A systematic review of successes and failures in home telehealth: preliminary results

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Summary

We conducted a systematic review of the literature to identify studies in home telehealth that compared a home telehealth intervention with a non-telehealth standard/usual care alternative in terms of administrative changes, patient management decisions, patient outcomes, caregiver outcomes, economic impact or social impact on patients. A search of various databases produced 6643 references. Of these 769 papers were selected for more detailed investigation. These papers, combined with hand searching of relevant telehealth journals and cross-referencing of citations in identified publications, resulted in 138 papers referring to 130 projects for review. In this preliminary analysis we used a quality appraisal approach that took into account the study design. An additional analysis of patient numbers was then used to calculate a net evidence score. A large proportion of studies (80%) were randomised controlled trials. Only 22 projects (17%) reported economic data deemed to be sufficient for appraisal. Evidence exists for the clinical effectiveness of home telehealth in diabetes, the general area of mental health, high risk pregnancy monitoring, heart failure and cardiac disease.

Introduction

Current health care systems focus on acute care, they neglect the patient's role in managing their own health and provide only sporadic follow-up.[1] Home health care offers a substitute for acute hospitalisation, an alternative to conventional hospital outpatient or physician visits, and a complementary means of maintaining individuals in their own community.[2] Home telehealth is an emerging area of interest to service providers and consumers.[3] It provides, amongst other things, a means to monitor, educate and counsel patients at a distance. Home telehealth has the potential to collect improved monitoring data, to give patients access to their own data and improve self-management, to reduce the need for in-person home visits and ultimately the cost of home care.[3]

To provide an overview of the available evidence for home telehealth we completed a systematic review of the literature. Our aim was to review studies that compared, in a scientifically valid manner, a home telehealth intervention with a non-telehealth standard/usual care alternative.

Methods

Literature search

Searches of the following computerised literature databases were conducted: Allied and complementary medicine via WebSpirs (1985-March 2006), Rehabilitation and physical medicine via WebSpirs (1995-December 2005), EMBASE Drugs and pharmacology via WebSpirs (1990-December 2005), Medline via WebSpirs (1950–2006), Cumulative index to nursing and allied health literature via EBSCOhost (1982–2006), and PsycINFO via Cambridge Scientific Abstracts (1840–2006) using the search strategy described in Table 1. Manual searches of the two specialist telehealth journals, the Journal of Telemedicine and Telecare and the Telemedicine and e-Health Journal, were also undertaken to identify relevant studies.

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Selection of publications

References without abstracts were excluded, as were references related to meeting abstracts (these were deemed to have insufficient detail for full analysis). Where duplicate publications were identified, i.e. papers reporting results on the same set of patient data in different journals or papers reporting preliminary results of a research project where a subsequent paper reported the full project results, the most comprehensive publication was selected for review.

We included studies that reported outcomes in terms of administrative changes, patient management decisions, patient outcomes, caregiver outcomes, economic impact or social impact on patients. Included studies were classified as randomised controlled trials, non-randomised controlled prospective trials and non-randomised controlled retrospective trials. Relevant interventions involved the delivery of health care, directly to the home, using information communication technologies.

Table 1 The search strategy

Step	Search term
1	Telehomecare OR Tele-homecare
2	Telemedicine OR Remote consultation OR Online health OR On-line health OR Telepathology OR Tele-pathology OR Telehealth OR Tele-health OR e-Health OR ehealth OR Telecare OR Tele-care OR Teledermatology OR Tele-dermatology OR Telepsychiatry OR Tele-psychiatry OR Telesurgery OR Tele-surgery OR Teleconsult* OR Tele-consult* OR Telecardiology OR Tele-cardiology OR Teleophthalmology OR Tele-ophthalmology OR Teleoncology OR Tele-oncology OR Teleradiology OR Tele-radiology OR Teleneurology OR Tele-neurology OR Telemental health OR Tele-mental heath OR Teleradiology OR Tele- radiology OR e-mental health OR Telemetry OR Telegeriatric* OR Tele-geriatric* OR Teledialysis OR Tele-dialysis OR Telerehabilitation OR Tele-rehabilitation
3	home* OR home-care OR home health care* OR home nursing* OR home care agencies OR home care services* OR home dialysis OR home health agencies OR home monitoring OR rehabilitation OR home visits OR homebound patients OR homebound persons OR self help devices OR self administration OR self care OR self evaluation OR self help OR self medication
4	cost OR cost-effectiveness OR economic* OR cost analysis OR budget OR financial OR health care costs OR cost-benefit analysis OR cost of illness OR cost description OR cost minimization analysis OR cost-utility analysis
5	Teleeducation OR Tele-education OR Teleteaching OR Tele-teaching OR Telelearning OR Tele-learning
6	2 AND 3
7	1 AND 4
8	2 AND 3 AND 4
9	3 AND 5

Expanding on review data published elsewhere,[2] included participants were classified as antenatal, neonatal, paediatric, adult and elderly (65 years or older[4]). Also included were interventions directed at family members caring for patients in the home.

The abstracts of selected articles were reviewed independently by at least two of the authors. When disagreement about inclusion occurred between the two reviewing authors the third author reviewed the abstract and consensus was reached in discussion with all authors.

Full text articles were obtained for studies identified as meeting the review criteria. Citations in these publications were cross-referenced for relevant titles. The abstract of articles identified via cross-referencing were then reviewed in the same manner.

Data extraction

One author extracted data from the identified studies. A second reviewer cross checked the extracted data to ensure accuracy and completeness. Where disagreement occurred, consensus was reached via discussion between these reviewers. The basic information included year of publication, country the study was undertaken in, area of application, participant category and study design.

Home telehealth practice

In looking at the type of home telehealth being practised, studies were grouped into seven different categories: active or passive monitoring (active monitoring involves direct participation of the patient whereas passive monitoring involves indirect methods of data collection such as falls detection via an accelerometer), counselling (the process of listening to someone and giving them advice about their problems[5]), education, peer support, self-help and virtual home visits/televisits.

Technology

In examining the technological side of home telehealth, consideration of both the physical device being used with patients and the telecommunications infrastructure required for data transmission is important.[2] For example, the study undertaken in the US by Gray *et al*.[6] found that the use of the Internet (via ordinary home telephone lines) and videoconferencing (via digital telephone lines) supported the educational and emotional needs of families with very low birth weight infants and facilitated earlier discharge from hospital. However, in a different context, for example in Australia, providing digital connections to families from rural and remote areas may be technically and economically prohibitive. Without knowing what telecommunications infrastructure is required to use a particular device, it is impossible to establish a home telehealth device's suitability in different contexts.

Summary of conclusion reached

The conclusion reached in each study was summarised in one of four categories, reflecting the conclusion reached by the study's authors:

(1) the home telehealth intervention had advantages over the non-home telehealth alternative approach;
(2) the home telehealth intervention had advantages over the non-home telehealth alternative approach, but there were also some disadvantages;
(3) it was unclear whether the home telehealth intervention had advantages. Further work is probably needed;
(4) the alternative non-home telehealth approach had advantages over the home telehealth intervention.

Success and failures in home telehealth

The conclusion summary categorisation outlined above provided an insight into the success or failure of different home telehealth interventions. In terms of providing unequivocal evidence that the home telehealth intervention was successful only studies categorised into group 1 were counted as successes. Studies that were classified as group 2 or 3 were counted as neutral, and studies classified into group 4 were counted as failures (we stress here that this is a pragmatic approach to looking at the outcomes of studies. Studies where the outcome was unclear or where the alternative was found to be advantageous are still successful forms of research providing valuable information and insight into the use of home telehealth).

In considering the strength of evidence provided by each study, we used the methodology employed in previous reviews of telemedicine.[7–9] The preliminary strength of evidence data reported here was based on a study design score[8] (we did not assess the way in which selected studies were conducted).

To provide additional information participant numbers were also extracted. Full participant numbers were used for studies that analysed data on an intention to treat basis. For other studies the number of participants providing data for analysis, i.e. accounting for dropouts and patients lost to follow-up in both intervention and control groups, was used to calculate the total number of study participants.

Net evidence score

As well as assessing the direction of the evidence for each study, we also calculated a net evidence score. This was intended to take into account not only the strength of the study design, but also the number of participants in each trial. The following process was used for each study identified in the review:

(1) the direction of evidence was identified, based on whether home telehealth was advantageous (positive value) or disadvantageous (negative value). Studies where the evidence direction was equivocal were ignored;
(2) the study design score, D, was identified (5 for large RCT, 3 for small RCT, etc);
(3) an evidence score, ε, was calculated, ($=D.n$, where $n=$number of study participants);

Then for each disease or condition:
(4) a net evidence score was calculated ($=\sum\varepsilon$).

Results

The search strategy resulted in 6643 references. The automated duplicates search and exclusion of articles without abstracts reduced this to 4159 abstracts for review. From this, and the hand searching of the two specialist telehealth journals, 769 papers were selected for more detailed investigation. One hundred and thirty eight papers, referring to 130 projects met the inclusion criteria and were selected for review (a number of projects resulted in multiple publications reporting different aspects of the research; these papers were grouped and considered as a whole).

Description of the research

Country of origin

Investigations had been carried out in 18 countries (one multicentre study was undertaken in three countries: Germany, the UK and the Netherlands). Sixty-nine percent of research projects were undertaken in the US with the UK, Canada, Italy, Japan and France making up a further 19%.

Participant groups

Projects were most frequently directed at adult (60%) or elderly patients (18%). Antenatal care was the focus of 10% of projects with neonatal (2%), paediatric (3%) and obstetric patients (2%) less studied patient groups. The patient group studied was unspecified in four studies (3%). One study investigated the use of a call centre in a general medical practice covering paediatric, adult and elderly patient groups.[10]

Outcomes reported

The majority of projects (89%) reported evaluations with patient outcomes (evaluations of interventions based on measures pertinent to the condition being studied, such as blood glucose or HbA_{1c} for diabetic patients, or depression scores for mental health interventions). Caregiver outcomes were reported in 7 papers (5%). Administrative changes and social impact were reported in one study each. Only 27 projects (21%) contained any form of economic information.

Diseases/conditions

Of the projects reviewed, those looking at diabetes related interventions were the most common (Table 2). Investigations looked at the regular transfer of blood glucose readings from the home via a modem for monitoring,[11] the use of virtual home visitation using videotelephony to monitor and manage patients in the home[12] and, more recently, the use of regular telephone calls to diabetic patients from a call centre providing education, counselling and monitoring.[13] Other areas of investigation have included the general area of mental health (including investigations for more specific conditions such as substance abuse, depression, schizophrenia and panic disorders), different forms of home monitoring to detect preterm labour (either uterine activity monitoring, tocography, or fetal heart rate

Table 2 Diseases/conditions investigated in the home telehealth projects reviewed (the total number of projects is 130, but one study was categorised into two separate categories because it dealt with both patients with cardiac disease and their caregivers in separate evaluations)

Disease/condition category	Number of projects
Diabetes	21
Mental health	16
High risk pregnancy	14
Heart failure	12
Cardiac disease	10
Caregiver	8
Cancer	8
Smoking cessation	6
Asthma	5
Hypertension	5
Home care	4
Arthritis	3
Hypercholesterolaemia	3
Chronic disease management	2
Chronic lung disease	2
Spinal cord injury	2
Acute infection	1
Child health	1
Community care	1
Elderly	1
Epilepsy	1
Medication compliance	1
Multiple sclerosis	1
Obesity	1
Palliative care	1
Very low birth weight infants	1
Total	*131*

monitoring, cardiotocography), heart failure and cardiac disease (including post-myocardial infarction rehabilitation at a distance, communication with patients after coronary artery bypass graft surgery and telephonic monitoring of arrhythmia). Projects classified as interventions focusing on support provided to family caregivers of patients related to the following conditions: Alzheimer's disease, stroke, brain injury, cardiac disease and patients in a prolonged state of reduced consciousness. (A number of papers reported interventions aimed at both patients and caregivers but provided no evaluation data on the impact of the intervention for caregivers and hence were not counted as caregiver studies). One study investigated the use of telephone education and support for both patients and their family caregiver after coronary artery bypass graft surgery[14] and was classified into both the cardiac disease and caregiver categories.

Practice

Over 60% of studies combined more than one home telehealth practice. The most frequent combination was active monitoring and counselling (30%) or active monitoring, counselling and education (8%). An example of this is the use of automated calls to gather information on diabetic patients' self-monitored blood glucose readings and symptoms, i.e. active monitoring. Subsequent nurse telephone follow-up, based on the monitoring data, provided a discussion of problem areas and promotion of the appropriate use of preventative diabetes care, i.e. counselling.[15] Only one project involved passive monitoring through the use of a pill counter for monitoring medication compliance in patients with schizophrenia.[16]

Table 3 Summary of devices used

Device	Number of projects
Telephone alone	57*
Telephone combined with additional device	17
Videophone	8†
Composite device with videophone	8
Composite device without videophone	29
Computer	1‡
Mobile phone	1
Multiple devices	1
Internet	7
Still image videophone	1
Total	*130*

*Eight projects used the home telephone connecting with a computer or automated system in the health care facility
†Four studies compared telephone, videophone and in-person groups
‡One study used a computer in the home connecting to a hospital network rather than the Internet

Provider

Nurses provided half of the home telehealth interventions reported. They provided, for example, cardiac rehabilitation monitoring and education to patients with coronary heart disease.[17] Physicians were the next most frequent provider (10%) followed by mental health professionals (8%), combined multidisciplinary care teams (5%) and counsellors (5%). Other providers included social workers, pharmacists and dieticians. The profession of the provider was unspecified in 10% of projects. In 7 projects (5%) no professional provider was involved; instead these interventions focused on peer support, self-help, support by a non–health related technician or the use of an automated interactive voice response system.

Technology

The ordinary home telephone was the device most frequently used (Table 3), either alone, as the primary communications link, or combined with an additional device allowing transmission of physiological data such as blood pressure readings, electrocardiograph data, blood glucose concentrations or pulse oximetry readings. In five studies the telephone was compared against other devices such as videophones, still image videophones or composite devices. Composite devices were further categorised as those with videophone functions and those without. Mobile phones and computers made up the remaining class of devices, the latter for access to the Internet or some other computer network.

Eighty-eight percent of these devices used the normal home telephone network. Other data transmission media included digital telephone lines in three projects and mobile telephone networks in two projects. In one project connectivity was provided either by the ordinary home

telephone network or a wireless network.[18] The telecommunications infrastructure was unspecified in seven studies (5%).

Conclusion summary

Over three-quarters of projects reported that the home telehealth alternative had advantages over the non-telehealth standard/usual care alternative studied (78%). A breakdown of the outcomes of projects in the different diseases/conditions identified in the review is shown in Figure 1.

Preliminary strength of evidence findings

Clinical evidence

Figure 2 presents a breakdown of the different study designs used in each disease/condition category. Of the 130 projects reviewed, 104 (80%) were randomised controlled trials (RCTs), 51 were small RCTs (with less than 50 participants in each arm) and 53 were large RCTs (with 50 or more participants in each arm).[7–9] One small RCT used a crossover design but was still categorised into this group. Twenty projects were classified as non-randomised controlled prospective trials. One prospective trial used a crossover design, another two studies used a case-controlled design and a fourth study used a matched cohort; these papers were all categorised as non-randomised controlled prospective trials as all data were collected prospectively and involved the comparison of intervention and control groups. Six projects were classified as non-randomised controlled retrospective trials.

Design score data combined with success and failures information are shown in Figure 3.

Economic evidence

Of the 27 projects (21%) containing economic information, 22 (17%) were judged as sufficient for

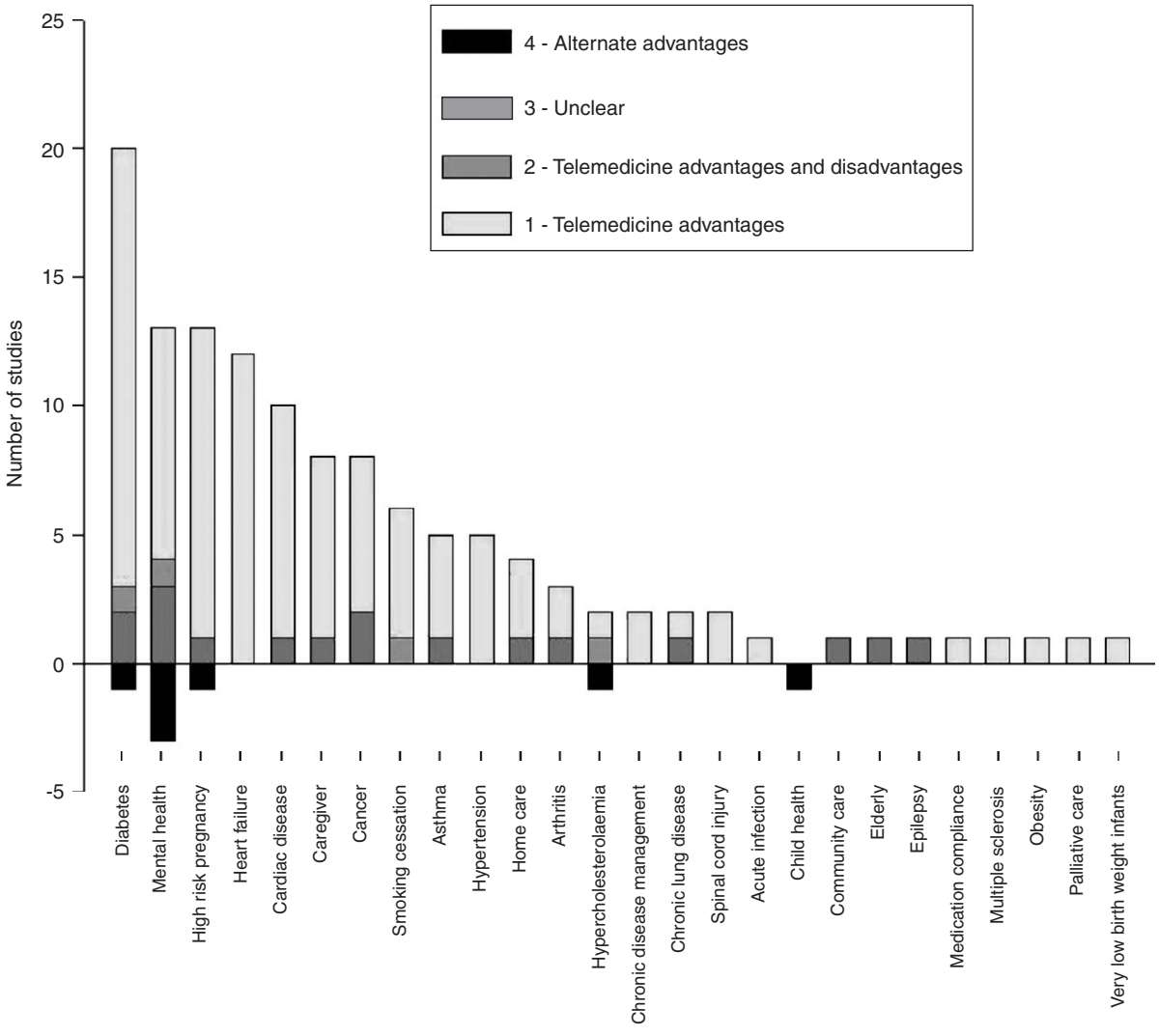

Figure 1 Successes and failure of home telehealth projects based on conclusion summary categorization ($n = 131$: incorporating one study classified in the cardiac disease and caregiver categories)

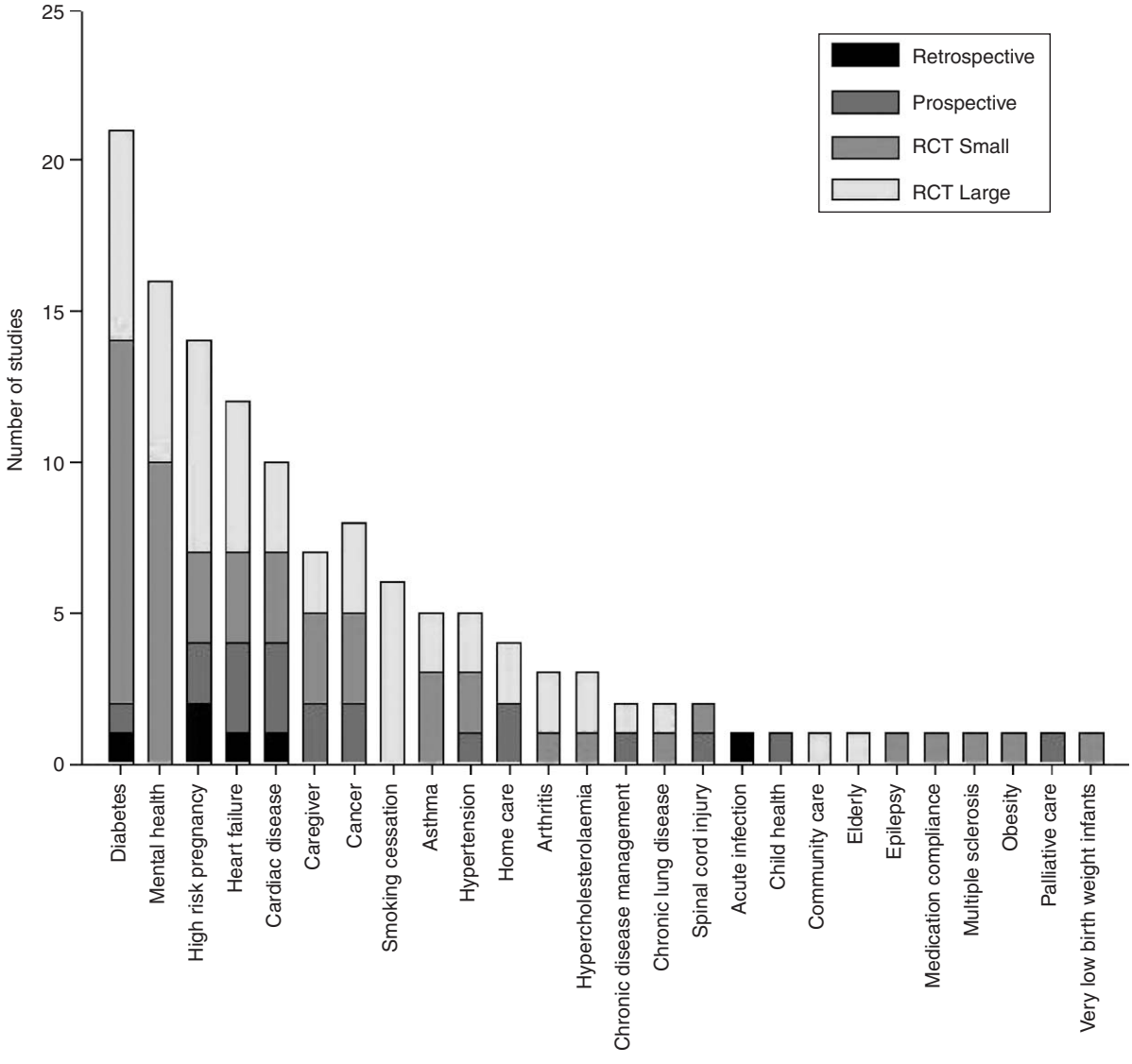

Figure 2 Study design used in the disease/conditions identified in this review ($n = 131$: incorporating one study classified in the cardiac disease and caregiver categories)

economic strength of evidence evaluation. Excluded papers provided insufficient economic information for evaluation. Some of these papers introduced economic information in the discussion section, rather than providing an analysis of economic data in the results section and deliberating on these findings in the discussion section. Areas where economic evidence was available included high risk pregnancy home monitoring (5 projects), heart failure (4 projects), cancer (2 projects), diabetes (2 projects), hypertension (2 projects) and non-specific home care (2 projects).

Discussion

The results of the systematic review allow a number of questions to be answered.

(1) *home telehealth: what is being done?* The literature review revealed a common theme in the reports concerning home telehealth and telemedicine in general. That is, a lot has been written about its potential and promise, but little clinical research has been undertaken. Of the 769 references selected for closer review, only 18% were controlled studies meeting our inclusion criteria.

The studies that were identified covered a broad range of diseases/conditions, the most commonly investigated being diabetes. Other areas such as mental health, high-risk pregnancy monitoring, heart failure and cardiac disease were less commonly investigated.

(2) *what is being investigated?* The majority of studies reported investigations in terms of patient

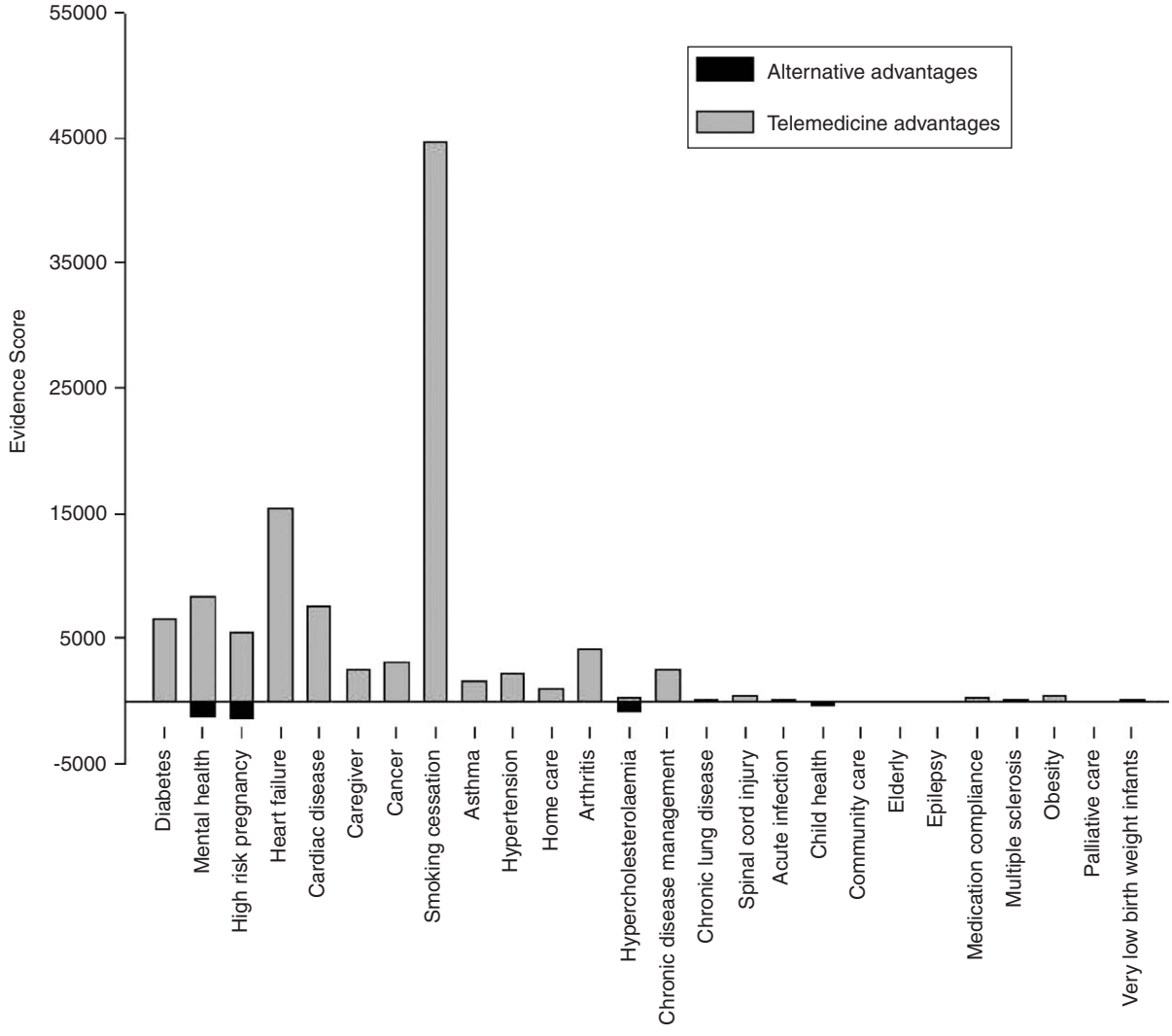

Figure 3 Combined successes and failures information, design score and participant number information ($n = 109$: This total is the total number of projects identified minus those studies where the outcome was unclear, i.e. only those projects that clearly showed home telehealth was advantageous or that the standard/usual care was advantageous were used in the analysis)

outcomes reflecting the need to prove that home telehealth can work effectively. Establishing safety and feasibility is essential (see Bensink *et al.*[2] for a summary of the recommended stages in any telemedicine evaluation). However, what has been neglected is the need for economic evaluations of home telehealth applications. Solid economic data are needed to motivate health care decision makers and would probably act as a catalyst for the widespread implementation of home telehealth.

(3) *how is home telehealth being researched?* Large RCTs remain the gold standard in clinical research[19] providing much more reliable estimates of the relative effects of interventions than other study designs.[20] Other study designs, although not providing the same level of evidence as RCTs, still provide valuable information. The large proportion of RCTs identified in the present review contrasts with the research being undertaken in other areas of telehealth, such as teleradiology and teledermatology,[7] which generally have a much lower proportion of RCTs. That only half of the controlled trials identified were large trials (with greater than 50 subjects in each arm) reflects the challenges involved with designing, running and ensuring the methodological rigour of large RCTs in home telehealth.

(4) *what technology is being used?* The telephone was the most commonly used device in the studies reviewed and correspondingly the ordinary telephone network was the most commonly utilised communications infrastructure. A number of studies that used the Internet were excluded from the review as they compared a home telehealth intervention with another home telehealth intervention: for example, Internet-delivered

therapy versus telephone-delivered therapy or compared a home telehealth intervention with a wait-list control group rather than an active non-home telehealth standard/usual care alternative. As the use of the Internet increases in home telehealth, it can be assumed that research into its use will move beyond feasibility testing to investigations of its place in routine care delivery.

(5) *what effect does home telehealth have?* The majority of research identified in the review reported that home telehealth had advantages over the non home telehealth alternative studied. The high proportion of projects with good study design provides some assurance of the validity of these conclusions. Seven projects reported that the non-home telehealth alternative held advantages over the home telehealth alternative. The number of studies where the effect of the home telehealth intervention was unclear highlights the need for further research and for the development of research skills and experience for those involved. Careful study design and again, a focus on cost-effectiveness, are required to build the evidence base for home telehealth application.

Another issue identified in the present study is the need to ensure the comparability of home telehealth interventions with standard or usual care practices. A case in point is home uterine activity monitoring (HUAM). An early paper on this form of home telehealth found no difference in preterm birth rate, preterm labour incidence, average birth weight or the gestational age of infants with home monitoring.[21] The authors concluded that the favourable effects attributed to HUAM in past papers may have instead been related to the increased nursing contact, concentration on symptoms of preterm labour and perceived contractions. In a recent review on the topic, Morrison *et al.*[22] identified that one problem was the use of control groups whose care was, in some studies, more similar to HUAM than the usual or standard care available at the time, setting an artificially high standard to compare HUAM against. Their conclusion was, when HUAM is used correctly by patients at high risk for preterm birth (i.e. with suitable alarm rates and precise monitors), early diagnosis of preterm labour, prolongation of pregnancy, reduced incidence of preterm birth and reduced neonatal morbidity is always demonstrated when compared to a standard care control group.

(6) *where is the evidence for home telehealth?* As has been noted in previous literature reviews,[7,8] the evidence for telehealth in general is sparse. However, the evidence supporting the application of home telehealth to a number of diseases/conditions is growing. In the present review the top five diseases/conditions were diabetes, the general area of mental health, high risk pregnancy monitoring, heart failure and cardiac disease. The analysis of patient numbers also revealed smoking cessation as an additional area where evidence exists with over 10,000 participants involved in the six RCTs undertaken.

Thus there is some evidence available to support the use of home telehealth in different areas. To build a convincing and scientifically sound case for the use of home telehealth there is a need for large RCTs to be undertaken with appropriate methodological rigour which investigate the use of the same intervention in comparable populations. In addition, more economic evidence is required together with subsequent meta-analyses of results.

Limitations

Due to time and cost constraints no attempt was made to contact authors for missing information. Also publication bias may have played a part in the high number of papers reporting that the home telehealth intervention studied was advantageous. Again, due to time and cost restraints no attempt was made to search the 'grey literature' for relevant unpublished studies or reports. Whilst the ultimate goal in undertaking a systematic review is commonly accepted to be the aggregation of studies in a meta-analysis,[23] the general area of home telehealth, as covered in the present review, is too heterogeneous a subject to permit such an analysis. Instead we focused on providing an overview of the available evidence for home telehealth. In this preliminary analysis the way in which studies were conducted was not assessed. However an attempt was made to account for sample size and study design. Due to space restrictions a full list of reviewed articles is not included with this paper (please contact the primary author for this information if required).

Conclusion

There is a growing body of evidence supporting the application of home telehealth to different conditions. Evidence exists for the clinical effectiveness of home telehealth in diabetes, the general area of mental health, high risk pregnancy monitoring, heart failure and cardiac disease. The majority of these applications have used the ordinary home telephone network as a simple, cheap and readily available communications infrastructure. To build a convincing and scientifically sound case for the use of home telehealth, more evidence is needed through large RCTs with appropriate rigour and quality. This will provide a larger data set of equivalent interventions, in comparable

populations, on which a meta-analysis can be conducted. Economic evaluations are also essential to provide high quality evidence about the cost-effectiveness of home telehealth, preceding widespread adoption.[8,9,24–27] In addition, long-term studies of applications are required to gain a better understanding of the true effectiveness of home telehealth and to demonstrate its sustainability.

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