ISSN 1949-8462 (online)

World Journal of *Cardiology*

World J Cardiol 2022 December 26; 14(12): 617-664

Published by Baishideng Publishing Group Inc

World Journal of Cardiology

Contents

Monthly Volume 14 Number 12 December 26, 2022

ORIGINAL ARTICLE

Observational Study

Randomized Clinical Trial

SYSTEMATIC REVIEWS

CASE REPORT

World Journal of Cardiology

Monthly Volume 14 Number 12 December 26, 2022

Contents

NAME OF JOURNAL

World Journal of Cardiology

ISSN

ISSN 1949-8462 (online)

LAUNCH DATE

December 31, 2009

FREQUENCY

Monthly

EDITORS-IN-CHIEF

Ramdas G Pai, Dimitrios Tousoulis, Marco Matteo Ciccone, Pal Pacher

EDITORIAL BOARD MEMBERS

https://www.wjgnet.com/1949-8462/editorialboard.htm

PUBLICATION DATE

December 26, 2022

INSTRUCTIONS TO AUTHORS

https://www.wjgnet.com/bpg/gerinfo/204

GUIDELINES FOR ETHICS DOCUMENTS

https://www.wjgnet.com/bpg/GerInfo/287

GUIDELINES FOR NON-NATIVE SPEAKERS OF ENGLISH

https://www.wjgnet.com/bpg/gerinfo/240

PUBLICATION ETHICS

https://www.wjgnet.com/bpg/GerInfo/288

PUBLICATION MISCONDUCT

https://www.wjgnet.com/bpg/gerinfo/208

ARTICLE PROCESSING CHARGE

https://www.wjgnet.com/bpg/gerinfo/242

STEPS FOR SUBMITTING MANUSCRIPTS

https://www.wjgnet.com/bpg/GerInfo/239

ONLINE SUBMISSION

https://www.f6publishing.com

World Journal of Cardiology

Submit a Manuscript: https://www.f6publishing.com

World J Cardiol 2022 December 26; 14(12): 640-656

DOI: 10.4330/wjc.v14.i12.640

ISSN 1949-8462 (online)

SYSTEMATIC REVIEWS

Telemonitoring in heart failure patients: Systematic review and meta-analysis of randomized controlled trials

Chukwuemeka Anthony Umeh, Adrian Torbela, Shipra Saigal, Harpreet Kaur, Shadi Kazourra, Rahul Gupta, Shivang Shah

Specialty type: Cardiac and cardiovascular systems

Provenance and peer review: Unsolicited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's scientific quality classification

Grade A (Excellent): 0
Grade B (Very good): B, B, B
Grade C (Good): 0
Grade D (Fair): 0
Grade E (Poor): 0

P-Reviewer: Lakusic N, Croatia; Su Q, China; Yang YQ, China

Received: August 28, 2022
Peer-review started: August 28, 2022
First decision: October 24, 2022
Revised: November 2, 2022
Accepted: November 30, 2022
Article in press: November 30, 2022
Published online: December 26, 2022

Chukwuemeka Anthony Umeh, Adrian Torbela, Shipra Saigal, Harpreet Kaur, Shadi Kazourra, Rahul Gupta, Internal Medicine, Hemet Global Medical Center, Hemet, CA 92543, United States

Shivang Shah, Department of Cardiology, Loma Linda University School of Medicine, Loma Linda, CA 92350, United States

Shivang Shah, Department of Cardiology, University of California Riverside School of Medicine, Riverside, CA 92507, United States

Corresponding author: Chukwuemeka Anthony Umeh, MD, Attending Doctor, Internal Medicine, Hemet Global Medical Center, 1117 E Devonshire Ave, Hemet, CA 92543, United States. emmyumeh@gmail.com

Abstract

BACKGROUND

Home telemonitoring has been used as a modality to prevent readmission and improve outcomes for patients with heart failure. However, studies have produced conflicting outcomes over the years.

AIM

To determine the aggregate effect of telemonitoring on all-cause mortality, heart failure-related mortality, all-cause hospitalization, and heart failure-related hospitalization in heart failure patients.

METHODS

We conducted a systematic review and meta-analysis of 38 home telemonitoring randomized controlled trials involving 14993 patients. We also conducted a sensitivity analysis to examine the effect of telemonitoring duration, recent heart failure hospitalization, and age on telemonitoring outcomes.

RESULTS

Our study demonstrated that home telemonitoring in heart failure patients was associated with reduced all-cause [relative risk (RR) = 0.83, 95% confidence interval (CI): 0.75-0.92, $P = 0.001$] and cardiovascular mortality (RR = 0.66, 95%CI: 0.54-0.81, $P < 0.001$). Additionally, telemonitoring decreased the all-cause hospitalization (RR = 0.87, 95%CI: 0.80-0.94, $P = 0.002$) but did not decrease heart failure-related hospitalization (RR = 0.88, 95%CI: 0.77-1.01, $P = 0.066$). However,

prolonged home telemonitoring (12 mo or more) was associated with both decreased all-cause and heart failure hospitalization, unlike shorter duration (6 mo or less) telemonitoring.

CONCLUSION
Home telemonitoring using digital/broadband/satellite/wireless or blue-tooth transmission of physiological data reduces all-cause and cardiovascular mortality in heart failure patients. In addition, prolonged telemonitoring (≥ 12 mo) reduces all-cause and heart failure-related hospitalization. The implication for practice is that hospitals considering telemonitoring to reduce heart failure readmission rates may need to plan for prolonged telemonitoring to see the effect they are looking for.

Key Words: Telemonitoring; Heart failure; Telehealth; Home monitoring; Remote monitoring

Core Tip: Home telemonitoring has been used as a modality to prevent readmission and improve outcomes for patients with heart failure. However, studies have produced conflicting outcomes over the years. This meta-analysis aims to determine the aggregate effect of telemonitoring on all-cause mortality, heart failure-related mortality, all-cause hospitalization, and heart failure-related hospitalization in heart failure patients. This study found that home telemonitoring using digital/broadband/satellite/wireless or blue-tooth transmission of physiological data reduces all-cause and cardiovascular mortality in heart failure patients. Additionally, prolonged home telemonitoring (12 mo or more) led to both decreased all-cause and heart failure hospitalization, unlike shorter duration (6 mo or less) telemonitoring. The implication for practice is that hospitals considering telemonitoring to reduce heart failure readmission rates may need to plan for prolonged telemonitoring to see the effect they are looking for.

Citation: Umeh CA, Torbela A, Saigal S, Kaur H, Kazourra S, Gupta R, Shah S. Telemonitoring in heart failure patients: Systematic review and meta-analysis of randomized controlled trials. *World J Cardiol* 2022; 14(12): 640-656
URL: https://www.wjgnet.com/1949-8462/full/v14/i12/640.htm
DOI: https://dx.doi.org/10.4330/wjc.v14.i12.640

INTRODUCTION

Heart failure is a clinical syndrome in which patients develop signs and symptoms, including dyspnea, fatigue, and/or fluid retention due to cardiac dysfunction or abnormality in cardiac structure[1]. Heart failure is classified as heart failure with reduced ejection fraction (EF) (< 40%), heart failure with mildly reduced EF (41% to 49%), or heart failure with preserved EF (> 50%)[1]. Heart failure has become the primary cause of hospitalization in the United States in the elderly[2,3]. The prevalence increases with increasing age, and affected individuals significantly consume healthcare resources. It has significant public health implications, with an estimated cost of about $30.7 billion in the United States in 2012, with the projected total rise in cost up to $69.7 billion by 2030[2,4]. Additionally, heart failure is associated with high morbidity and mortality, with a readmission rate during six months following discharge as high as 50%[5]. Heart failure is not just a problem in the United States but a global disease, with its prevalence increasing across the globe[1,2].

As the survival of patients with acute myocardial infarction improves and with a population that continues to age, we will continually see a rise in patients with heart failure and, thus, more rehospitalizations. Various modalities have been in the works to improve outcomes for patients with heart failure to prevent readmission. One of these modalities, termed home telemonitoring, involves tracking patients' health status using electronic devices at home[6-10]. Healthcare providers can obtain patients' vital signs, weight, and other parameters recorded and transmitted through communication technology and contact the patients if abnormalities are noted. In this way, deteriorations in patients' conditions are detected early, resulting in early interventions. A review of randomized controlled trials of noninvasive home telemonitoring compared to standard practice for people with heart failure has shown a reduced risk of all-cause mortality, heart failure-related hospitalizations, and improvement in quality of life and heart failure knowledge and self-care behaviors in some studies[6].

Though using home telemonitoring to monitor patients remotely has been going on for a while, further evaluation is needed as studies have reported inconsistent results over the years. While telemonitoring was beneficial in reducing hospital admission, all-cause mortality, and emergency room visits in some studies, others did not show such benefits[7-10]. These differences in outcomes from multiple

studies suggest that careful analysis of study outcomes is needed to determine its aggregate benefit to heart failure patients. This meta-analysis aims to determine the aggregate effect of telemonitoring on all-cause mortality, heart failure-related mortality, all-cause hospitalization, and heart failure-related hospitalization in heart failure patients. We also conducted sensitivity analysis to examine the effect of telemonitoring duration, recent heart failure hospitalization, and age on telemonitoring outcome.

MATERIALS AND METHODS

Study design

Our systematic review and meta-analysis was designed according to the guidelines included in the PRISMA statement[11].

Outcomes

Our primary outcomes were all-cause and heart failure-related mortality and all-cause and heart failure-related hospitalizations.

Eligibility criteria

We included only randomized controlled trials of home telemonitoring in heart failure patients that reported mortality or readmissions as the outcome measure. We defined home telemonitoring as patients self-measuring their vital signs (such as pulse, weight, blood pressure) at home and using a digital/broadband/satellite/wireless or blue-tooth device to transmit the data to healthcare professionals. The healthcare professionals reviewed the transmitted data and instructed the patient on the next steps if the values were abnormal, including medication adjustment. We excluded studies not written in English. Two authors independently reviewed the abstracts after our literature search to assess if they met the inclusion and exclusion criteria to be included in the study.

Literature search

Articles were obtained by searching the PubMed, Embase, Google scholar, Reference Citation Analysis and Cochrane databases with the term heart failure, combined with the following terms: "telemonitoring", "telehealth", "home monitoring", and "remote monitoring". In PubMed and Embase, we used a filter to limit our search to randomized controlled trials conducted between January 1, 2000, and September 2021. In the Google scholar search, we restricted the search to the article titles that contain the search terms.

Data extraction of primary studies

Information on study participants, methods, interventions, and outcomes, including hospitalization and death, was extracted onto a data-sheet in Excel (Microsoft Corporation, 2018). We reported only the result of the heart failure patients for articles that included heart failure patients and patients with other illnesses but reported separate results.

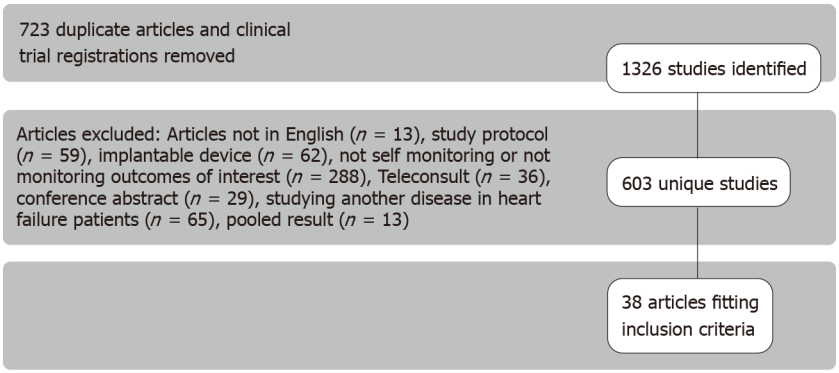
Methods for assessing the risk of bias

We assessed the risk of bias using the methods presented in the Cochrane handbook[12]. First, the risk of bias was evaluated independently by two authors. In case of disagreement between the two authors, the matter was discussed and decided by consensus. The presence of publication bias for each outcome was assessed using funnel plots.

Quantitative data synthesis

The study's primary endpoints are the effect of telemonitoring on all-cause mortality, heart failure-related mortality, all-cause hospitalization, and heart failure-related hospitalization in heart failure patients. We calculated the relative risk (RR) and 95% confidence interval (CI) for each outcome in each study. We used the random effect model and tested the null hypothesis using Z-score. A P value of < 0.05 was interpreted as statistically significant. We tested heterogeneity in study outcomes using the χ^2 test and the I^2 statistic.

To assess the outcomes in different sub-groups, we performed a series of subgroup analyses: (1) Comparison of cumulative outcomes in the telemonitoring and usual care approach, according to the duration of follow-up (≤ 6 mo and ≥ 12 mo). The median and modal duration of follow-up in the studies was six months, and most of the studies that extended beyond six months lasted for at least 12 mo. Thus, we decided to compare studies with a duration of ≤ 6 mo with those ≥ 12 mo; (2) Comparison of cumulative outcomes in the telemonitoring and usual care approach, in studies of patients with recent heart failure hospitalization, which we defined as heart failure hospitalization within six weeks before the study, and those that did not; and (3) Comparison of cumulative outcomes in the telemonitoring and usual care approach, in studies that recruited patients ≥ 65 years. The analysis was done using Comprehensive Meta-Analysis Version 3.



DOI: 10.4330/wjc.v14.i12.640

Figure 1 The literature search result.

RESULTS

Identification of relevant studies

Our search produced 1326 articles, of which 603 were unique articles after removing duplicate publications and clinical trial registrations. Two researchers independently reviewed the 603 abstracts to assess if they met the inclusion and exclusion criteria in the review. We excluded papers not in English (n = 13), papers that used implantable devices such as pacemakers (n = 62), papers on telemonitoring study protocol (n = 59), papers on teleconsulting (n = 36), conference abstracts (n = 29), papers that did not measure heart failure patients' hospitalization or mortality or did not include self-monitoring (n = 288), papers studying another disease in heart failure patients (n = 65), and papers that joined the results of patients with heart failure and patients with other illnesses (n = 13) (Figure 1).

Our study included 38 randomized controlled trials on telemonitoring in heart failure patients between January 1, 2000, and October 3, 2021[7-10,13-46] (Table 1). Fourteen thousand nine hundred and ninety-three patients were recruited in the 38 studies, with a mean of 394 and a range of 48 to 1653. The mean duration of the studies was 9.4 mo and a range of 1 to 32 mo in Table 1. Forty-seven percent of the studies were done in North America (the United States of America and Canada), and the majority of the remaining were done in Europe. All the studies involved patients measuring their vital signs and weight and using digital/broadband/satellite/wireless or blue-tooth to transmit the data to the healthcare providers. The patients transmitted their data daily in 92% of the studies and weekly in 8% of studies (Table 1). The nurses were the primary healthcare professionals that monitored the patients' data and informed the physicians of abnormal values in 79% of the studies. They also contacted the patient if there were abnormal values with instructions on what to do next. Physicians led the process in 6 studies (16%), where the physicians reviewed the transmitted patients' data and contacted them if values were abnormal with instructions on what to do next. A case manager led the process in one of the studies, and a non-clinician led one study (Table 1).

Risk of bias assessment

There was a low risk of bias in the randomization process, measurement of outcome data, or missing outcome data in the studies included in the meta-analysis. However, the intervention was not blinded in any of the primary studies because of the nature of the studies. Additionally, many of the studies did not provide information on whether outcome assessors were aware of the intervention received by study participants. Thus, it is unclear how these affected the study outcomes. Furthermore, many studies did not indicate if the data was analyzed per a pre-specified plan that was finalized before unblinded outcome data were available for analysis. Thus, we did not have information to assess the risk of bias in selecting the reported result. Table 2 shows the bias assessment in each of the primary studies. The heterogeneity within the studies ranged from low (for cardiovascular mortality, I^2 = 0%) to substantial (for all-cause hospitalizations, I^2 = 69%). The funnel plots did not show any major publication bias in the primary outcomes assessed (Supplementary Figures 1-3).

All-cause mortality

The pooled estimate of the effect of telemonitoring on all-cause death in comparison with standard care in 28 studies with 13188 patients showed that telemonitoring was associated with reduced all-cause mortality in heart failure patients (RR = 0.83, 95%CI: 0.75-0.92, P = 0.001) (Figure 2A). Our sensitivity analysis showed that the duration of telemonitoring did not influence all-cause mortality in heart failure patients. Analysis of 15 studies of six months or less duration showed reduced all-cause mortality (RR = 0.78, 95%CI: 0.65-0.94, P = 0.009). Similarly, analysis of 12 studies of 12 mo or more months duration also showed reduced all-cause mortality (RR = 0.86, 95%CI: 0.74-0.99, P = 0.032) (Table 3).

Table 1 Summary of studies included in the meta-analysis

Ref.	Number of patients	Duration of follow-up (mo)	Country	Person responsible for monitoring telemedicine data	Frequency of measuring and transmitting vital signs	Frequency of clinicians reviewing data	Included telemonitoring patients' education	Included control group patient education	Recruited patients ≥ 65 yr	Recruited recently discharged patients	Recruited frequently hospitalized patients
Nouryan *et al* [15], 2019	89	6	United States	Nurse	Daily	Daily	Yes	Yes	Yes	No	No
Seto *et al*[16], 2012	100	6	Canada	Physician	Daily	Daily	No	No	No	No	No
Weintraub *et al* [17], 2010	188	3	United States	Nurse	Daily	Daily	Yes	Yes	No	Yes	No
Blum and Gottlieb[18], 2014	156	27	United States	Nurse	Daily	Daily	No	No	No	No	No
Dansky *et al* [19], 2008	284	4	United States	Nurse	Daily	Daily	No	No	No	No	No
Kashem *et al* [20], 2008	48	12	United States	Nurse	Daily	Daily	No	No	No	No	No
Benatar *et al* [21], 2003	216	12	United States	Nurse	Daily	Daily	No	Yes	No	Yes	No
Pedone *et al* [22], 2015	96	6	Italy	Physician	Daily	Daily	No	No	Yes	No	No
Wade *et al*[23], 2011	316	6	United States	Case manager	Daily	Daily	Yes	Yes	Yes	No	No
Comín-Colet *et al*[24], 2016	178	6	Spain	Nurse	Daily	Daily	No	No	No	Yes	No
Olivari *et al* [25], 2018	339	12	Italy	Non-clinician	Daily	Daily	No	No	Yes	No	No
Lyngå *et al*[26], 2012	319	12	Sweden	Nurse	Daily	3 d a week	No	No	No	No	No
Scherr *et al*[27], 2009	120	6	Austria	Physician	Daily	Daily	No	No	No	Yes	No
Antonicelli *et al* [28], 2008	57	12	Italy	Nurse	Weekly	Weekly	Yes	No	Yes	No	No
Giordano *et al* [29], 2009	460	12	Italy	Nurse	Daily	Daily	Yes	No	No	No	No

Ong *et al*[30], 2016	1437	6	United States	Nurse	Daily	Daily	Yes	No	No	Yes	No
Kalter-Leibovici *et al*[10], 2017	1360	32	Isreal	Nurse	Daily	Daily	Yes	No	No	No	No
Mortara *et al* [31], 2009	461	12	United Kingdom, Poland, and Italy	Nurse	Weekly	Weekly	No	No	No	No	No
Dar *et al*[32], 2009	182	6	United Kingdom	Nurse	Daily	Daily	No	No	No	Yes	No
Vuorinen *et al* [33], 2014	94	6	Finland	Nurse	Weekly	Weekly	No	No	No	No	No
Goldberg *et al* [34], 2003	280	6	United States	Nurse	Daily	Daily	No	No	No	No	No
Soran *et al*[35], 2008	315	6	United States	Nurse	Daily	Daily	No	No	Yes	No	No
Chaudhry *et al* [36], 2010	1653	6	United States	Physician	Daily	Daily	No	No	No	Yes	No
Koehler *et al* [13], 2018	1571	12	Germany	Physician	Daily	Daily	Yes	No	No	No	No
Cleland *et al* [14], 2005	418	8	Germany, Netherlands, and United Kingdom	Nurse	Daily	Daily	Yes	No	No	Yes	No
Koehler *et al*[7], 2011	710	26	Germany	Physician	Daily	Daily	No	No	No	No	No
Kotooka *et al* [8], 2018	181	15	Japan	Nurse	Daily	Daily	No	No	No	Yes	No
Pekmezaris *et al* [9], 2019	104	3	United States	Nurse	Daily	Daily	Yes	No	No	Yes	No
Villani *et al*[37], 2014	80	12	Italy	Nurse	Daily	Daily	No	No	Yes	Yes	Yes
Dendale *et al* [38], 2012	160	6	Belgium	Nurse	Daily	Daily	No	No	No	Yes	No
Woodend *et al* [39], 2007	121	3	Canada	Nurse	Daily	Daily	Yes	No	No	Yes	No
Galinier *et al* [40], 2020	937	18	France	Nurse	Daily	Daily	Yes	No	No	No	No
Capomolla *et al* [41], 2004	133	12	Italy	Nurse	Daily	Daily	Yes	No	No	No	No

Kulshreshtha *et al*[42], 2010	150	6	United States	Nurse	Daily	Daily	No	No	No	Yes	Yes
Kenealy *et al* [43], 2015	98	6	New Zealand	Nurse	Daily	Daily	No	No	No	No	No
Dawson *et al* [44], 2021	1380	1	United States	Nurse	Daily	Daily	No	No	No	Yes	Yes
Delaney *et al* [45], 2013	100	3	United States	Nurse	Daily	Daily	No	No	No	No	No
Schwarz *et al* [46], 2008	102	3	United States	Nurse	Daily	Daily	No	No	Yes	Yes	No

Furthermore, our sensitivity analysis showed that being recently hospitalized for heart failure, which we defined as heart failure hospitalization within six weeks before the study, did not affect the telemonitoring outcome. The analysis of 12 studies that recruited patients recently hospitalized for heart failure showed reduced all-cause mortality in telemonitoring patients (RR = 0.83, 95%CI: 0.71-0.97, P = 0.021). Similarly, an analysis of 16 studies that recruited patients who were not recently hospitalized showed reduced all-cause mortality in telemonitoring patients (RR = 0.81, 95%CI: 0.69-0.95, P = 0.01) (Table 3). Analysis of seven studies that recruited only patients 65 years or more showed that telemonitoring reduced all-cause mortality in this age group (RR = 0.66, 95%CI: 0.50-0.87, P = 0.004).

Cardiovascular mortality

The pooled estimate of the effect of telemonitoring on cardiovascular death in comparison with standard care in nine studies with 4043 patients showed that telemonitoring was associated with reduced cardiovascular mortality in heart failure patients (RR = 0.66, 95%CI: 0.54-0.81, P < 0.001) (Figure 2B). Two studies were excluded from the analysis because they reported no cardiovascular deaths in the telemonitoring and usual care groups.

Our sensitivity analysis showed that the duration of telemonitoring did not influence cardiovascular mortality in heart failure patients. Analysis of 3 studies of 6 mo or less duration showed reduced cardiovascular mortality in telemonitoring patients (RR = 0.47, 95%CI: 0.28-0.79, P = 0.005). Similarly, our analysis of 5 studies of 12 mo or more duration showed reduced cardiovascular mortality in telemonitoring patients (RR = 0.71, 95%CI: 0.56-0.90, P = 0.005) (Table 3).

Furthermore, our sensitivity analysis showed that being recently hospitalized for heart failure, which we defined as heart failure hospitalization within six weeks before the study, did not affect the telemonitoring outcome. Analysis of 3 studies that recruited patients with recent hospitalization showed reduced cardiovascular mortality in telemonitoring patients (RR = 0.57, 95%CI: 0.35-0.94, P = 0.026). Similarly, our analysis of 6 studies that recruited patients with no recent hospitalization showed reduced cardiovascular mortality in telemonitoring patients (RR = 0.68, 95%CI: 0.54-0.85, P = 0.001) (Table 3).

All-cause hospitalization

The pooled estimate of the effect of telemonitoring on all-cause hospitalization in comparison with

Table 2 Showing the bias assessment of the primary studies

Ref.	The allocation sequence was random	The allocation sequence was adequately concealed	Participants aware of their assigned intervention	Interventions implementors were aware of participants' assigned groups	Outcome data were available for all, or nearly all, participants randomized	Outcome measurement could have differed between groups	Outcome assessors were aware of the intervention received by participants	Data analysis plan was finalized before data were available for analysis
Nouryan *et al* [15], 2019	Yes	Probably yes	Yes	Yes	Yes	No	No information	No information
Seto *et al*[16], 2012	Yes	Yes	Yes	Yes	Yes	No	No information	No information
Weintraub *et al* [17], 2010	Probably yes	No information	Yes	Yes	Yes	No	No	Yes
Blum and Gottlieb[18], 2014	Probably yes	No information	Yes	Yes	Yes	No	No information	No information
Dansky *et al* [19], 2008	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Kashem *et al* [20], 2008	Yes	Yes	Yes	Yes	Yes	No	No information	No information
Benatar *et al* [21], 2003	Probably yes	No information	Yes	Yes	Probably yes	No	No information	No information
Pedone *et al*[22], 2015	Probably yes	No information	Yes	Yes	Yes	No	No information	No information
Wade *et al*[23], 2011	Yes	No information	Yes	Yes	No	No	No information	No information
Comín-Colet *et al*[24], 2016	Yes	Yes	Yes	Yes	Yes	No	No	No information
Olivari *et al*[25], 2018	Yes	Yes	Yes	Yes	Yes	No	No information	Yes
Lyngå *et al*[26], 2012	Probably yes	No information	Yes	Yes	Yes	No	No information	No information
Scherr *et al*[27], 2009	Probably yes	No information	Yes	Yes	No	No	No information	No information
Antonicelli *et al* [28], 2008	Probably yes	No information	Yes	Yes	Probably yes	No	No information	No information
Giordano *et al* [29], 2009	Yes	Yes	Yes	Yes	Yes	No	No information	No information

Ong *et al*[30], 2016	Yes	Yes	Yes	Yes	Probably yes	No	No	Yes
Kalter-Leibovici *et al*[10], 2017	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Mortara *et al* [31], 2009	Yes	Yes	Yes	Yes	Yes	No	No information	No information
Dar *et al*[32], 2009	Yes	Yes	Yes	Yes	Yes	No	No information	No information
Vuorinen *et al* [33], 2014	Yes	No information	Yes	Yes	Yes	No	No information	No information
Goldberg *et al* [34], 2003	Yes	No information	Yes	Yes	No	No	No information	No information
Soran *et al*[35], 2008	Yes	No information	Yes	Yes	Yes	No	No information	No information
Chaudhry *et al* [36], 2010	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Koehler *et al* [13], 2018	Yes	Yes	Yes	Yes	Yes	No	No information	Yes
Cleland *et al* [14], 2005	Yes	Yes	Yes	Yes	Yes	No	No information	Yes
Koehler *et al*[7], 2011	Yes	Yes	Yes	Yes	Yes	No	No information	Yes
Kotooka *et al*[8], 2018	Yes	Yes	Yes	Yes	No	No	No	Yes
Pekmezaris *et al* [9], 2019	Yes	No information	Yes	Yes	Yes	No	No information	No information
Villani *et al*[37], 2014	Yes	Yes	Yes	Yes	Yes	No	No information	No information
Dendale *et al* [38], 2012	Yes	Yes	Yes	Yes	Yes	No	No	No information
Woodend *et al* [39], 2007	Yes	No information	Yes	Yes	Yes	No	No information	No information
Galinier *et al* [40], 2020	Yes	Yes	Yes	Yes	Yes	No	No information	No information
Capomolla *et al* [41], 2004	Yes	No information	Yes	Yes	No	No	No information	No information
Kulshreshtha *et*	Yes	No	Yes	Yes	No	No	No information	No information

al[42], 2010								
Kenealy *et al* [43], 2015	Yes	Yes	Yes	Yes	Yes	No	No	No information
Dawson *et al* [44], 2021	Yes	Yes	Yes	Yes	No	No	No information	No information
Delaney *et al* [45], 2013	Yes	Yes	Yes	Yes	Yes	No	No information	No information
Schwarz *et al* [46], 2008	Yes	No information	Yes	Yes	Yes	No	No information	No information

Table 3 Result of sensitivity analysis

	All-cause mortality			Cardiovascular mortality			All-cause hospitalization			Heart failure hospitalization		
	No of studies	Number of patients	Effect	No of studies	Number of patients	Effect	No of studies	Number of patients	Effect	No of studies	Number of patients	Effect
Follow up ≤ 6 mo	15	6781	Reduced	3	773	Reduced	19	7442	No effect	8	2774	No effect
Follow up ≥ 12 mo	12	6159	Reduced	5	3022	Reduced	13	5360	Reduced	6	2962	Reduced
Recent hospitalization	12	5865	Reduced	3	607	Reduced	13	6057	Reduced	6	2486	No effect
No recent hospitalization	16	7417	Reduced	6	3436	Reduced	20	6993	Reduced	8	3250	Reduced
Patients ≥ 65 yr	7	1522	Reduced	-	-	-	8	1611	No effect	-	-	-

standard care in 33 studies with 13050 patients showed that telemonitoring was associated with reduced all-cause hospitalization in heart failure patients (RR = 0.87, 95%CI: 0.80-0.94, P = 0.002) (Figure 2C).

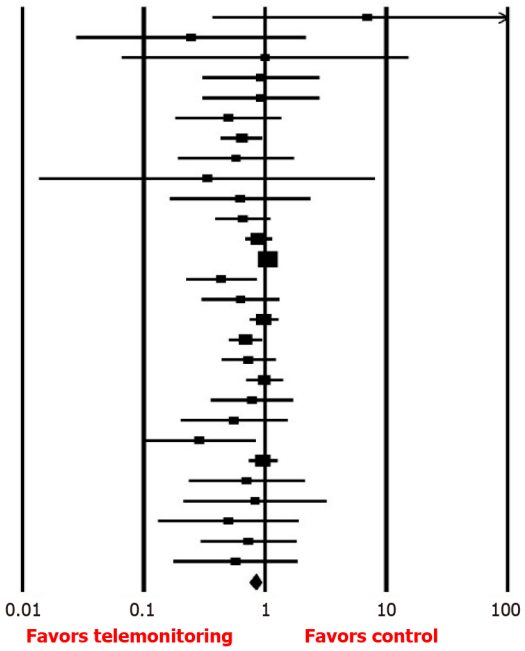
Our sensitivity analysis showed that the duration of telemonitoring influenced all-cause hospitalization in heart failure patients. Analysis of 19 studies with six months or less duration showed no effect of telemonitoring on all-cause hospitalization (RR = 0.93, 95%CI: 0.83-1.04, P = 0.21). Conversely, our analysis of 13 studies with 12 mo or more duration showed that telemonitoring reduced all-cause hospitalization (RR = 0.79, 95%CI: 0.68-0.92, P = 0.002) (Table 3).

Furthermore, our sensitivity analysis showed that being recently hospitalized for heart failure did not affect the all-cause hospitalization. Analysis of 13 studies that recruited recently hospitalized heart failure patients showed that telemonitoring reduced all-cause hospitalization (RR = 0.85, 95%CI: 0.74-0.98, P = 0.03). Similarly, our analysis of 20 studies that recruited patients that were not recently hospitalized showed that telemonitoring also reduced all-cause hospitalization in this group (RR = 0.88, 95%CI: 0.78-0.98, P = 0.03) (Table 3). Analysis of eight studies that recruited only patients 65 years or older showed that telemonitoring did not affect all-cause hospitalization in this age group (RR = 0.77, 95%CI: 0.58-1.02, P = 0.071).

A

Effect of home telemonitoring on all-cause mortality in heart failure patients

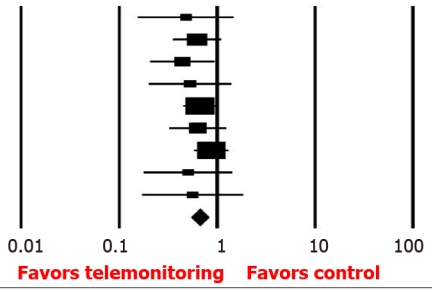
Study name	Risk ratio	Lower limit	Upper limit	*P* value
Seto *et al*[16], 2012	7.000	0.371	132.101	0.194
Weintraub *et al*[17], 2010	0.245	0.028	2.149	0.204
Kashem *et al*[20], 2008	1.000	0.066	15.081	1.000
Pedone *et al*[22], 2015	0.927	0.305	2.812	0.893
Wade *et al*[23], 2011	0.927	0.305	2.812	0.893
Comín-Colet *et al*[24], 2016	0.499	0.183	1.357	0.173
Olivari *et al*[25], 2018	0.643	0 .437	0.947	0.025
Lyngå *et al*[26], 2012	0.567	0.193	1.723	0.324
Scherr *et al*[27], 2009	0.333	0.014	8.005	0.498
Antonicelli *et al*[28], 2008	0.621	0.164	2.359	0.485
Giordano *et al*[29], 2009	0.656	0.390	1.103	0.112
Ong *et al*[30], 2016	0.886	0.691	1.135	0.337
Kalter-Leibovici *et al*[10], 2017	1.058	0.909	1.231	0.465
Goldberg *et al*[34], 2003	0.435	0.224	0.846	0.014
Soran *et al*[35], 2008	0.627	0.303	1.295	0.207
Chaudhry *et al*[36], 2010	0.980	0.747	1.285	0.883
Koehler *et al*[13], 2018	0.693	0.508	0.944	0.020
Cleland *et al*[14], 2005	0.730	0.438	1.216	0.227
Koehler *et al*[7], 2011	0.987	0.699	1.395	0.942
Kotooka *et al*[8], 2018	0.778	0.360	1.682	0.523
Villani *et al*[37], 2014	0.556	0.204	1.512	0.250
Dendale *et al*[38], 2012	0.286	0.098	0.831	0.021
Galinier *et al*[40], 2020	0.965	0.742	1.255	0.791
Capomolla *et al*[41], 2004	0.704	0.235	2.106	0.530
Kulshreshtha *et al*[42], 2010	0.829	0.215	3.193	0.785
Kenealy *et al*[43], 2015	0.500	0.132	1.887	0.306
Dawson *et al*[44], 2021	0.727	0.294	1.797	0.490
Schwarz *et al*[46], 2008	0.571	0.178	1.833	0.347
	0.829	0.745	0.923	0.001



B

Effect of home telemonitoring on cardiovascular mortality in heart failure patients

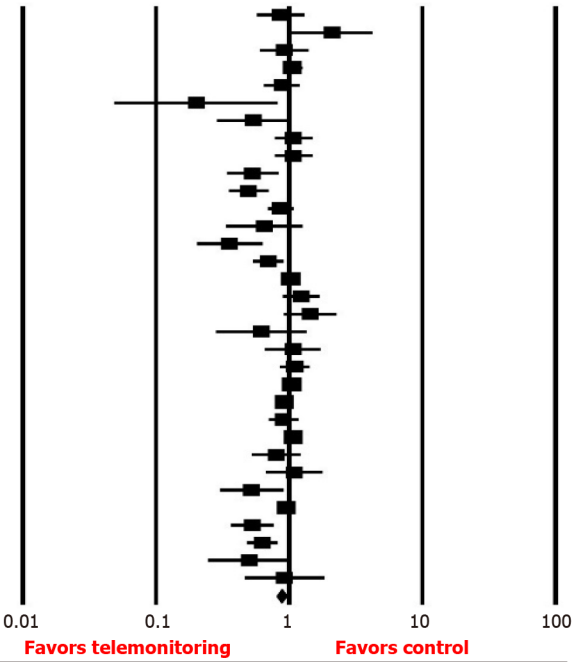
Study name	Risk ratio	Lower limit	Upper limit	*P* value
Comín-Colet *et al*[24], 2016	0.479	0.156	1.470	0.198
Giordano *et al*[29], 2009	0.621	0.355	1.086	0.094
Goldberg *et al*[34], 2003	0.441	0.209	0.929	0.031
Soran *et al*[35], 2008	0.528	0.200	1.394	0.197
Koehler *et al*[13], 2018	0.668	0.451	0.988	0.044
Cleland *et al*[14], 2005	0.633	0.328	1.221	0.173
Koehler *et al*[7], 2011	0.874	0.588	1.301	0.508
Kotooka *et al*[8], 2018	0.506	0.180	1.421	0.196
Capomolla *et al*[41], 2004	0.563	0.173	1.833	0.340
	0.660	0.537	0.810	0.000

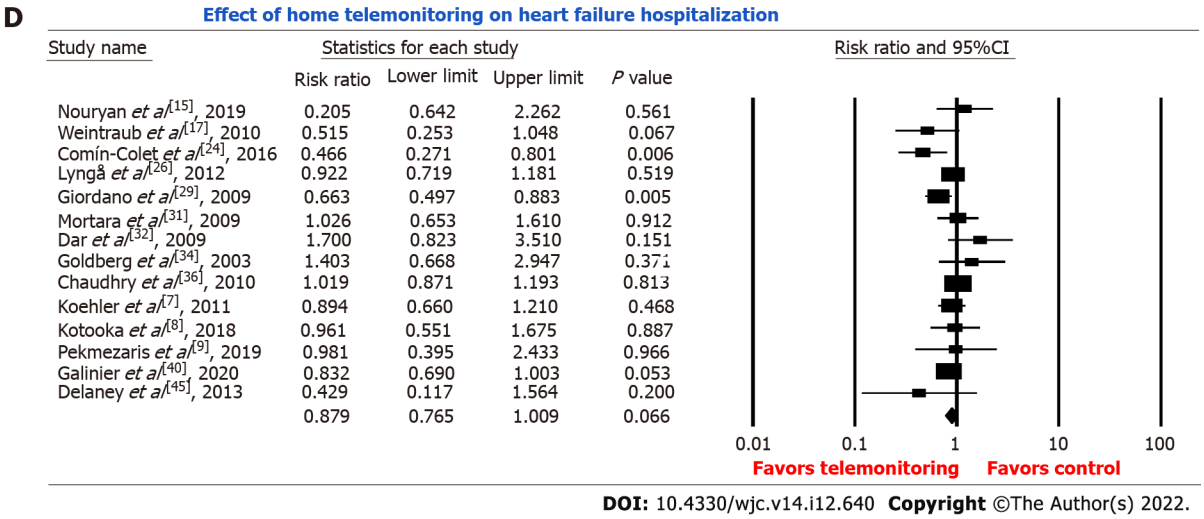


C

Effect of home telemonitoring on all-cause hospitalization in heart failure patients

Study name	Risk ratio	Lower limit	Upper limit	*P* value
Nouryan *et al*[15], 2019	0.861	0.572	1.295	0.472
Seto *et al*[16], 2012	2.111	1.059	4.207	0.034
Weintraub *et al*[17], 2010	0.916	0.603	1.391	0.680
Blum and Gottlieb[18], 2014	1.060	0.904	1.243	0.471
Dansky *et al*[19], 2008	0.883	0.652	1.195	0.419
Kashem *et al*[20], 2008	0.200	0.049	0.818	0.025
Benatar *et al*[21], 2003	0.542	0.291	1.007	0.053
Pedone *et al*[22], 2015	1.078	0.790	1.472	0.636
Wade *et al*[23], 2011	1.078	0.790	1.472	0.636
Comín-Colet *et al*[24], 2016	0.532	0.344	0.823	0.005
Olivari *et al*[25], 2018	0.496	0.355	0.692	0.000
Lyngå *et al*[26], 2012	0.867	0.699	1.074	0.192
Scherr *et al*[27], 2009	0.647	0.335	1.249	0.195
Antonicelli *et al*[28], 2008	0.359	0.206	0.623	0.000
Giordano *et al*[29], 2009	0.689	0.542	0.899	0.005
Ong *et al*[30], 2016	1.033	0.931	1.145	0.544
Mortara *et al*[31], 2009	1.231	0.904	1.676	0.188
Dar *et al*[32], 2009	1.435	0.918	2.241	0.113
Vuorinen *et al*[33], 2014	0.615	0.281	1.346	0.224
Goldberg *et al*[34], 2003	1.067	0.664	1.714	0.788
Soran *et al*[35], 2008	1.101	0.861	1.408	0.444
Chaudhry *et al*[36], 2010	1.040	0.941	1.149	0.446
Koehler *et al*[13], 2018	0.923	0.706	1.165	0.445
Cleland *et al*[14], 2005	0.803	0.531	1.213	0.297
Koehler *et al*[7], 2011	1.089	0.676	1.754	0.726
Kotooka *et al*[8], 2018	0.803	0.531	1.213	0.297
Pekmezaris *et al*[9], 2019	1.089	0.676	1.754	0.726
Villani *et al*[37], 2014	0.522	0.303	0.898	0.019
Galinier *et al*[40], 2020	0.948	0.837	1.073	0.398
Capomolla *et al*[41], 2004	0.525	0.366	0.753	0.000
Dawson *et al*[44], 2021	0.628	0.486	0.812	0.000
Delaney *et al*[45], 2013	0.500	0.249	1.004	0.051
Schwarz *et al*[46], 2008	0.923	0.467	1.825	0.818
	0.869	0.796	0.949	0.002





DOI: 10.4330/wjc.v14.i12.640

Figure 2 Forest plot showing the effect of home telemonitoring. A: On all-cause mortality; B: On cardiovascular mortality; C: On all-cause hospitalization; D: On heart failure hospitalization. CI: Confidence interval.

Heart failure hospitalization

The pooled estimate of the effect of telemonitoring on heart failure hospitalization compared to standard care in 14 studies with 5736 patients showed that telemonitoring had no effect on heart failure hospitalization (RR = 0.88, 95%CI: 0.77-1.01, *P* = 0.066) (Figure 2D). Our sensitivity analysis showed that the duration of telemonitoring influenced heart failure hospitalization. Analysis of 8 studies of six months or less duration showed no effect of telemonitoring on heart failure hospitalization (RR = 0.90, 95%CI: 0.65-1.23, *P* = 0.50). Conversely, our analysis of 6 studies of 12 mo or more duration showed that telemonitoring reduced heart failure hospitalization (RR = 0.85, 95%CI: 0.75-0.95, *P* = 0.004) (Table 3).

Sensitivity analysis showed that telemonitoring had no effect on heart failure hospitalization in patients recently discharged from the hospital. Analysis of 6 studies showed no effect on heart failure hospitalization (RR = 0.85, 95%CI: 0.61-1.21, *P* = 0.37). Conversely, our analysis of 8 studies that recruited patients that were not recently hospitalized showed that telemonitoring reduced heart failure hospitalization (RR = 0.86, 95%CI: 0.76-0.98, *P* = 0.02) (Table 3).

DISCUSSION

Our study demonstrated that home telemonitoring in heart failure patients was associated with reduced all-cause and cardiovascular mortality. These findings are consistent with previous meta-analyses of heart failure patients but inconsistent with some others[6,47-49]. Our sensitivity analysis showed that all-cause and cardiovascular mortality reduction was seen with short (six months or less) and longer (one year or more) telemonitoring. The decrease in mortality was also seen in studies that recruited recently hospitalized heart failure patients, which we defined as heart failure hospitalization within six weeks before the study, and those that did not. The decrease in mortality seen in-home telemonitoring could be due to early detection of clinical deterioration and early intervention.

Our study found that telemonitoring marginally decreased the all-cause hospitalization but did not decrease heart failure-related hospitalization. Some prior meta-analysis did not show reduced all-cause hospitalization[49-52] or heart failure-related hospitalization[52] with telemonitoring in heart failure patients. It is reasonable to expect that telemonitoring and early intervention will reduce hospitalization by detecting clinical deterioration early and early intervention. Conversely, telemonitoring could lead to more frequent hospitalization. This is because telemonitoring patients have more frequent contact with the healthcare system, and severe episodes of decompensation requiring hospitalization will be detected early. In this case, it will be expected that such patients will come to the hospital at the early stage of severe decompensation and that duration of hospitalization will be shorter. Unfortunately, length of hospital stay was inconsistently reported in the studies, preventing meta-analysis of telemonitoring on this outcome. However, our sensitivity analysis showed that while short-duration telemonitoring (6 mo or less) did not affect both all-cause hospitalization and heart failure hospitalization, long-duration telemonitoring (12 mo or more) showed a reduction in both all-cause and heart failure hospitalization. This may explain why some earlier meta-analyses with fewer studies showed a decrease in heart failure hospitalization with telemonitoring[49,53]. In the long run, telemonitoring may lead to early detection of clinical deterioration and early interventions that reduce hospitalization.

Some studies included scheduled nurse-led patient interaction or education as part of the intervention in addition to measuring and transmitting vital signs. The scheduled patient-nurse interactions included counseling if there is an acute change in health status, providing patient self-care education, adjusting medications using designated protocols, monitoring disease signs and symptoms, monitoring medication adherence, and addressing technical and social issues[10,13,14]. Three studies had the scheduled patient-nurse education and interaction in both the control and telemonitoring groups, while seven had the education and interaction in only the telemonitoring group. Thus, we thought that the additional intervention might partially explain the decrease in all-cause mortality with telemonitoring in those studies. However, our sensitivity analysis in the seven studies that received further intervention showed that telemonitoring with additional patient education did not affect heart failure hospitalization or mortality. This points that telemonitoring and not the additional interventions were likely responsible for the improved mortality seen in these studies.

Additionally, we had thought that home telemonitoring might be more helpful in reducing hospitalization and death in recently hospitalized or newly diagnosed heart failure patients who need support and education. However, our sensitivity analysis showed that home telemonitoring reduced all-cause and cardiovascular mortality in both studies that recruited patients recently hospitalized for heart failure and those that did not. Similarly, telemonitoring reduced all-cause hospitalization in both studies that recruited patients who were recently hospitalized for heart failure and those who had not. However, contrary to our expectation, home telemonitoring did not affect heart failure hospitalization in studies that recruited patients recently hospitalized for heart failure. However, this might reflect the small number of trials and participants rather than an actual lack of effect.

Limitations of the study

There are certain limitations to this study. First, home telemonitoring organizations sponsored some of the studies included in this review. This may have introduced a conflict of interest and bias in the results that were published. Secondly, many of the studies had incomplete reporting of their study methodology, making it difficult to classify them as high or low bias studies. Thus, the risk of bias in some of the studies was unclear. Thirdly, some of the sensitivity analyses involved a combination of a few small-sized studies. The small number of studies and participants may make it difficult to detect an effect, even if one exists.

Implications of the results for practice, policy, and future research

Prolonged home telemonitoring (12 mo or more) was associated with both decreased all-cause and heart failure hospitalization, unlike shorter duration (6 mo or less) telemonitoring. The implication for practice is that hospitals considering telemonitoring to reduce heart failure readmission rates may need to plan for prolonged telemonitoring to see the effect they are looking for. In addition, these hospitals or organizations will need to consider the cost of prolonged telemonitoring *viz-a-viz* the cost of rehospitalization. The opportunities for future research include a cost-benefit analysis of home telemonitoring in heart failure patients. There is also a need for more studies on the effect of telemonitoring on frequently hospitalized heart failure patients.

CONCLUSION

The results of this meta-analysis support the benefit of home telemonitoring using digital/broadband/satellite/wireless or blue-tooth transmission of physiological data in reducing all-cause and cardiovascular mortality in heart failure patients. In addition, this analysis also shows the benefit of prolonged telemonitoring (≥ 12 mo) in reducing all-cause and heart failure-related hospitalization.

ARTICLE HIGHLIGHTS

Research background

Home telemonitoring has been used as a modality to prevent readmission and improve outcomes for patients with heart failure.

Research motivation

However, while telemonitoring was beneficial in reducing hospital admission, all-cause mortality, and emergency room visits in some studies, others did not show such benefits. These differences in outcomes from multiple studies suggest that a careful analysis of study outcomes is needed to determine its aggregate benefit to heart failure patients.

Research objectives

This meta-analysis aims to determine the aggregate effect of telemonitoring on all-cause mortality, heart failure-related mortality, all-cause hospitalization, and heart failure-related hospitalization in heart failure patients.

Research methods

We conducted a systematic review and meta-analysis of 38 home telemonitoring randomized controlled trials involving 14993 patients.

Research results

Home telemonitoring in heart failure patients was associated with reduced cardiovascular [relative risk (RR) = 0.66, 95% confidence interval (CI): 0.54-0.81, $P < 0.001$] and all-cause mortality (RR = 0.83, 95%CI: 0.75-0.92, $P = 0.001$). Furthermore, telemonitoring was associated with decreased all-cause hospitalization (RR = 0.87, 95%CI: 0.80-0.94, $P = 0.002$) but not heart failure-related hospitalization (RR = 0.88, 95%CI: 0.77-1.01, $P = 0.066$). Interestingly, prolonged home telemonitoring (12 mo or more) was associated with both decreased all-cause and heart failure hospitalization, unlike shorter duration (6 mo or less) telemonitoring.

Research conclusions

Home telemonitoring reduces all-cause and cardiovascular mortality in heart failure patients. This study found that prolonged home telemonitoring (12 mo or more) led to both decreased all-cause and heart failure hospitalization, unlike shorter duration (6 mo or less) telemonitoring. The implication for practice is that hospitals considering telemonitoring to reduce heart failure readmission rates may need to plan for prolonged telemonitoring to see the effect they are looking for.

Research perspectives

The opportunities for future research include a cost-benefit analysis of home telemonitoring in heart failure patients. There is also a need for more studies on the effect of telemonitoring on frequently hospitalized heart failure patients.

ACKNOWLEDGEMENTS

We will like to thank Dr. Hycienth Ahaneku for reviewing the data analysis and methods section.

FOOTNOTES

Author contributions: Umeh CA, Torbela A, Saigal S, Kaur H, Kazourra S, Gupta R, and Shah S conceptualized and revised the study design; Umeh CA, Torbela A, Saigal S, Kaur H, and Kazourra S extracted the data; Umeh CA analyzed the data; Umeh CA, Torbela A, Saigal S, Kaur H, and Kazourra S wrote the first draft of the paper; Gupta R and Shah S reviewed and revised the paper; and all authors have read and approved the final manuscript.

Conflict-of-interest statement: All the authors report no relevant conflicts of interest for this article.

PRISMA 2009 Checklist statement: The authors have read the PRISMA 2009 Checklist, and the manuscript was prepared and revised according to the PRISMA 2009 Checklist.

Country/Territory of origin: United States

ORCID number: Chukwuemeka Anthony Umeh 0000-0001-6574-8595.

S-Editor: Wang JJ
L-Editor: A
P-Editor: Wang JJ

REFERENCES

1 **Bozkurt B**, Coats A, Tsutsui H. A Report of the Heart Failure Society of America, Heart Failure Association of the European Society of Cardiology, Japanese Heart Failure Society and Writing Committee of the Universal Definition of Heart Failure Consensus Conference. *European J Heart Fail* 2021 [DOI: 10.1002/ejhf.2115]

2 **Writing Committee Members**, Yancy CW, Jessup M, Bozkurt B, Butler J, Casey DE Jr, Drazner MH, Fonarow GC, Geraci SA, Horwich T, Januzzi JL, Johnson MR, Kasper EK, Levy WC, Masoudi FA, McBride PE, McMurray JJ, Mitchell JE, Peterson PN, Riegel B, Sam F, Stevenson LW, Tang WH, Tsai EJ, Wilkoff BL; American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology Foundation/American Heart Association Task Force on practice guidelines. *Circulation* 2013; **128**: e240-e327 [PMID: 23741058 DOI: 10.1161/CIR.0b013e31829e8776]

3 **Kolte D**, Abbott JD, Aronow HD. Interventional Therapies for Heart Failure in Older Adults. *Heart Fail Clin* 2017; **13**: 535-570 [PMID: 28602371 DOI: 10.1016/j.hfc.2017.02.009]

4 **Go AS**, Mozaffarian D, Roger VL, Benjamin EJ, Berry JD, Borden WB, Bravata DM, Dai S, Ford ES, Fox CS, Franco S, Fullerton HJ, Gillespie C, Hailpern SM, Heit JA, Howard VJ, Huffman MD, Kissela BM, Kittner SJ, Lackland DT, Lichtman JH, Lisabeth LD, Magid D, Marcus GM, Marelli A, Matchar DB, McGuire DK, Mohler ER, Moy CS, Mussolino ME, Nichol G, Paynter NP, Schreiner PJ, Sorlie PD, Stein J, Turan TN, Virani SS, Wong ND, Woo D, Turner MB; American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics--2013 update: a report from the American Heart Association. *Circulation* 2013; **127**: e6-e245 [PMID: 23239837 DOI: 10.1161/CIR.0b013e31828124ad]

5 **Jencks SF**, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med* 2009; **360**: 1418-1428 [PMID: 19339721 DOI: 10.1056/NEJMsa0803563]

6 **Inglis SC**, Clark RA, Dierckx R, Prieto-Merino D, Cleland JG. Structured telephone support or non-invasive telemonitoring for patients with heart failure. *Cochrane Database Syst Rev* 2015; **2015**: CD007228 [PMID: 26517969 DOI: 10.1002/14651858.CD007228.pub3]

7 **Koehler F**, Winkler S, Schieber M, Sechtem U, Stangl K, Böhm M, Boll H, Baumann G, Honold M, Koehler K, Gelbrich G, Kirwan BA, Anker SD; Telemedical Interventional Monitoring in Heart Failure Investigators. Impact of remote telemedical management on mortality and hospitalizations in ambulatory patients with chronic heart failure: the telemedical interventional monitoring in heart failure study. *Circulation* 2011; **123**: 1873-1880 [PMID: 21444883 DOI: 10.1161/CIRCULATIONAHA.111.018473]

8 **Kotooka N**, Kitakaze M, Nagashima K, Asaka M, Kinugasa Y, Nochioka K, Mizuno A, Nagatomo D, Mine D, Yamada Y, Kuratomi A, Okada N, Fujimatsu D, Kuwahata S, Toyoda S, Hirotani SI, Komori T, Eguchi K, Kario K, Inomata T, Sugi K, Yamamoto K, Tsutsui H, Masuyama T, Shimokawa H, Momomura SI, Seino Y, Sato Y, Inoue T, Node K; HOMES-HF study investigators. The first multicenter, randomized, controlled trial of home telemonitoring for Japanese patients with heart failure: home telemonitoring study for patients with heart failure (HOMES-HF). *Heart Vessels* 2018; **33**: 866-876 [PMID: 29450689 DOI: 10.1007/s00380-018-1133-5]

9 **Pekmezaris R**, Nouryan CN, Schwartz R, Castillo S, Makaryus AN, Ahern D, Akerman MB, Lesser ML, Bauer L, Murray L, Pecinka K, Zeltser R, Zhang M, DiMarzio P. A Randomized Controlled Trial Comparing Telehealth Self-Management to Standard Outpatient Management in Underserved Black and Hispanic Patients Living with Heart Failure. *Telemed J E Health* 2019; **25**: 917-925 [PMID: 30418101 DOI: 10.1089/tmj.2018.0219]

10 **Kalter-Leibovici O**, Freimark D, Freedman LS, Kaufman G, Ziv A, Murad H, Benderly M, Silverman BG, Friedman N, Cukierman-Yaffe T, Asher E, Grupper A, Goldman D, Amitai M, Matetzky S, Shani M, Silber H; Israel Heart Failure Disease Management Study (IHF-DMS) investigators. Disease management in the treatment of patients with chronic heart failure who have universal access to health care: a randomized controlled trial. *BMC Med* 2017; **15**: 90 [PMID: 28457231 DOI: 10.1186/s12916-017-0855-z]

11 **Page MJ**, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, McGuinness LA, Stewart LA, Thomas J, Tricco AC, Welch VA, Whiting P, Moher D. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021; **372**: n71 [PMID: 33782057 DOI: 10.1136/bmj.n71]

12 **Higgins JPT**, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA. Cochrane Handbook for Systematic Reviews of Interventions. Chichester: John Wiley & Sons, 2019

13 **Koehler F**, Koehler K, Deckwart O, Prescher S, Wegscheider K, Kirwan BA, Winkler S, Vettorazzi E, Bruch L, Oeff M, Zugck C, Doerr G, Naegele H, Störk S, Butter C, Sechtem U, Angermann C, Gola G, Prondzinsky R, Edelmann F, Spethmann S, Schellong SM, Schulze PC, Bauersachs J, Wellge B, Schoebel C, Tajsic M, Dreger H, Anker SD, Stangl K. Efficacy of telemedical interventional management in patients with heart failure (TIM-HF2): a randomised, controlled, parallel-group, unmasked trial. *Lancet* 2018; **392**: 1047-1057 [PMID: 30153985 DOI: 10.1016/S0140-6736(18)31880-4]

14 **Cleland JG**, Louis AA, Rigby AS, Janssens U, Balk AH; TEN-HMS Investigators. Noninvasive home telemonitoring for patients with heart failure at high risk of recurrent admission and death: the Trans-European Network-Home-Care Management System (TEN-HMS) study. *J Am Coll Cardiol* 2005; **45**: 1654-1664 [PMID: 15893183 DOI: 10.1016/j.jacc.2005.01.050]

15 **Nouryan CN**, Morahan S, Pecinka K, Akerman M, Lesser M, Chaikin D, Castillo S, Zhang M, Pekmezaris R. Home Telemonitoring of Community-Dwelling Heart Failure Patients After Home Care Discharge. *Telemed J E Health* 2019; **25**: 447-454 [PMID: 30036166 DOI: 10.1089/tmj.2018.0099]

16 **Seto E**, Leonard KJ, Cafazzo JA, Barnsley J, Masino C, Ross HJ. Mobile phone-based telemonitoring for heart failure management: a randomized controlled trial. *J Med Internet Res* 2012; **14**: e31 [PMID: 22356799 DOI: 10.2196/jmir.1909]

17 **Weintraub A**, Gregory D, Patel AR, Levine D, Venesy D, Perry K, Delano C, Konstam MA. A multicenter randomized controlled evaluation of automated home monitoring and telephonic disease management in patients recently hospitalized for congestive heart failure: the SPAN-CHF II trial. *J Card Fail* 2010; **16**: 285-292 [PMID: 20350694 DOI: 10.1016/j.cardfail.2009.12.012]

18 **Blum K**, Gottlieb SS. The effect of a randomized trial of home telemonitoring on medical costs, 30-day readmissions, mortality, and health-related quality of life in a cohort of community-dwelling heart failure patients. *J Card Fail* 2014; **20**: 513-521 [PMID: 24769270 DOI: 10.1016/j.cardfail.2014.04.016]

19 **Dansky KH**, Vasey J, Bowles K. Impact of telehealth on clinical outcomes in patients with heart failure. *Clin Nurs Res* 2008; **17**: 182-199 [PMID: 18617707 DOI: 10.1177/1054773808320837]

20 **Kashem A**, Droogan MT, Santamore WP, Wald JW, Bove AA. Managing heart failure care using an internet-based telemedicine system. *J Card Fail* 2008; **14**: 121-126 [PMID: 18325458 DOI: 10.1016/j.cardfail.2007.10.014]

21 **Benatar D**, Bondmass M, Ghitelman J, Avitall B. Outcomes of chronic heart failure. *Arch Intern Med* 2003; **163**: 347-352 [DOI: 10.1001/archinte.163.3.347]

22 **Pedone C**, Rossi FF, Cecere A, Costanzo L, Antonelli Incalzi R. Efficacy of a Physician-Led Multiparametric Telemonitoring System in Very Old Adults with Heart Failure. *J Am Geriatr Soc* 2015; **63**: 1175-1180 [PMID: 26031737 DOI: 10.1111/jgs.13432]

23 **Wade MJ**, Desai AS, Spettell CM, Snyder AD, McGowan-Stackewicz V, Kummer PJ, Maccoy MC, Krakauer RS. Telemonitoring with case management for seniors with heart failure. *Am J Manag Care* 2011; **17**: e71-e79 [PMID: 21504262]

24 **Comín-Colet J**, Enjuanes C, Verdú-Rotellar JM, Linas A, Ruiz-Rodriguez P, González-Robledo G, Farré N, Moliner-Borja P, Ruiz-Bustillo S, Bruguera J. Impact on clinical events and healthcare costs of adding telemedicine to multidisciplinary disease management programmes for heart failure: Results of a randomized controlled trial. *J Telemed Telecare* 2016; **22**: 282-295 [PMID: 26350543 DOI: 10.1177/1357633X15600583]

25 **Olivari Z**, Giacomelli S, Gubian L, Mancin S, Visentin E, Di Francesco V, Iliceto S, Penzo M, Zanocco A, Marcon C, Anselmi M, Marchese D, Stafylas P. The effectiveness of remote monitoring of elderly patients after hospitalisation for heart failure: The renewing health European project. *Int J Cardiol* 2018; **137-142**: CD007228 [PMID: 29506685 DOI: 10.1016/j.ijcard.2017.10.099]

26 **Lyngå P**, Persson H, Hägg-Martinell A, Hägglund E, Hagerman I, Langius-Eklöf A, Rosenqvist M. Weight monitoring in patients with severe heart failure (WISH). A randomized controlled trial. *Eur J Heart Fail* 2012; **14**: 438-444 [PMID: 22371525 DOI: 10.1093/eurjhf/hfs023]

27 **Scherr D**, Kastner P, Kollmann A, Hallas A, Auer J, Krappinger H, Schuchlenz H, Stark G, Grander W, Jakl G, Schreier G, Fruhwald FM; MOBITEL Investigators. Effect of home-based telemonitoring using mobile phone technology on the outcome of heart failure patients after an episode of acute decompensation: randomized controlled trial. *J Med Internet Res* 2009; **11**: e34 [PMID: 19687005 DOI: 10.2196/jmir.1252]

28 **Antonicelli R**, Testarmata P, Spazzafumo L, Gagliardi C, Bilo G, Valentini M, Olivieri F, Parati G. Impact of telemonitoring at home on the management of elderly patients with congestive heart failure. *J Telemed Telecare* 2008; **14**: 300-305 [PMID: 18776075 DOI: 10.1258/jtt.2008.071213]

29 **Giordano A**, Scalvini S, Zanelli E, Corrà U, Longobardi GL, Ricci VA, Baiardi P, Glisenti F. Multicenter randomised trial on home-based telemanagement to prevent hospital readmission of patients with chronic heart failure. *Int J Cardiol* 2009; **131**: 192-199 [PMID: 18222552 DOI: 10.1016/j.ijcard.2007.10.027]

30 **Ong MK**, Romano PS, Edgington S, Aronow HU, Auerbach AD, Black JT, De Marco T, Escarce JJ, Evangelista LS, Hanna B, Ganiats TG, Greenberg BH, Greenfield S, Kaplan SH, Kimchi A, Liu H, Lombardo D, Mangione CM, Sadeghi B, Sarrafzadeh M, Tong K, Fonarow GC; Better Effectiveness After Transition–Heart Failure (BEAT-HF) Research Group. Effectiveness of Remote Patient Monitoring After Discharge of Hospitalized Patients With Heart Failure: The Better Effectiveness After Transition -- Heart Failure (BEAT-HF) Randomized Clinical Trial. *JAMA Intern Med* 2016; **176**: 310-318 [PMID: 26857383 DOI: 10.1001/jamainternmed.2015.7712]

31 **Mortara A**, Pinna GD, Johnson P, Maestri R, Capomolla S, La Rovere MT, Ponikowski P, Tavazzi L, Sleight P; HHH Investigators. Home telemonitoring in heart failure patients: the HHH study (Home or Hospital in Heart Failure). *Eur J Heart Fail* 2009; **11**: 312-318 [PMID: 19228800 DOI: 10.1093/eurjhf/hfp022]

32 **Dar O**, Riley J, Chapman C, Dubrey SW, Morris S, Rosen SD, Roughton M, Cowie MR. A randomized trial of home telemonitoring in a typical elderly heart failure population in North West London: results of the Home-HF study. *Eur J Heart Fail* 2009; **11**: 319-325 [PMID: 19174529 DOI: 10.1093/eurjhf/hfn050]

33 **Vuorinen AL**, Leppänen J, Kaijanranta H, Kulju M, Heliö T, van Gils M, Lähteenmäki J. Use of home telemonitoring to support multidisciplinary care of heart failure patients in Finland: randomized controlled trial. *J Med Internet Res* 2014; **16**: e282 [PMID: 25498992 DOI: 10.2196/jmir.3651]

34 **Goldberg LR**, Piette JD, Walsh MN, Frank TA, Jaski BE, Smith AL, Rodriguez R, Mancini DM, Hopton LA, Orav EJ, Loh E; WHARF Investigators. Randomized trial of a daily electronic home monitoring system in patients with advanced heart failure: the Weight Monitoring in Heart Failure (WHARF) trial. *Am Heart J* 2003; **146**: 705-712 [PMID: 14564327 DOI: 10.1016/S0002-8703(03)00393-4]

35 **Soran OZ**, Piña IL, Lamas GA, Kelsey SF, Selzer F, Pilotte J, Lave JR, Feldman AM. A randomized clinical trial of the clinical effects of enhanced heart failure monitoring using a computer-based telephonic monitoring system in older minorities and women. *J Card Fail* 2008; **14**: 711-717 [PMID: 18995174 DOI: 10.1016/j.cardfail.2008.06.448]

36 **Chaudhry SI**, Mattera JA, Curtis JP, Spertus JA, Herrin J, Lin Z, Phillips CO, Hodshon BV, Cooper LS, Krumholz HM. Telemonitoring in patients with heart failure. *N Engl J Med* 2010; **363**: 2301-2309 [PMID: 21080835 DOI: 10.1056/NEJMoa1010029]

37 **Villani A**, Malfatto G, Compare A, Della Rosa F, Bellardita L, Branzi G, Molinari E, Parati G. Clinical and psychological telemonitoring and telecare of high risk heart failure patients. *J Telemed Telecare* 2014; **20**: 468-475 [PMID: 25339632 DOI: 10.1177/1357633X14555644]

38 **Dendale P**, De Keulenaer G, Troisfontaines P, Weytjens C, Mullens W, Elegeert I, Ector B, Houbrechts M, Willekens K, Hansen D. Effect of a telemonitoring-facilitated collaboration between general practitioner and heart failure clinic on mortality and rehospitalization rates in severe heart failure: the TEMA-HF 1 (TElemonitoring in the MAnagement of Heart Failure) study. *Eur J Heart Fail* 2012; **14**: 333-340 [PMID: 22045925 DOI: 10.1093/eurjhf/hfr144]

39 **Woodend AK**, Sherrard H, Fraser M, Stuewe L, Cheung T, Struthers C. Telehome monitoring in patients with cardiac

disease who are at high risk of readmission. *Heart Lung* 2008; **37**: 36-45 [PMID: 18206525 DOI: 10.1016/j.hrtlng.2007.04.004]

40 **Galinier M**, Roubille F, Berdague P, Brierre G, Cantie P, Dary P, Ferradou JM, Fondard O, Labarre JP, Mansourati J, Picard F, Ricci JE, Salvat M, Tartière L, Ruidavets JB, Bongard V, Delval C, Lancman G, Pasche H, Ramirez-Gil JF, Pathak A; OSICAT Investigators. Telemonitoring versus standard care in heart failure: a randomised multicentre trial. *Eur J Heart Fail* 2020; **22**: 985-994 [PMID: 32438483 DOI: 10.1002/ejhf.1906]

41 **Capomolla S**, Pinna G, La Rovere MT, Maestri R, Ceresa M, Ferrari M, Febo O, Caporotondi A, Guazzotti G, Lenta F, Baldin S, Mortara A, Cobelli F. Heart failure case disease management program: a pilot study of home telemonitoring *vs* usual care. *European Heart J Suppl* 2004; **6**: F91-F98 [DOI: 10.1016/j.ehjsup.2004.09.011]

42 **Kulshreshtha A**, Kvedar JC, Goyal A, Halpern EF, Watson AJ. Use of remote monitoring to improve outcomes in patients with heart failure: a pilot trial. *Int J Telemed Appl* 2010; **2010**: 870959 [PMID: 20508741 DOI: 10.1155/2010/870959]

43 **Kenealy TW**, Parsons MJ, Rouse AP, Doughty RN, Sheridan NF, Hindmarsh JK, Masson SC, Rea HH. Telecare for diabetes, CHF or COPD: effect on quality of life, hospital use and costs. A randomised controlled trial and qualitative evaluation. *PLoS One* 2015; **10**: e0116188 [PMID: 25768023 DOI: 10.1371/journal.pone.0116188]

44 **Dawson NL**, Hull BP, Vijapura P, Dumitrascu AG, Ball CT, Thiemann KM, Maniaci MJ, Burton MC. Home Telemonitoring to Reduce Readmission of High-Risk Patients: a Modified Intention-to-Treat Randomized Clinical Trial. *J Gen Intern Med* 2021; **36**: 3395-3401 [PMID: 33506388 DOI: 10.1007/s11606-020-06589-1]

45 **Delaney C**, Apostolidis B, Bartos S, Morrison H, Smith L, Fortinsky R. A randomized trial of telemonitoring and self-care education in heart failure patients following home care discharge. *Home Health Care Management & Practice* 2013; **25**: 187-195 [DOI: 10.1177/1084822312475137]

46 **Schwarz KA**, Mion LC, Hudock D, Litman G. Telemonitoring of heart failure patients and their caregivers: a pilot randomized controlled trial. *Prog Cardiovasc Nurs* 2008; **23**: 18-26 [PMID: 18326990 DOI: 10.1111/j.1751-7117.2008.06611.x]

47 **Yun JE**, Park JE, Park HY, Lee HY, Park DA. Comparative Effectiveness of Telemonitoring Versus Usual Care for Heart Failure: A Systematic Review and Meta-analysis. *J Card Fail* 2018; **24**: 19-28 [PMID: 28939459 DOI: 10.1016/j.cardfail.2017.09.006]

48 **Polisena J**, Tran K, Cimon K, Hutton B, McGill S, Palmer K, Scott RE. Home telemonitoring for congestive heart failure: a systematic review and meta-analysis. *J Telemed Telecare* 2010; **16**: 68-76 [PMID: 20008054 DOI: 10.1258/jtt.2009.090406]

49 **Clarke M**, Shah A, Sharma U. Systematic review of studies on telemonitoring of patients with congestive heart failure: a meta-analysis. *J Telemed Telecare* 2011; **17**: 7-14 [PMID: 21097564 DOI: 10.1258/jtt.2010.100113]

50 **McAlister FA**, Stewart S, Ferrua S, McMurray JJ. Multidisciplinary strategies for the management of heart failure patients at high risk for admission: a systematic review of randomized trials. *J Am Coll Cardiol* 2004; **44**: 810-819 [PMID: 15312864 DOI: 10.1016/j.jacc.2004.05.055]

51 **Clark RA**, Inglis SC, McAlister FA, Cleland JG, Stewart S. Telemonitoring or structured telephone support programmes for patients with chronic heart failure: systematic review and meta-analysis. *BMJ* 2007; **334**: 942 [PMID: 17426062 DOI: 10.1136/bmj.39156.536968.55]

52 **Pekmezaris R**, Tortez L, Williams M, Patel V, Makaryus A, Zeltser R, Sinvani L, Wolf-Klein G, Lester J, Sison C, Lesser M, Kozikowski A. Home Telemonitoring In Heart Failure: A Systematic Review And Meta-Analysis. *Health Aff (Millwood)* 2018; **37**: 1983-1989 [PMID: 30633680 DOI: 10.1377/hlthaff.2018.05087]

53 **Inglis SC**, Clark RA, McAlister FA, Stewart S, Cleland JG. Which components of heart failure programmes are effective? *Eur J Heart Fail* 2011; **13**: 1028-1040 [PMID: 21733889 DOI: 10.1093/eurjhf/hfr039]

Published by **Baishideng Publishing Group Inc**
7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA
Telephone: +1-925-3991568
E-mail: bpgoffice@wjgnet.com
Help Desk: https://www.f6publishing.com/helpdesk
https://www.wjgnet.com