pain) and psychological outcomes (distress, falls self-efficacy, depression, anxiety). In studies with control groups, outcomes were similar or better to control group. Some suggestions of decline with long-term follow-up although inconsistent findings.	One study found reduced stuttering in all subjects but gains not always maintained long term. No other studies examined this type of outcome.
Clinical process	Attendance at sessions and adherence to exercise programmes were high although no comparison group available.	Attendance rates were high and drop out rates low. They were comparable between groups in 2 studies with control groups. High level of satisfaction in group tele-exercise sessions for balance training	Studies showed high attendance rates (similar with and without telerehabilitation) and lower drop out rates with telerehabilitation. Contact time with patients was increased with telerehabilitation. High satisfaction rates from clients and therapists, weakest satisfaction for video quality and scheduling of sessions. Telerehabilitation seen as valid alternative to clinic visits. Study for behavioural intervention found moderate satisfaction for interpersonal relationship between therapist and patient.	High patient attendance. Mixed findings relating to time spent for consultations, same as face-to-face or longer. High satisfaction, but one study reported higher satisfaction in remote clinicians than specialists and one reported higher satisfaction for face-to-face assessment than for videoconference, felt videoconference care plans were incomplete without face-to-face. Additional information on underlying reasons for satisfaction obtained from focus groups with therapists.

(*continued*)

Table II. (*Continued*).

Location of intervention Outcome	Group intervention in community setting ($n=2$) [51,52]	Home intervention providing group interaction ($n=3$) [31,32,37]	Home intervention one-on-one ($n=19$) [20–24,26,27,29,30,33–35,50,53–58]	Intervention between healthcare centres ($n=4$) [25,28,36,59]
Healthcare utilization	Not reported	Development of arrhythmias in small number of participants in cardiac rehabilitation studies that resulted in some change in management	Few studies examined this. Mixed results concerning adverse events. Two studies of cardiac rehabilitation programmes found slightly more angina and arrhythmias with ECG monitoring but it may be a positive outcome as it led to change in management; another study found more angina in control group, but no difference for dyspnea. Home physiotherapy in one small study did not lead to any fall or incidents. No significant difference in hospitalizations, ER use, doctor visits although trends are variable between studies.	Not reported
Costs	Not reported	Only one study presents a brief cost analysis for tele-exercise intervention from organizational perspective, so no conclusion can be drawn.	Two studies report 18–58% savings with telerehabilitation from an organizational perspective. Insufficient evidence to allow conclusions to be drawn regarding cost-effectiveness.	Two studies did cost-analyses and assumed equal efficacy. From organizational perspective, breakeven point at 850 sessions per year, decreased if equipment charge decreased or was used for other purposes as well, and depended on intensity of face-to-face intervention. From patient perspective, would cost $20 more per speech therapy session, an amount acceptable to patients.

Main outcomes identified in telerehabilitation studies according to location of intervention; $n=$ number of studies included for each location of intervention.

Table III. Main outcomes reported in telerehabilitation studies according to type of rehabilitation.

Outcome Type of rehabilitation	Clinical outcomes	Clinical process	Healthcare utilization	Costs
Rehabilitation for community-dwelling individuals with disability ($n=9$) [20,23,24,27,35,37,50–52]	All studies reported significant improvement in physical (active/passive ROM, strength, pain, swelling), functional (functional autonomy, mobility, gait, balance) and psychological (falls self-efficacy, QOL, self-esteem) outcome measures following telerehabilitation. Mixed findings in 3 studies with comparison group, two found greater increase in falls-self-efficacy and functional status and one reported similar outcomes for lower extremity physical and functional measures with in-home telerehabilitation	Adherence to recommendations was moderate following in-home multifactorial intervention for balance (61%). Studies consistently report moderate to high adherence to exercise programme (>78%) and high compliance with home exercise program One study reported a greater number of patient consultations with telerehabilitation compared to traditional home care services. There was a high level of satisfaction with the usefulness of telerehabilitation, lowest satisfaction for visual clarity	There were no adverse events such as falls with telephysiotherapy. As only one study examined this aspect in a small sample, no conclusions can be made at this time.	Comparison with theoretical home visit showed 12 sessions of telephysiotherapy to be 17% cheaper. Home teleexercise balance programme was estimated to cost $2140 per patient for 45 sessions over 15 weeks. Due to lack of evidence, further conclusions cannot be drawn regarding cost-effectiveness of telerehabilitation.
Neurological rehabilitation ($n=6$) [21,22,53–56]	Most studies reported improvement in physical (arm movement) and functional (arm function and cognitive function) outcomes. One study reported improved psychological outcomes (QOL, fatigue depression) in patients with multiple sclerosis receiving video interventions compared to phone interventions or standard follow-up care.	One study reported that 18% of a 3-hour training session involved communication between the therapist and patient who could train independently with monitoring. Little data is available on clinical process outcomes in neurological rehabilitation so no conclusions can drawn.	Not reported.	Not reported.
Cardiac rehabilitation ($n=4$) [30–32,57]	All studies examined cardiovascular and exercise capacity and found similar significant improvement in transtelephonic ECG monitoring groups and control rehabilitation in hospital. Most studies reported psychological measures (QOL, depression, anxiety) but findings were mixed, some reporting similar and some better outcomes in	Attendance and adherence to exercise programme was similar for telerehabilitation and hospital based programmes. No satisfaction data is presented in these studies.	Adverse events (arrhythmias, angina) were identified more often in transtelephonic groups compared to hospital-based programmes although these were not necessarily attributed to the exercise, or may reflect increased monitoring used at home.	One study reported significant savings per patient (58%) for transtelephonic monitoring compared to in-patient hospital rehabilitation programme from the healthcare establishment perspective.

(*continued*)

Table III. (*Continued*).

Outcome Type of rehabilitation	Clinical outcomes	Clinical process	Healthcare utilization	Costs
	telerehabilitation group. 2 studies had large sample sizes ($n > 100$) and most had rigorous methodology strengthening conclusions.			
Rehabilitation for spinal cord injured patients ($n = 3$) [33,34,58]	Findings support equivalence of telerehabilitation home monitoring and standard follow-up at 2 months, but only relevant if programme is in place because of limited accessibility to follow-up services. Several studies from the same group of authors examined pressure ulcer development, with no significant difference between types of interventions, although trend to more ulcers identified by video.	Insufficient reporting of clinical process measures to draw conclusions.	Mixed results for annual days of hospitalization in 2 studies from same author, earlier study with long term assessment found no difference between telerehabilitation and standard care, while later study that did not include long term outcomes but had larger sample showed decreased hospitalizations.	Not reported
Rehabilitation for speech-language impairments ($n = 2$) [28,29]	Physical measures of voice quality (jittering, stuttering) significantly improved with remote speech-therapy and to a similar extent as with face-to-face therapy, but not all gains were maintained at 6-month follow-up. Strength of conclusions limited by small number of studies in this area and larger control trial used a simulated environment in the hospital as proof-of-concept.	High patient adherence and high satisfaction reported for patients and therapists, lowest for quality of video. Identified some clients who may not be suitable for remote speech-therapy.	Not reported.	One cost analysis from patient perspective reports additional cost of $20 per session to attend session at primary care centre. Lack of empirical evidence to date limits further conclusions for cost-effectiveness of remote speech therapy.
Rehabilitation for multiple clienteles ($n = 4$) [25,26,36,59]	Findings limited to one study of behavioural intervention, found no significant difference in relaxation and pain between face-to-face and video conference. Study done in clinical setting with therapist and patient in separate rooms.	Moderate satisfaction, lower for specialist than clinician at local hospital or residential facility, higher satisfaction for face-to-face than video conference sessions. Mixed findings relating to time spent face-to-face versus video conference sessions.	Not reported	Only reported in one study of consultations to residential facility. Found breakeven point for cost of video conference or face-to-face consultation of 850 sessions per year, which varied depending on intensity of face-to-face intervention and equipment cost.

Main outcomes reported in telerehabilitation studies according to type of rehabilitation; n = number of studies included in each type of rehabilitation.

compared to an in-person home-visit [23]. Completeness of care plans was addressed in only one study, using a single-group cross-over design with each participant having a face-to-face and a videoconference consultation. The authors found that care plans were incomplete after having only a videoconference consultation but not after having only an in-person consultation [25].

In summary, there are fewer studies that examined process outcomes as compared to clinical outcomes. Nevertheless there is a trend from one fair quality RCT and six quasi-experimental studies with and without control groups of good attendance at programmes and good compliance with recommendations when a programme is offered by telerehabilitation.

Findings relating to satisfaction

With respect to perception of and satisfaction with services, 11 studies (39%) report patient satisfaction findings, seven (25%) report the clinicians' perspective and only four of these studies examine both perspectives. Overall the findings are very encouraging, with patients and therapists reporting positive perceived benefits, convenience and usefulness of the telerehabilitation program. The only study to report any problematic area from the patient's point of view found moderate satisfaction with the interpersonal relationship between patient and therapist [26]. Main complaints from therapists were related to the quality of video transmission [24,27,28], scheduling issues [24], and difficulties in using the technology with certain clienteles such as active or shy children [28]. In one study, remote therapists tended to be more satisfied than the consulted specialists [25]. Except for two studies [25,29], the remaining studies that report satisfaction with telerehabilitation do not provide any comparison even when a control group is available.

Findings relating to healthcare utilization

Some 26% of studies ($n = 7$) report healthcare utilization outcomes. The most commonly reported outcomes include adverse events such as falls, arrhythmias, angina and dyspnea ($n = 4$), number and days of hospitalizations ($n = 3$), visits to the emergency room ($n = 1$) and doctor visits ($n = 1$). With respect to cardiorespiratory events, findings were conflicting, with two quasi-experimental cardiac rehabilitation studies reporting significantly more angina [30] and more hospitalizations in the control groups compared to the transtelephonic groups, while two others identified slightly more adverse events in the telerehabilitation group [31,32]. However, it was argued by the latter two authors that this was a positive outcome suggesting better monitoring with the telerehabilitation home intervention. Similar conflicting results are reported by Phillips et al. [33,34], where in a quasi-experimental study, the authors report a trend for higher use of health services in the telephone and video intervention groups, whereas a later RCT found lower hospitalization rates in the video group. Finally, one before-and-after study reported no falls in patients receiving home physiotherapy. In summary, due to the low number of studies measuring and reporting these outcomes, and with some conflicting findings emerging, the literature available does not yet allow us to draw any clear conclusions regarding the effect of telerehabilitation on healthcare utilization.

Findings relating to costs

Finally, only five studies (19%) presented some type of cost analysis of the telerehabilitation intervention, two in studies dealing with community-dwelling individuals, one in cardiac rehabilitation, one addressing speech impairments and one regarding consultations for multiple clienteles. None of the studies calculated costs using the same elements.

In conducting cost analyses, it is crucial to identify from which perspective the analysis is being conducted; in other words, who is defraying the costs or achieving the savings, be it the patient, caregiver, clinician, healthcare establishment or organization, healthcare system, reimbursement agency, society and so on. Four studies reported cost analyses from an organizational perspective. Tousignant et al. [35] calculated costs using duration of sessions, hourly salaries of therapists, travel time and cost of internet with installation, and estimated that it would be 17% or $100 cheaper per patient for 12 sessions of telephysiotherapy in the home compared to a programme of theoretical home visits. Kortke et al. [30] reported differences of a greater magnitude, with costs that would be 58% lower for a 3-month home cardiac rehabilitation programme with transtelephonic monitoring of ECG signals as compared to the 3-week in-hospital rehabilitation programme currently offered. The basis for their cost estimate included the costs for the home programme including equipment, setup, consultations, training, transportation of equipment, clinical tests, and transportation cost for the patient, as well as hospital costs for the control group based on the daily rate. Hassal et al. [36] based their cost estimate on the equipment and internet lines required, staff training, calls made, salaries, travel time and accommodations for face-to-face assessments. They found a breakeven point of 850 sessions per year for videoconferencing compared to a typical face-to-face assessment of elderly people in a residential facility; interestingly

they showed how this could change if equipment costs changed or if the face-to-face option differed. While Wu et al. [37] did not provide any basis for comparison, they calculated that it would cost $2140 per patient at risk of falling or with a history of falls to participate in a group balance tele-exercise programme from home for four months. They estimated the costs based on the equipment used, the internet fees, rental of the studio and equipment and technical support. Only one study examined costs from the patient's perspective. Sicotte et al. [28] reported that patients incurred a maximum of $20 per session, based on personal costs (e.g., work time lost) related to having to attend videoconference speech therapy sessions at their primary care centre in a rural area, given by a speech-language pathologist at an urban tertiary care centre.

In summary, there are two quasi-experimental studies with control groups and two small pre-post studies that found lower costs for the healthcare facility when using telerehabilitation. While the evidence is gradually emerging, the lack of studies providing cost analyses from similar perspectives and accounting for similar costs prevents us from drawing any definite conclusions about the cost-effectiveness of telerehabilitation. The same is true in many areas of rehabilitation research.

Overall findings related to study methodology

There was an impressive proportion ($n = 13/28$) of well conducted RCTs and quasi-experimental designs with control groups, particularly for studies reporting clinical measures. It is generally accepted in meta-analyses and systematic reviews that clinical trials, particularly RCTs and other quasi-experimental designs, are best suited for assessing the efficacy and cost-effectiveness of an intervention, and thus provide stronger evidence on which to base conclusions.

There was heterogeneity in the scientific quality of the studies reviewed. The eight RCTs had PEDro scores ranging from 5–9 out of 10, as reported in Table I. Common methodological weaknesses in these studies included lack of blinding of therapists, patients or assessors. While in telerehabilitation it is not always feasible to design studies with patients and therapists who are not aware of group assignment, the use of outside assessors reduces the potential for evaluation bias. Although seven of the 13 studies with controls did not randomly allocate patients, five of the studies demonstrated baseline group equivalence for some clinical and socio-demographic parameters. There was variability in the type of control intervention used as a comparison to the telerehabilitation intervention, five of the studies using no therapy as the control intervention, which was in some cases the standard care, while 10 used face-to-face comparisons. In two studies, the between-group statistical tests were not robust as multiple t-tests were conducted comparing multiple pairs of groups (e.g., telerehabilitation intervention compared to control, telerehabilitation intervention compared to telephone only and telephone only compared to control) at each evaluation time (pre and post-intervention), increasing the chance of finding a significant difference when one is not present. They did not adjust for the numerous tests or apply ANOVAs or regression models.

Slightly more than half the studies ($n = 15/28$) used a single-group design and the authors often cite this as a limitation of their study that should be addressed in future studies as they cannot exclude natural evolution. Many of the studies used convenience samples based on geographical location of patients or patient preference, clearly introducing the possibility of selection bias. None of the studies used multiple time series analyses, with repeated pre- and post-intervention assessments that would allow an analysis of trends even with no control group and strengthen the conclusions about the role of the telerehabilitation programme in the observed changes. Finally, a few studies ($n = 6$) presented only outcomes in a single group of patients at post-intervention only, which compromised the strength of conclusions derived from these studies about the effect of the telerehabilitation intervention as there was no basis for comparison either between groups or before and after the intervention.

Close to 40% ($n = 11$) of studies had sample sizes of fewer than 20 subjects, and none of the studies provided power calculations. Small sample sizes can lead authors to conclude that no significant difference exists between groups, i.e., a Type II error, whereas in reality the study had insufficient power to identify a significant difference [39,47]. Several larger non-randomized controlled trials were conducted in the area of cardiac rehabilitation. For example, Ades et al. [32] and Kortke et al. [30] had 133 participants and 170 participants, respectively, divided into two groups. This may be a reflection of the longer history of telerehabilitation in that area [48] and may partly explain the more widespread use and acceptability of the transtelephonic ECG monitoring systems technology, and thus facilitate access to a larger study population. As well, a large RCT was conducted by Man et al. [21], examining telecognitive rehabilitation in patients with traumatic brain injury in 103 patients divided into three intervention groups and one control group. The authors were able to design the study despite the heterogeneous nature of traumatic brain injuries. Nevertheless, larger studies often remain challenging to carry out, as many of the programmes are still in

their pilot phases and there is often limited availability of the patient population concerned. While small sample size is often identified by authors as a limitation, smaller studies are essential as long as they are conducted in a scientifically sound manner and provide contextualized outcomes or some basis for comparison that allow a better analysis of the results; however results should be interpreted cautiously.

These methodological issues are not isolated to telerehabilitation research. They are common to many rehabilitation research fields, particularly when patient populations are small and interventions are not widely accepted or easily available.

Discussion

Outcomes of telerehabilitation

The findings from the current systematic review are in part supported by those reported by other telemedicine systematic reviews not related to rehabilitation. These reviews consistently report that there are a few areas of telemedicine, such as teledermatology, teleradiology, telemental health and home telecare for some chronic conditions, where there is emerging evidence for the efficacy of telemedicine, but few studies supporting the cost benefits of telemedicine, and no evidence of the long term outcomes of telemedicine (e.g., [38–41]). More specifically, our systematic review of telerehabilitation showed that although there is heterogeneity between studies in terms of study designs, clienteles, settings and outcomes measured, there is a consistent trend in the literature supporting the efficacy and effectiveness of telerehabilitation. Many good quality studies, including 13 studies with control groups, report similar or better clinical outcomes when compared to conventional interventions. A smaller number of studies examining process measures indicate a trend towards the positive impact of telerehabilitation on process outcomes, particularly adherence and compliance.

Overall, satisfaction ratings regarding the use of telerehabilitation were very high from both patients and therapists, regardless of the patient population, setting or study design. However, certain measurement issues limit the usefulness of the reported data. For example, the tools used to measure satisfaction are for the most part poorly described and not standardized. The underlying satisfaction concept is often vague and therefore the interpretation of the satisfaction findings is unsatisfactory. In addition, they are generally limited to satisfaction with the technology and with the service received/given, and do not specify any aspects of the service delivery or their experience in the program. The underlying reasons for satisfaction or dissatisfaction therefore remain unclear. All except two studies [25,29] report satisfaction only in the telerehabilitation group, even when a control group is available. A few studies report some qualitative data from interviews; however, description of data collection methods and results are generally too brief to draw any overall conclusions. The findings in this review are similar to the conclusions arrived at by Mair and Whitten [42] as well as Williams et al. [43] in their systematic reviews of studies reporting patient satisfaction with telemedicine. Continuing to measure user satisfaction in the current manner will simply confirm previous findings of acceptability of the technology, but will not increase the understanding of the underlying processes of telerehabilitation use. A better understanding of satisfaction therefore remains an important area for future research in telerehabilitation.

Limitations of cost analyses

Few of the studies reported here examined any costs aspects (19%, $n = 5$). However, reduced costs or better resource utilization is often cited as one of the main goals of telerehabilitation. While the studies presented here included calculations of costs incurred or saved from an organizational or patient perspective, the costs were not related to the other clinical, process or healthcare utilization outcomes. If outcomes are similar between a telerehabilitation programme and an alternative programme, then cost-minimization, or the cheapest of the two interventions is an appropriate measure of costs. If outcomes are different, then it is more relevant to identify how much more or less a telerehabilitation programme costs compared to an alternative, taking into account the change in clinical outcomes of each program. Cost differentials such as the incremental cost-effectiveness ratio can be useful in this case. It may also be pertinent to examine whether certain resources or programmes will no longer be available if a telerehabilitation programme is introduced, particularly in a context of limited public healthcare funding. As well, it may be appropriate to relate the cost difference to the impact on services offered. For example, the number of patients who can receive the telerehabilitation service may change due to the costs saved or incurred, an important factor for a decision-maker to take into account. Furthermore, and certain authors alluded to this, in longer term cost analyses, the value of the technology needs to be accrued over time. Costs may also change over time as the technology becomes increasingly used for similar or other activities or as therapists gain experience with the technology for example. It may therefore be appropriate to conduct sensitivity

analyses by adjusting some of these parameters, as were calculated by Hassal et al. [36]. Finally, it is essential to identify whether the program's goal is in fact direct cost savings. It may be more appropriate to examine whether it allows for better utilization of scarce resources, as often promoted by champions of telemedicine [44]. It is also important to remember that with the introduction of a telerehabilitation programme, costs may be redistributed to a different level of care [44], such as from a home care service to a rehabilitation centre, emphasizing the importance of the perspective of the cost analysis.

Issues relating to study design

Health technology assessments (HTA), the model often followed by telemedicine evaluations, generally adhere to the normative approach favouring findings from RCTs. But as many of the systematic reviews of telemedicine have reported, and as found in this review of telerehabilitation, many studies have trouble fitting into the HTA mould. This is in part due to some of the intrinsic limitations of the technology such as small groups of patients who use the technology, rapidly evolving technology limiting long term evaluations and the difficulty in obtaining a valid control group [45]. Therefore, in order to develop an evidence base that is useful for decision-making, it is essential to pursue research that gives us a better understanding of the underlying processes when they are implemented in a real context. Studies using research methodologies that allow the processes to be examined, such as through case studies [46] combining qualitative and quantitative data, can provide essential information for the integration of telerehabilitation into organization of services. For example, in a recent in-depth study of three telehomecare evaluation projects, Gagnon et al. identified different types of evaluation models (e.g., process evaluation, economic evaluation, randomized controlled trial) that can be applied depending on the type of telehomecare programme, size of patient population and objective of the evaluation [44].

As noted previously, four of the studies examining the benefit of a home telerehabilitation programme did so using a simulated environment in a hospital setting. Clearly the generalizability of such findings to home telerehabilitation is limited as there are numerous context-related factors that may affect the quality of the telerehabilitation sessions, and acceptability and ease of use within the home may differ.

Limitations of this systematic review

One of the limitations of this systematic review is that it uses studies published in a peer-reviewed journal. It is well documented that there is a publication bias towards studies that have positive findings [49]. Therefore, studies that do not demonstrate any effect or report a negative effect of telerehabilitation may not carry as much weight in the synthesis of the data because they were not identified through the search. Moreover, this study did not include studies looking at patient assessment as the focus of this review was on intervention programmes. This was a first attempt to identify scientifically sound evidence of telerehabilitation intervention programmes and synthesize and critically appraise the published literature in this area. In part this also helps identify areas of weakness and possible directions for future studies. Future reviews could extend the scope of this analysis.

In addition, there is an inevitable time lag between the conducting of studies and their publication [49]. A further delay is added with the synthesis of these findings. Reporting and synthesizing findings in a timely manner is crucial, particularly in a field where the technology is evolving so fast. Studies identified in this review ranged from 1993–2006, the majority being published after 2003. While some of the studies may have published their results after a longer delay than others, this suggests that the findings are probably generalizable to the technologies currently in use. Furthermore, a description of the technologies used by the studies has been provided in order to assess the relevance to current telerehabilitation programmes.

Conclusion

This systematic review of telerehabilitation programmes identified a substantial amount of scientific literature in the relatively new area of telerehabilitation. The results of this study indicate that telerehabilitation can lead to similar clinical outcomes compared to traditional rehabilitation programmes, with possible positive impacts on some areas of healthcare utilization. There is overall high acceptance from both patients and therapists although we have very little understanding of the underlying factors that lead to the perceptions and acceptance. To date, there is insufficient evidence to confirm that telerehabilitation is a cost-saving or cost-effective solution. Further research in the area of telerehabilitation, with methodologically sounder studies examining healthcare utilization and costs in greater depth is essential. In addition, for this research to be useful to clinical and policy decision makers, it must be combined with a more complete understanding of the underlying changes involved in telerehabilitation and of the factors influencing the sustainability of telerehabilitation programmes.

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