Home-based telehealth: a review and meta-analysis

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Summary

We conducted a systematic review to identify studies on the effect of home telehealth on clinical care outcomes. The search was restricted to peer-reviewed publications (published between 2001 and 2007) about studies conducted in home or residential settings. The search yielded 154 potential articles and dissertations. A total of 29 articles met the inclusion criteria and were included in a meta-analysis. The weighted mean effect size for the overall meta-analysis was 0.50, and the z-statistic was 3.0, indicating that telehealth had a moderate, positive and significant effect ($P \leq 0.01$) on clinical outcomes. Subanalyses also indicated positive significant effects of telehealth for some disease categories (heart disease and psychiatric conditions), but not others (diabetes), patient populations and telehealth interventions. Overall, the meta-analysis indicated that telehealth positively affects clinical outcomes of care, even in different patient populations.

Introduction

Numerous studies have shown that home telehealth can produce clinically similar care to face-to-face visits with health practitioners, that it can improve patients' access to care and can reduce hospital and patient travel costs. However, studies on clinical outcomes of care have focused on different patient populations, different disease categories and different telehealth technologies. Although they have contributed to our knowledge regarding the use of home telehealth, the range of patient populations, disease categories, telehealth technologies and research methodologies makes it difficult to assess the overall effect of telehealth on clinical outcomes of care. This explains why Bensink *et al.*'s review of telehealth interventions[1] reported mixed findings and identified unanswered questions.

We have reviewed the literature to determine the effect of home telehealth in specific disease conditions, patient populations and types of technology.

Methods

Literature search

The search terms *telehealth*, *telemedicine* or *telehomecare* and the linking terms *remote monitoring*, *home* or *nursing*, were used to locate studies on the effects of telehealth on clinical outcomes between 2001 and 2007. The following databases were searched: Proquest, MEDLINE, ABI, CINAHL and Dissertation Abstracts International. The reference lists in the papers provided additional references for review.

The search was restricted to peer-reviewed journals and dissertations written in English between 2001 and 2007. The search was limited to studies of home or residential settings. There was no age limit of the subjects studied. We were interested only in clinical outcomes of home telehealth. Although several studies reported clinical and non-clinical outcomes, the non-clinical outcomes were not included in the meta-analysis. We excluded qualitative studies and studies without comparison groups. Both authors reviewed all articles and abstracts to ensure that they met the inclusion criteria.

Calculation of effect sizes

Information from the studies reviewed was coded and stored in a database. One author was the primary coder and the other checked a sample of the studies to ensure reliable coding. Disease and outcome information, and patient demographic information, such as age, gender and race, were recorded. The type of telehealth or health care used by the treatment and control groups (monitor, Internet, monitor plus home health) was also recorded, as well as the randomization method used (if any) and length of time from intervention to outcome measurement. Sample size, means, proportions and SDs were used to calculate the effect size (ES) statistics. Source descriptors, such as publication type and year of publication, were also recorded. We used SPSS 13.0 for data management and statistical analysis.

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For each outcome measure, we computed Cohen's standardized mean difference effect size statistic. This statistic applies to research findings that contrast two groups (experimental and control) on the mean scores of the dependent variables.[2] However, this effect size statistic is upwardly biased when based on samples of less than 20.[3] To correct for this, we used Hedges correction to calculate the unbiased effect size statistic. Effect size statistics were given positive signs when the treatment group (home telehealth) had better outcomes than the control group, and negative signs when the treatment group had worse outcomes than the control group.

In studies with multiple clinical outcome measures, a separate effect size statistic was computed for each outcome. Effect sizes were then averaged to create one effect size for each study. For studies with outcome measurements at multiple times (i.e. 1, 3 and 6 months), only the results of the measurement closest to six months were recorded.

Effect size statistics were weighted according to the inverse of the variance using the formula in Lipsey and Wilson, and the overall effect size was calculated for the study.[2] A statistical test for homogeneity, based on the Q statistic, was used to examine whether the effect size was larger than would be expected from sampling error alone. A significant Q statistic indicated that variability among the effect sizes was greater than sampling error alone, so a random effects model was estimated. A random effects model accounts for differences among studies whose sources cannot be identified or controlled.[2] Since our sample was very broad in terms of patient population, disease categories, outcomes and type of telehealth used, a random effects model seemed to be appropriate due to the study-level and subject-level variability. Weighted means, a mean effect size and a confidence interval for the mean were then re-calculated using the random effects model inverse variance weights.

Results

The search yielded 154 potential articles and dissertations. Ten articles failed to meet the inclusion criteria and were eliminated. Of the remaining 144 articles, 45 lacked relevance to telehealth conducted in a home or residential setting and 14 articles examined outcomes that were not clinical. We also eliminated 13 case studies that involved one patient or reported no numerical results.

Of the remaining 72 articles, 25 were eliminated because the studies were pretest–post-test design studies with no comparison group. Three articles were eliminated because they were duplicates of previous research. Other articles eliminated included three substandard studies, one of which was a poster from a conference, and 12 studies with insufficient statistical information to calculate effect sizes. In cases where a researcher had conducted similar studies on the same patient population, the study with the most rigorous research design (e.g. a randomized control group) and the most complete statistical results was used. Only 29 articles met all the criteria.[3–32]

The 29 articles represented a variety of patient populations, disease categories and telehealth technologies (Table 1). Although most patients were middle-aged

Table 1 Studies of home telehealth included in the analysis

	Source	Type of telehealth intervention	Diagnosis	*n*	Randomized	Weighted ES
1	Artinian *et al.*[4]	Data monitor, Telephone	Hypertension	26	Yes	1.25
2	Artinian *et al.*[5]	Internet	Heart disease	18	Yes	−0.23
3	Barnason *et al.*[6]	Data monitor	Heart disease	50	Yes	1.04
4	Bellazzi *et al.*[7]	Internet, Telephone, Data monitor	Diabetes	67	Yes	0.30
5	Benatar *et al.*[8]	Data monitor, Telephone	Heart disease	216	Yes	0.52
6	Biermann *et al.*[9]	Data monitor, Telephone	Diabetes	43	Yes	−0.12
7	Chan *et al.*[10]	Internet	Asthma	10	Yes	0.62
8	Chase *et al.*[11]	Data monitor, Telephone	Diabetes	70	Yes	0
9	Chumbler *et al.*[12]	Video monitor	Multiple	226	Yes	0.82
10	de Lusignan *et al.*[13]	Video monitor, Data monitor	Heart disease	20	Yes	0.69
11	D'Souza[14]	Video monitor	Psychiatric	51	Cannot tell	3.35
12	Egner *et al.*[15]	Video monitor	Multiple sclerosis	27	Yes	0.69
13	Farmer *et al.*[16]	Data monitor, Telephone	Diabetes	93	Yes	0.29
14	Finkelstein *et al.*[17]	Video monitor, Data monitor	Multiple	53	Yes	2.08
15	Frangou *et al.*[18]	Data monitor	Psychiatric	103	Yes	1.19
16	Goulis *et al.*[19]	Data monitor	Overweight	122	Yes	0.38
17	Harvey-Berino *et al.*[20]	Internet	Overweight	44	Yes	−0.11
18	Hopp *et al.*[21]	Video monitor, Data monitor	Multiple	37	Yes	0.44
19	Jerant *et al.*[22]	Video monitor	Heart disease	37	Yes	−0.36
20	Kenwright *et al.*[23]	Internet, Telephone	Psychiatric	27	No	0.12
21	LaFramboise *et al.*[24]	Data monitor	Heart disease	90	Yes	0.04
22	Mengden *et al.*[25]	Data monitor	Hypertension	53	Cannot tell	−0.27
23	Montori *et al.*[26]	Data monitor	Diabetes	31	Yes	0.40
24	Nelson *et al.*[27]	Internet	Psychiatric	28	Yes	0.68
25	Nguyen *et al.*[28]	Internet	Chronic obstructive pulmonary disease	16	No	0.38
26	Noel *et al.*[29]	Data monitor	Multiple	104	Yes	0.08
27	Pariser *et al.*[30]	Telephone	Arthritis	85	Yes	0.20
28	Simon *et al.*[31]	Telephone	Psychiatric	106	Yes	3.91
29	Wilbright *et al.*[32]	Video monitor	Diabetes	140	No	0.08

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(21–65 years) or elderly (over 65 years), four studies investigated the effect of telehealth on children. The three most common diseases were heart disease, diabetes and psychiatric conditions. Slightly more than half of the studies focused on men. Most studies did not report the racial composition of patients, but a few focused on Caucasians, Blacks or a mixture. Telehealth technologies varied from web-based interventions, data monitors only, video and data monitors, and telephone only interventions (Table 2).

Meta-analyses

A meta-analysis was performed on the 29 studies to assess the overall effect of telehealth on clinical outcomes of care. The mean weighted effect size for the studies was 0.50. This ES statistic indicates that home telehealth moderately and positively affected clinical outcomes.[2] The confidence interval for this ES statistic was 0.18–0.82; the z-test for the meta-analysis was 3.04, indicating that the ES statistic was significant ($P < 0.01$). The Q statistic for the overall meta-analysis was 20.75, indicating no heterogeneity in the sample distribution.

Separate meta-analyses were performed for subgroups of the studies. The first subanalysis examined the effect size for randomized studies, i.e. those with the most methodologically rigorous design. There were 23 studies which randomized patients into intervention and control groups. The mean weighted ES was 0.50, indicating a medium effect size. The confidence interval and z-statistic indicate that the ES was significant ($P \leq 0.01$). Subanalyses were also performed for subgroups based on disease category, age category, gender, race and telehealth technology type (Table 3).

Table 2 Scope of studies in meta-analysis

Scope of studies reviewed	Studies (*n*)
Summary of disease/condition categories	
Asthma	1
Diabetes	6
Heart disease	6
Hypertension	2
Psychiatric conditions	5
Chronic obstructive pulmonary disease	1
Multiple sclerosis	1
Multiple conditions	4
Arthritis	1
Overweight	2
Summary of patient populations	
Children (under 21 years)	4
Middle-aged (21–65 years)	15
Elderly (65 years and over)	10
Mostly female (over 50%)	11
Mostly male (over 50%)	12
Gender split evenly	4
Cannot tell gender distribution	2
Mostly Caucasian (over 50%)	7
Mostly Black (over 50%)	4
Mostly Hispanic (over 50%)	0
Mixed	3
Cannot tell racial composition	15
Summary of technologies used	
Telephone alone	2
Internet, with or without video, data, or telephone	7
Video monitor, with or without data or telephone monitor	8
Data monitor, with or without telephone monitor	12

Table 3 Meta-analysis using random effects model and subanalyses

	Studies (*n*)	Weighted ES	95% CI	z	Q
Overall	29	0.50	0.18, 0.82	3.0***	20.8
Randomized studies	23	0.50	0.13, 0.87	2.6***	12.8
Age group					
Children[a]	4	0.22	−0.06, 0.49	1.5	2.0
Adults	15	0.61	0.07, 1.16	2.2**	10.7
Elderly	10	0.41	0.10, 0.73	2.6***	10.8
Gender					
Mostly men	12	0.77	0.13, 1.42	2.4**	9.2
Mostly women[a]	11	0.32	0.17, 0.46	4.2***	13.2
Race					
Mostly White	8	0.65	−0.33, 1.62	1.3	3.4
Mostly Black[a]	4	0.36	0.12, 0.61	2.9***	3.9
Diagnosis					
Diabetes[a]	6	0.13	−0.07, 0.33	1.3	1.5
Heart disease[a]	6	0.32	0.11, 0.52	3.0***	7.6
Psychiatric	5	1.42	0.29, 2.55	2.5**	3.8
Intervention[b]					
Data monitor	12	0.26	0.07, 0.44	2.7***	13.3
Video monitor	8	0.78	0.21, 1.35	2.7***	9.7
Internet[a]	7	0.20	−0.06, 0.46	1.5	2.9

[a]A random effects model was not used to calculate these effect sizes because the initial Q statistic indicated no heterogeneity
[b]Intervention modes listed are the primary source of telehealth used. These modes may or may not have included additional services such as telephone feedback
$^{**}P \leq 0.05$; $^{***}P \leq 0.01$

Diabetes

Six studies evaluated the effect of telehealth in diabetes. Five of the studies[7,9,11,16,26] investigated changes in HbA_{1c} levels, and one used ulcer healing time as the main outcome variable.[32] Sample sizes ranged from 31–140. The effect size was 0.13 (z = 1.3), indicating that the meta-analysis did not support a link between telehealth and diabetes outcomes.

Heart disease

Five studies evaluated the effect of telehealth in heart failure,[4,8,13,22,24] and one investigated telehealth in coronary artery bypass grafting.[6] The sample sizes for the studies ranged from 18–216, and all were randomized. The effect size for the heart disease subgroup was 0.32 (z = 3.0, $P < 0.01$), indicating a moderately positive relationship between telehealth and heart failure outcomes. None of these studies found significant negative outcomes.

Psychiatric conditions

Five studies sampled patients with psychiatric diagnoses, including bipolar disorders,[14] schizophrenia,[18] anxiety disorders[23] and depression.[15,31] The sample sizes ranged from 27–106; three of the five studies were randomized. Clinical measures included medication adherence,[14,18] self-reported mental health status[23,27,31] and hospital re-admission or emergency visits.[14,18] The effect size (ES =

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1.42, $z = 2.5$, $P < 0.05$) indicated a positive relationship between telehealth and mental illness outcomes.

Demographic characteristics

Most subjects in the meta-analysis were adults. The most pronounced effect size involved subjects aged 21–65 years ($ES = 0.61$, $P < 0.05$). The effect size for elderly subjects was weaker ($ES = 0.41$) but significant ($P < 0.01$). More than half of the studies were performed mainly on males. The effect size was stronger for male subjects ($ES = 0.77$) than for females ($ES = 0.32$); however, both were significant. Most studies did not state the racial compositions of the subjects. In the studies on Blacks, the effect size was mild ($ES = 0.36$) but significant ($P < 0.01$).

Telehealth technology

Video technology was more efficacious than other technologies, although telephone only was not evaluated in this subanalysis due to the very limited numbers of studies. The effect size for this subset was 0.78 ($P < 0.01$), suggesting that real-time interaction between the health-care provider and the patient strongly influences clinical outcomes.

Discussion

The present meta-analysis indicates that telehealth positively affects clinical outcomes, with effect sizes ranging from mild to moderate. This suggests that telehealth may be useful for conditions that require close monitoring, clinical assessment and early intervention to avoid adverse events such as hospitalization or emergency visits.

Limitations

Our research had some limitations. First, 12 comparative studies were not included in the analysis due to insufficient statistical information. Although several of these studies were methodologically rigorous randomized comparative studies with large sample sizes, the statistical findings did not contain the necessary statistics needed for a meta-analysis. These studies indicated that telehealth improved clinical outcomes. If we had been able to include these studies in our analysis, they would have strengthened the overall effect size.

The second limitation is possible publication bias, a limitation of most meta-analyses.[11] Studies with significant findings are more likely to be published. Many studies in our meta-analysis had non-significant findings; therefore, our effect size might be upwardly biased if publication bias was present in the literature. Also, some studies included in the analysis had less rigorous methodological designs, as noted in other reviews,[1] and inclusion of some of these studies could also have influenced our results. Third, we only included studies published in English, which could potentially bias our findings.

A final limitation was the variation in the types of telehealth technology that were employed, as well as the type of care the control groups received. Although we categorized telehealth technology intervention as asynchronous, synchronous, Internet and telephone technology, many of these interventions used more than one technology type. Similar limitations existed for the control groups in the studies. Although some control groups received no care compared to the telehealth groups, others received home health care or physician follow-up visits at different times. Although we analyzed only comparative studies, we could not control for varied care types among studies.

Future research

The present study demonstrates that telehealth significantly and positively affects clinical outcomes, in a range of patient populations and disease categories. Since good clinical outcomes can result in fewer visits to the emergency room, fewer admissions to the hospital, shorter lengths of stay and fewer visits to the physician, it is clear that telehealth has the potential to decrease the cost of care. However, there have been few studies of the cost effectiveness of telehealth, so further research is needed.

Additional research on the similarity of telehealth to usual care is needed. Specifically, standardized outcomes and interventions are desirable. In their review of home telehealth studies, Bensink *et al.* concluded that comparisons between the two are difficult because of the variation in interventions and usual care and that these variations can influence the conclusions of studies. This variation partly explains why some studies found positive effects of telehealth on clinical outcomes, while other studies found no benefit of telehealth over usual care.[1]

In conclusion, the present study provides support that telehealth is an effective clinical intervention in many settings with different patient groups. Investigation into the clinical and cost effectiveness of telehealth interventions should continue, since telehealth interventions have the potential to reduce costs, improve outcomes and increase access to care.

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