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REVIEW

Remote Monitoring of Patients with Heart Failure: Characteristics of Effective Programs and Implementation Strategies

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Background and Objectives: Although the effectiveness of remote monitoring (RM) has been extensively studied, a focus on the post-pandemic time period is needed given the social changes and technology advances since this global event occurred.

Aim: The present paper responds to this need by reviewing post-pandemic research, to determine if RM of patients with heart failure (HF) using non-implantable devices represents an effective strategy.

Materials and Methods: A systematic literature review was conducted using PubMed and PMC, and the number of articles included was 19.

Results: A total of 3,031 patients participated in the 19 studies in this review, who had HF (NYHA class I–IV). Most frequent outcomes of interest were: rates of hospitalization (13 studies), death (5 studies), adherence to medications / healthy behaviors (4 studies), associated costs (4 studies), symptom intensity or frequency (3 studies), etc. The studies included in this review unanimously presented significant findings in favor of RM.

Conclusion: The post-pandemic research targeting RM of patients with HF presents more homogenous results to support this type of intervention, as compared to the heterogeneity of the pre-pandemic research.

Keywords: heart failure, remote monitoring, medical technology, prevention

Introduction

A modern-age pandemic traditionally associated with advanced age, heart failure (HF) has increasingly become prevalent among younger individuals as well.[1] Importantly, HF is a preventable condition and cause of disability and death.[2] As such, primary prevention programs may be applied to individuals at risk to develop HF, but secondary and tertiary prevention programs are also needed for patients who already received a HF diagnosis. For example, effective management of later stages of HF, involving adequate medication adjustments according to the guidelines and to patient's medical condition, may significantly lengthen HF life expectancy beyond the average 5 years for 50% of patients.[3] Unfortunately, despite its preventable nature, HF causes high rates of decompensation episodes and subsequent hospital readmissions—especially during the first six months following a hospital discharge.[4] Such an event characterized by congestion and/or poor perfusion 70–80% of times,[5] represents an emergency with a very high mortality and morbidity rate.[6] Besides diuretics—the backbone for the prevention of HF exacerbations, monitoring specific physiological parameters[7] and using this information for a timely adjustment of treatments represents the most effective preventive strategy.[8]

Remote monitoring (RM) as a type of telemedicine has been defined in terms of recording specific physiological parameters and transmitting real-time information to a medical facility or provider, with the general goal of early detection of HF-associated signs.[9,10] Advantages of using RM include that it: (a) offers possibilities for frequent /

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continuous monitoring of patients' medical data;[3,11] (b) allows recognition of signs of decompensation in their early stages;[3] (c) allows prompt intervention through monitoring patients' medical regimens based on patients' incoming data flow;[11] (d) surmounts physical distances between providers and patients who live remotely or who have difficulty travelling long distances for medical appointments;[12,13] (e) decreases the burden on the healthcare system by reducing the number of hospital visits,[14] (f) responds to the shortage of health care providers required to address the needs of an increasing number of patients with HF;[15] and last but not least, (g) empowers patients to have a role in their healthcare,[3,12,14] which in turn might help increase their self-care and treatment adherence.[11]

General Overview of Remote Monitoring

What Parameters May Be Monitored Through RM?

Blood pressure (BP) and heart rate (HR) are among the most frequently measured parameters. Hypertension often precedes and is associated to HF, given the LV hypertrophy associated to high BP and its consequences—diastolic dysfunction, increased LV and LA pressure, with long-term consequences such as impact on the right heart and venous stasis. As a result of these pathological mechanisms, BP may rise even more—a potential sign of HF progression related to increased filling pressure. However, low BP may also be associated with HF—specifically, with advanced stages of HF and poor outcomes.[16] Preserving BP in the normal ranges avoids organ hypoperfusion; also, measuring BP in patients with HF may help assess a potential autonomic nervous system imbalance, as well as a potential up-titration of HF medication.[17] In addition, nightly blood pressure dipping patterns have been associated with the risk of HF progression, and thus might be worth monitoring through RM techniques. For example, both reverse dipper/ riser and extreme dipper patterns have been associated with unpropitious consequences[18] and also, patients with a nocturnal systolic BP under 105 mm Hg (extreme dippers) were more likely to die within one year, compared to patients with values above this threshold.[19] Conversely, patients with a nocturnal diastolic blood pressure dip of less than 6 mm Hg had longer survival.[19] Among patients with HF, HR represents an important variable to monitor along with blood pressure. However, measurements may be altered by the presence of conditions such as atrial fibrillation, frequent atrial/ventricular premature beats, chronic pacing, and high-dose beta-blocker therapy.[20]

Congestion represents another frequently assessed parameter. Markers of congestion include body weight, impedance (which measures both intracellular and extracellular fluid as a reflection of peripheral fluid accumulation),[21] and edema. Some studies suggest that weight gain over 2 kilograms in one week among patients with HF can predict the need for a re-hospitalization within a week.[16] However, providers need to keep in mind that body weight may fluctuate based on food and fluid intake, as well as the usage of diuretics.[12] Consequently, some authors consider that weight change is not a sensitive enough measure for worsening HF. Minimally, weight should be measured in association with other parameters rather than be the only measured parameter. Fluid redistribution may be a more reliable measure,[9] and increased tissue water assessed through bio-impedance may be an earlier alarm sign compared to measurement of body weight[8]—allowing earlier interventions such as timely adjustment of the diuretics dose. Body impedance may be assessed in a non-invasive RM strategy, which has been proven to effectively impact all-cause death and hospitalization days among patients with HF.[22] As a cautionary note however, body impedance is unfortunately not recommended for patients with implanted pacemakers.[21] Also, recent studies suggest that measurement of intrathoracic impedance should be combined with other variables, since it has not been shown yet to have high sensitivity and specificity for HF decompensation.[23]

ECG data and atrial fibrillation (aFib) have also been tested as potential RM markers. ECG data represents the main tool for cardiovascular screening and it allows detection of functional and structural heart disease.[24] ECG abnormalities included, supraventricular and ventricular arrhythmias, atrioventricular and intraventricular conduction disturbances, myocardial ischemia, left ventricular overload (based on Romhilt Estes criterion), pacemaker rhythm, and prolonged QT[24] and also P-wave and T-wave abnormalities, reduced amplitude or widening of the QRS complex.[25] ECG information used as part of a multiparameter prediction model that collected ECG data, 3-axis accelerometry, skin impedance, skin temperature, and information on activity and posture to estimate the risk of HF decompensation; the model had good sensitivity (76% to 88%, depending upon the decision made based on alert) and 85% specificity in predicting hospitalizations for HF in the next 6 days.[26] Additionally, it has been estimated that approximately 20–40% of all patients with HF also experience atrial fibrillation (AFib)[27]—which may increase the risk of HF progression, given

that the two conditions share pathophysiological mechanisms such as left atrial enlargement, increased left ventricular wall thickness, and reduced left ventricular function.[28] When AFib is present in patients with HF the estimated mortality risk increases from 14% to about 57%.[29] *Yet* another candidate for RM in HF is nightly respiratory rate, which was the most accurate predictor of hospital HF re-admissions in a study that recorded nightly physiological information including breathing, pumping of the heart, and generalized body movements.[30]

What Types of Devices May Be Used for RM?

Several types of non-implantable devices have been described so far by the RM literature. First, wearable devices represent external sensors that capture continuous functional or physiological data and are connected to other devices which collect, transmit, and interpret data.[10] Wearable devices may include patches, and shirts that have sensors to record information and then send it remotely and real-time to a cloud or server.[11,31] Examples include Zio patch (an adhesive patch to monitor heart rhythm),[31] AliveCor (a handheld device that records single-lead ECG to detect atrial fibrillation which then transmits signals through a smartphone app),[32] or disposable chest patches which represent multiparameter sensors that collect information on a continuous basis.[26] Smart watches, as a special category of wearables, may be used to assess heart rhythm and to also transmit self-assessed data. For example, the Apple Heart Study used smart watches to detect irregular pulse, which was cross-validated against AFib on ECG.[33] A smartphone-based RM device (Luscii)[34] combined a smartphone app with self-assessment of BP, pulse rate, and body mass transmitted to a cloud-based server. Bluetooth RM was also used in a German study (Physio-Gate 1000, GTMED) to send oxygen saturation, blood pressure, and ECG information to a monitoring center.[35] Yet another category of RM devices are based on electric polarity/electromagnetic signals; examples include an under-the-mattress piezoelectric sensor that converts pressure into electrical signals, and is able to record physiological vibrations resulting from breathing, pumping of the heart, and generalized body movements.[30] More complex cardiovascular RM measurements offer a diversity beyond the traditional BP and HR measurements. For example, FibriCheck was described as an app that uses photoplethysmography through a smartphone camera, which is capable of detecting atrial fibrillation with an estimated accuracy similar to 12-lead ECG.[36] Digital stethoscopes with cloud-based systems are also available.[37] Also, the kinocardiograph (KCG) is an unobtrusive device, consisting of a chest sensor, which records local thoracic vibrations produced as a result of cardiac contraction and ejection of blood into the great vessels (seismocardiography), and a lower back sensor, which records micromovements of the body in reaction to blood flowing through the vasculature (ballistocardiography).[37] A sophisticated technology for assessing congestion is the ReDS (remote dielectric sensing), consisting of two sensors placed in a wearable vest and used to record information regarding the extent of lung fluid, through measuring the dielectric current across the thorax.[38] Zoll HFMS is a patch-based system that utilizes radiofrequency to measure thoracic fluid levels, heart rate, respiratory rate, activity posture, and heart rhythm.[39] Also, the BodiGuide Edema Monitor is a battery-operated device that contains sensors placed on the ankles to measure fluid retention at this level.[3] The Bodyport Cardiac Scale provides an innovative, noninvasive approach to obtain clinically relevant hemodynamic parameters; this scale is a physical platform on which the user stands with bare feet for ≈20 −30 seconds and it captures several physiological parameters including weight, ECG, impedance plethysmography, and ballistocardiography signals.[40]

The actual trend is to use a composite of multiple specific parameters for RM of patients with HF, given the assumption that the use of only one parameter or device is most likely insufficient.[21] For example, the HeartLogic System (Boston Scientific) is comprised of multiple sensors which allow measurement of nocturnal heart rate, intrathoracic impedance, presence of a third heart sound, respiration rate, and level of patient activity; based on these five parameters, HeartLogic creates an algorithm used to predict HF decompensation events.[41] Also, VitalConnect (VitalPatch) is a commercially available device consisting of a sensor worn on the chest that continuously tracks the ECG, skin temperature, and activity. Based upon the notion that activity level was associated to the risk of HF exacerbations, it was proposed that wearable cardioverter-defibrillators may be used also as RM systems to record activity level and resting position on patients HF with reduced EF.[42] The authors used the LifeVest wearable defibrillator and the Sentinel System, an analog device that merged several clinical measurements and submitted alerts once a predefined threshold was reached.[42]

In sum, the RM literature published before the pandemic provide information regarding a plethora of devices available for patients with HF. Along with these technology developments, the acceptability of such methods might

have increased within the patient population. Thus, many conditions auspicious for the development and implementation of RM programs to assist patients with HF may be in place. However, despite the large number of studies focused on RM that were conducted before the Sars-Cov2 pandemic, there has been a surprising heterogeneity of research findings regarding the effectiveness of RM in preventing episodes of HF acute episodes/ hospitalizations and/or HF related death.[43–45] While many studies and meta-analyses found significant associations between RM and positive outcomes such as a reduction of HF-related hospitalizations and HF-related mortality,[46–49] others reported no significant associations between RM practices and patient adherence to medical regimens (eg,, the SUPPORT-H2 study), hospital readmissions or days of hospitalization,[50–53] death rate,[50,51,54] or healthcare cost-effectiveness.[55] Among factors assumed to be associated to this heterogeneity of research findings are: (a) participant characteristics (eg, HF severity, comorbidities, psychological co-morbidities such as depression, and familiarity with modern technologies), (b) physiological parameters being used through RM (eg, weight change, arterial pressure, nightly movements, atrial fibrillation episodes, etc).; and (c) intervention procedures (how often were the RM data transmitted, who received these data, what were the guide-lines on using the RM data input to assist patients with HF, etc).[43] The SARS-CoV-2 pandemic brought an increased societal openness to using electronic means of remote communication, an increased willingness to acquire the necessary skills for doing so, and an increased availability of more sophisticated electronic devices for data recording and transmission.[56–58] While maintaining an interest for the effectiveness of RM in preventing HF exacerbations, hospitalizations, and death, studies on RM for HF published after the pandemic also focus on upcoming technology, patients' acceptance of RM, and program cost-effectiveness.

The present paper aims to explore whether the studies focused on RM for heart failure for which data collection occurred during or after the pandemic may provide a more definite answer to the question: "Is RM for patients with HF significantly associated to positive outcomes?". Given the above-mentioned characteristics of the post-pandemic period, our hypothesis is that studies included in this review will unequivocally indicate positive effects of RM for patients with HF. A second aim was to explore what physiological parameters could be assessed through RM, in order to allow an accurate prediction of HF exacerbations. A third aim of this paper was to determine which non-implantable devices, among the ones currently available, are most effective for RM of patients with HF. Last but not least, a fourth aim of this paper is to discuss literature-based, practical ways of applying RM techniques to effectively reduce the rates of HF acute episodes (for example, examine if there are specific groups of HF patients who would benefit more, what characteristics do effective RM programs have, etc).

Materials and Methods

Eligibility Criteria

Studies were retained if they were published starting with January 1 2022 and if the data collection occurred at least in part after January 1 2020. Also, studies were eligible if they focused on patients with HF and if at least one non-implantable device was used to remotely record specific physiological parameters. To be included, studies also had to be written in English. On the other side, studies were not included in this review if they focused on participants with other medical conditions (eg, lung disease, etc.), if they were literature reviews, meta-analyses or conference papers, if the intervention used implantable devices, if the paper was in a language other than English, andif full text could not be retrieved. A summary of the inclusion and exclusion criteria is presented in Table 1.

Search Strategy

In order to address the first question regarding the effectiveness of RM, an online search was conducted using PubMed and PMC, using the search words „[(remote dielectric) OR (wearable devices)) OR (noninvasive monitoring)) OR (non-implantable)) OR (digital biomarker)) OR (telemedicine)) AND (heart failure)]" of papers published starting with January 1 2022 and up until the moment the search was conducted (April 2025). The following filters were used: "Clinical Trial, Controlled Clinical Trial, Observational Study, Randomized Controlled Trial".

Table 1 Summary of the Study Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
1. Patients with HF 2. Remote monitoring of specific physiological parameters 3. Non-invasive devices used for RM. 4. Published starting with January 1st, 2022 5. Data collection occurred at least in part during the pandemic or onward (after January 2020). 6. English language	1. Patients with other medical conditions than HF. 2. Implantable RM devices. 3. Literature reviews, meta-analyses, conference papers. 4. Description of a RM device but no measurable outcome. 5. RM program included only phone/ video communication but no assessment of physiological parameters. 5. Full text could not be retrieved. 6. Language other than English.

Study Selection Process

The articles retrieved through PubMed and PMC were saved in list format and were first examined for duplicates, which were marked to be examined only once. After this initial step, the titles were screened within the list of search results as a first step of the screening process and based on the inclusion and exclusion criteria. The studies retained from this initial step were marked with a check mark; the abstracts of these studies were reviews as a second screening step, by two independent researchers (CIT and AMP). The two examiners were in agreement regarding the inclusion/ exclusion of most studies with the exception of four studies—which were discussed and a decision was reached for each one of these, determining the final number of studies saved to be examined in full.

Results

Study Selection

The PubMed search rendered 135 results and the PMC 292 results. After the 76 duplicates between the two searches were excluded, the remaining 351 records were screened for title and abstract. From among these, 294 records were excluded based on the exclusion criteria (eg, RM for respiratory failure or diabetes rather than HF, measurements taken in the hospital, invasive devices, participants were ICU patients or neonates, etc). and also 2 records could not be found in full text. The remaining 55 articles were examined in full, and 36 more articles were excluded (20 collected data before 2019–2020, 11 were theoretical/ no data, 3 were focused on patients with lung disease or atrial fibrillation, one paper used an implantable device, and in one paper no physiological parameters were monitored remotely and the intervention consisted of phone calls to patients). Thus, the final number of studies included in the literature review was 19. The study selection for the purpose of this review is described in Figure 1.

Study Characteristics

Patients Included in the Studies

A total of 3,031 patients with HF were included, with various degrees of disease severity (7 studies specifically mentioned they included NYHA IV patients as well), two studies included only NYHA I–III and another one only mentioned that patient participants were evaluated to have a low-moderate risk (the remaining ones used other severity criteria such as NT-proNP levels). Severity of HF might be a relevant variable regarding the effectiveness and/or cost-effectiveness of RM programs; some previous studies have argued that RM programs are most effective for lower-risk patients who need surveillance,[59] other authors argued that it is particularly patients with advanced HF/ reduced EF with a greater risk of decompensation who would benefit from RM programs.[60] None of the studies included in this review conducted separate analyses for NYHA IV class as compared to less severe HF categories. Regarding race/ ethnicity and SES, one study specifically focused on Native American participants with HF and ran a culturally sensitive intervention, while a few studies mentioned having experienced difficulties including low SES participants (mostly due to limited access to the required technology and/or willingness to use it).

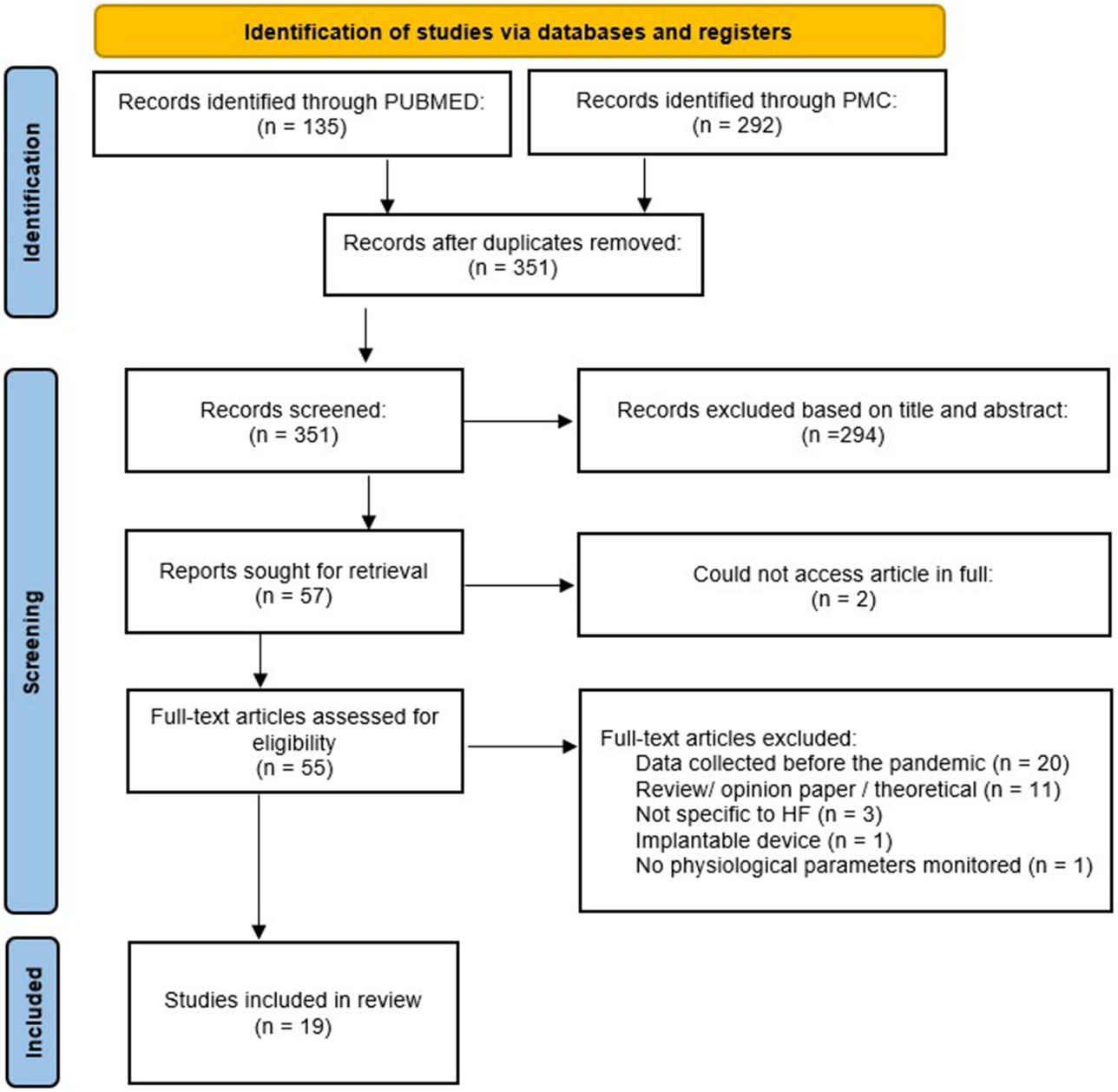

Figure 1 PRISMA flow chart for the systematic literature review.

Characteristics of RM Programs

The physiological parameters most often recorded were BP (10 studies), weight (10 studies), and heart rate (9 studies), suggesting that these are more readily available and cost-effective. Other variables measured were: symptom reporting including fatigue, chest pain and palpitations (7 studies), physical activity (4 studies), adherence to using the RM technology or to the medication regimen (4 studies), congestion, ankle edema, or lung fluid (4 studies), respiratory rate / pulmonary symptoms (cough, dyspnea) (2 studies), O_2 saturation (2 studies), and quality of life score, temperature, and ECG information (one study each).

The follow-up time interval varied between one month and 18 months, with most studies falling in the three- to six-months interval. Some studies reported continuous data collection (via wearable devices), other mentioned daily data collection, while yet other studies did not clearly specify the frequency of the RM data collection and analysis. Thus, it can be inferred that a frequency of at least daily data collection is efficient. For most studies, recorded data were sent to

a center and/or made available to a health care provider (nurse more often, but also physician in some cases). Some studies issued automated alerts based on pre-established thresholds—most of which also incorporated an action plan involving either contacting the patient, reviewing medication and dosage, referrals for early ambulatory appointments, or accessing emergency services as needed. Other studies used the recorded data to monitor patients' medical condition in association with a preestablished health care behaviors program that participants had to follow as part of the intervention (eg, a coaching app).

Technology Used

Out of the total of 19 studies, 13 used apps/ digital platforms (eg, ControlVit) and automated ways to record physiological data. Among the devices used to record and/or transfer data were: the ReDS, Zoll HFMS, Luscii, BodyPort Cardiac Scale, and VitalConnect systems—described in the overview of RM technology). Most studies used several modalities or one multifactorial modality (eg, VitalHealth digital platform, or Fitbit app plus individualized text messages, or Bodyport cardiac scale that combined multiple hemodynamic markers).

Study Outcomes and Results

The outcomes of interest were: rates of hospitalization (13 studies), death (5 studies), adherence to medications / healthy behaviors (4 studies), associated costs (4 studies), symptom intensity or frequency (3 studies), changes in physical activity performance as measured by the 6-minute walk test and cost effectiveness (2 studies each), and health related quality of life (one study).

A summary of findings for each one of these studies is presented in Table 2.

Discussion: Implementation of RM Programs for Patients with HF—Opportunities and Challenges

All studies included in this review displayed results in favor of RM practices, as compared to standard care. Only one study found significant differences regarding symptoms (ie, dyspnea and water retention) but no significant difference regarding the hospital visits and death over a 4-week period of time. At the same time, studies conducted for longer periods of time (between 3 and 18 months) did find hospital visits/ episodes of HF decompensation and death incidence to be lower for the RM study group. While the presence of episodes of HF decompensation and death incidence have been the most frequently used outcomes for studies involving RM for patients with HF, a trend was noticed of a more active role of patient participants in that RM was utilized not only to passively monitor patients' physiological state but also as a way to monitor their progress associated with some type of behavioral intervention (eg, engaging in a certain number of steps per day, etc). This type of research design, seems to respond to the increasingly numerous calls for patient empowerment and self-advocacy (for example though teaching them to adjust their diuretic medications in a manner similar to that in which patients with diabetes adjust their medication based upon their glucose levels).[61]

Our literature review reveals similar findings to previous studies, indicating that elements of successful RM programs include: (1) recording clinically meaningful physiological data, related to the pathophysiology of HF decompensations, (2) accurate measurements, (3) use clear guidelines on appropriate responses to the recorded data, (4) develop specific intervention algorithms to inform clinicians on how to adjust medical interventions in accord with the RM data input,[45,62] and (5) have a multidisciplinary approach, involving collaboration between administrators and decision-makers, physicians in multiple specialties (cardiologists, internists, geriatricians, rehabilitation doctors), as well as primary care physicians insurance companies, medical equipment technicians, and of course, patients themselves.[63]

The modality for data transmission represents an important aspect of RM programs. Safeguards for confidential data transmission to a coordinating center is a must.[8] Also, ideally, a RM system for patients with HF should incorporate the synchronous transfer to a medical center where trained medical personnel should be available to monitor these selected physiological measurements that indicate early HF decompensation so the crisis state can be averted.[12] At the same time, health care providers who monitor patient data would benefit from having access to comprehensive medical information, which would allow them to make informed decisions regarding these patients' medical regimens. This post-pandemic literature review revealed a multitude of RM technology available to be used.

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Table 2 Description of Studies Included in the Literature Review

Paper	Data Collection Dates	Type of Study	Outcomes	Participants	Intervention Arm	Control Arm	What was Assessed Through RM	Follow-up Interval	Specific RM Procedures	Results
Achury-Saldana et al, 2024 [1]	12. 2020 to 09. 2021	Retrospective randomized.	Hospital readmissions and death.	N=140 pts. with HF NYHA I–III	N=71 pts. ControlVit app + standard care.	N=69 pts. Standard care according to guidelines.	BP, weight, HR, and symptoms reporting.	6 mo.	Patient daily readings through ControlVit app sent to the hospital; real-time alerts could be issued based on readings.	RM had lower readmission rates (n=3) vs control (n=14), p=0.0081. RM had lower death rates (n=3) vs control (n=11), p=0.024.
Alvarez-Garcia et al, 2024 [2]	08. 2020 to 12. 2022	2-arm randomized, prospective	Composite of unplanned visit for ADHF, hospitalization for worsening HF, or death at 30 days after discharge.	N = 100 pts. Inclusion: hospitalized for HF diagnosis with fluid overload, NT-proBNP ≥ 400 pg/L or BNP ≥ 100 pg/L. Exclusion: height <155 or > 190cm, BMI > 22 or > 38 kg/m2, cardiogenic shock, LV device, etc.	N=50 pts. ReDS strategy with discharge based on specific recorded values.	N=5- pts. Routine care based on current medical practice.	Lung fluid content	1 mo.	Data recorded through ReDS sensors sent to a server was reviews by a healthcare provider and medication dosage was modified accordingly.	The ReDS group experienced a lower event rate, with an HR of 0.094 (95% CI: 0.012–0.731; P=0.003).
Bilbrey et al, 2024 [3]	05. 2023 to 08. 2023	Prospective, within-subjects	6-minute walk test HR QoL(12-Item Short-Form Health Survey)	N=75 pts. with low-moderate risk of a cardiac event	Pts. received two cardiac rehabilitation modalities: (1) a synchronous telehealth exercise training through videoconferencing; and (2) an asynchronous mobile health (mHealth) coaching app (RPH app).		HR App log data QoL questionnaire data	12 weeks	The study iPads were preloaded with the RPH app (a library of on-demand exercise videos with varying degrees of difficulty). HR and BP were monitored in real time. Feedback was also sent (eg, patient-rated difficulty for each exercise). Exercise difficulty was tuned accordingly.	50/62 (81%) participants' performance in the 6-minute walk test had improved. The average 12-Item Short-Form Health Survey's physical and mental summary scores improved by 2.7 (SD 6.47) points (95% CI 1.1–4.3) and 2.2 (SD 9.09) points (95% CI 0.1–4.5), respectively. No significant changes in HR.
Boehmer et al, 2024 [4]	After 2020	Prospective concurrent-control	Re-hospitalizations	N=522 pts Pts with HF NYHA I–IV, discharged from the hospital within the previous 10 days who had a HF event in the previous 6 months.	N=249 pts Wore heart monitoring system (Zoll HFMS system). Data sent to investigators for weekly reports.	N=245 pts Also wore monitoring system but investigators and patients were blinded to device data.	Thoracic fluid index HR Respiratory rate Activity Posture	90 days	Pts could activate trigger when they experienced symptoms. Weekly interviews between pts and investigators to decide if change in medication or an office/hospital visit are needed.	Intervention group: 38% lower HF hospitalization rate during (HR: 0.62; P=0.03).
Docherty et al, 2025 [5]	04.2019 to 07.2020 *	Prospective randomized	Kansas City Cardiomyopathy Questionnaire (KCCQ) and 6-minute walk distance	N=319 pts with HF NYHA I–III	Pts who wore accelerometers are a subset of the DETERMINE trial. Correlations between accelerometer data and the other measured variables were computed.		Accelerometer measures (eg, movement intensity while walking, total number of steps, etc).	14 weeks	Pts wore a waist-based accelerometer during 7-day periods at 3 points during the trial (baseline, week 8, and week 14).	The change from baseline to 16 weeks in accelerometer-measured physical activity correlated weakly with the change in KCCQ scores (Pearson r=0-0.18) and 6MWD (r=0.01–0.10).
Eberly et al, 2024 [6]	02.2023 to 08. 2023	Prospective randomized	Number of guideline-directed classes of drugs filled.	N=103 American Indian pts with HF with LVrEF.	N=21 pts received telehealth intervention initially. More pts. were crossed to intervention after 30 days until all pts received the intervention.		Number of medications filled. BP HR	30 days	Phone calls to discuss medication regimens. Blood work after every medication initiation. Weekly calls to assess drug tolerability, BP, HR.	Medication was filled significantly more often in the RM group (66.2% vs 13.1%) with prescription filled increase by 53% (OR 12.99; 95% CI, 6.87–24.53; P <0.001).

Fudim et al, 2025 [7]	07. 2021 to 06. 2022	Prospective observational	HF events (ie, unplanned administration i.v. diuretics or admission with a HF diagnosis).	N=329 pts with symptomatic HF. Exclusion: weight > 170 kg, chronic inotropic therapy, CKD.	N=329 pts Measurements at home by standing bare foot on the Bodyport Cardiac Scale for 20 sec per day.		A congestion index calculated from multiple hemodynamic markers.	Varied	Body port cardiac scale. Alerts were issues if the congestion index exceeded a threshold.	The congestion index and alert algorithm predicted 70% of the events compared with 35% with traditional weight-based rules.
Indraratna et al, 2022 [8]	02. 2019 to 03. 2020	Randomized controlled, 2 hospitals.	30-day hospital readmission. Cost effectiveness.	N=164 pts. with HF	N=81 pts. TeleClinica Care smart phone app (TCC) + Bluetooth + messages to promote healthy behaviors + usual care.	N=83 pts. Usual care.	Daily recordings of weight, BP, and physical activity.	6 mo.	Readings outside of thresholds were flagged to a monitoring team who discussed these values with patients' providers (cardiologists, GPs, nurses) for further management.	TCC was associated with a reduction in unplanned hospital readmissions (p=0.02) and cardiac readmissions (p=0.03).
Jafri et al, 2024 [9]	05. 2022 to 03.2023	Prospective observational	30-day readmission rates for HF exacerbations	N=90 pts with HF	3 groups: (a) N=10 pts only remote patient monitoring (RPM); (b) N=38 pts complete bundle (RPM, community paramedicine CCP and clinical pharmacist WPH) (c) N=42 pts partial bundles (2 out of 3).		BP Weight	Varied	HF bundle interventions, a RPM device, visits by an aligned community paramedic for in-home instruction and clinical escalation, and follow-up with a CCP and WPH.	The patients with the complete bundle had a readmission rate of 2.6% compared to 14.3% in the partial bundle and 20.0% in RPM alone.
Kagiyama et al, 2024 [10]	10. 2020 to 09. 2021	Prospective, observationalmulticenter.	Detection of changes in RM parameters before HF events.	N=72 pts. with HF Excluded: angina, valvular disease, severe arrhythmia, malignancy, respiratory/ cerebrovascular disease, end-stage renal failure.	All pts. received RM. The changes in recorded parameters from baseline to the pre-HF events (N=6 pts). were compared to those from baseline to the control period in pts. without HF events (N=66 pts).		Weight, BP, HR, t^0, O_2 saturation, ECG, and phonocardiogram.	Median follow-up 174 ± 35 days.	All measurements were wirelessly transferred; patients could also report subjective symptoms on a daily basis.	For patients with a HF event: presence of an increase in HR and diastolic BP, and a decrease in the interval from Q wave onset to the next heart sound.
Kitsiou et al, 2025 [11]	2020–2021 exact dates not specified	Prospective randomiozed	HF self-care subscale scores. Health behaviors. Health status, Beliefs about medication adheremce.	N=27 pts with HF NYHA I–III.	N=13 pts mHealth intervention (iCardia4HF)	N=14 pts Usual care	Vital signs symptoms tracking, and medication tracking	8 weeks	3 consumer mHealth apps and devices (Heart Failure Health Storylines, Fitbit, and Withings) with a program of individually tailored SMS text messages to improve HF self-care.	Subscale scores favored intervention group: maintenance (Cohen d=0.19, 95% CI –0.65 to 1.02), symptom perception (Cohen d=0.33, 95% CI –0.51 to 1.17), and self-care management (Cohen d=0.25, 95% CI –0.55 to 1.04), self-efficacy (Cohen d=0.68) and self-monitoring adherence (Cohen d=0.94).
Kokkonen et al, 2024 [12]	12. 2020 to 03. 2021	Pre-post intervention, non-randomized.	Number of pts. with at least 1 admission due to HF and hospital-related costs.	43 pts. with HF NYHA I–IV	All pts. treated with standard of care (SOC) for the first 6 mo. and then with a RM program + SOC for 6 mo.		Weight, BP, and symptom reporting via a digital platform.	6 mo. SC + 6 mo. SC + RM.	VitaHealth digital platform compared patients' readings to thresholds and generated alerts. Based on the alert, a nurse called the patient/ pts. Referred to a cardiologist.	ER visits decreased significantly during the RM period (by 44%). Mean hospitalization costs per patient decreased significantly with RM by 49%.

(*Continued*)

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Table 2 (Continued).

Paper	Data Collection Dates	Type of Study	Outcomes	Participants	Intervention Arm	Control Arm	What was Assessed Through RM	Follow-up Interval	Specific RM Procedures	Results
Mohapatra et al, 2025[13]	07. 2021 to 04. 2023	Prospective randomized	Level of adherence to using devices. The correlation between symptoms and activity tracker.	N=111 pts with HF NYHA I–IV	3 groups: Devices only (N=36 pts) Devices + mobile apps (N=35 pts) Devices + mobile apps + financial incentives (N=40 pts)		Step count, heart-rate, sleep, and active minutes, weight.	180 days	Devices: activity tracker, Body Trace scale Mobile apps *myHeartCare and Fitbit Charge*	The arm including the financial incentive had higher adherence to activity tracker (95% vs 72.2%, P=0.01) and weight (87.5% vs 69.4%, P=002). Fewer daily steps were associated with increased symptoms of HF (those responding "not really" vs "extremely" (P=0.001), and "moderately" vs "extremely" (P=0.005).
Ribeiro et al, 2025[14]	09. 2021 to 06. 2022	Prospective randomized	Rate of HF re-hospitalizations Rate of all-cause deaths.	N=127 pts with HF NYHA I–IV	N=70 pts (TMI group)	N=57 pts usual care	Weight, BP, HR, decompensation signs, treatment adherence	180 days	Structured phone support (STS), a self- care educational remote program (text messages), a 2- way channel for questions through sms to the case manager who could contact a cardiologist for based on clinical status.	26% of the TMI group had HF-related rehospitalizations versus 46% in usual care, rela tive risk [RR]=0.56, P<0.02. All-cause death or rehospitalizations occurred in 30% of the TMI group versus 47% in usual care (RR=0.63, P=0.04).
Scheenstra et al, 2025[15]	06. 2020 to 03/ 2024*	Prospective randomized	A composite endpoint of MACE (ie, cardiovascular death, myocardial infarction, stroke, hospitalization for heart failure or other life-threatening cardiac events, and earlier or repeated intervention.	N=394 pts with HF NYHA I–IV awaiting elective cardiac surgery / procedures.	N=197 pts online personalized teleprehabilitation program.	N=197 control group	RM of symptom progression on a weekly basis through a platform.	1 year (pre- and post-cardiac surgery).	Pts screened for modifiable risk factors discussed with a case manager these factors and underwent 5 behavior modifiication modules: functional exercise training, inspiratory muscle training, psychological support, nutritional support, and smoking cessation. Medfy BV platform was used.	Major cardiac events occurred in 33 patients (16.8%) in the intervention group and in 50 patients (25.5%) in the control group (difference 8.8%; 95% CI:0.7%-16.8%; P=0.032).
Tran et al, 2025 [16]	02. 2023 to 10. 2023	Randomized controlled, parallel-group	Minnesota Living with HF Questionnaire (MLHFQ) score. – health related quality of life.	N=170 pts with CHF NYHA II–III or NYHA IV in the last week or NT-proBNP > 300ng/mg and LVEF < 40%.	N=87 pts. reported daily to their monitoring doctor + usual care.	N=83 pts. Usual care	Weigt HR, BP Cough, fever, dyspnea, fatigue, chest pain, and palpitations.	6 mo.	For pts. with unstable readings: consult with the patient's cardiologist to provide final recommendations (eg, accessing a local laboratory for blood testing, seeking assistance from the nearest cardiology clinic or emergency service).	RM group had greater improvement in MLHFQ total scores than control group (mean change in MLHFQ score:-15.5–14.0 vs.-1.3–6.2; difference in change:-14.2 [95% confidence interval, CI:-17.5,-11.0]; p < 0.0001).

Vittorii et al, 2023 [17]		Prospective	Hospitalizations and ER visits due to HF.	22 pts. with HF	Pts. were ccompared to themselves before and after RM.		BP, HR, O_2 saturation, weight.	18.7 ± 8.8 mo.	Data sent to a center; threshold was used to elicit alarms which triggered appropriate response (eg, call, reporting to physician, alerting ER services).	RM was associated with a reduction of hospitalizations due to HF by 82% and of ER visits by 66%.
Yoon et al, 2024 [18]	10. 2022 to 01. 2023	Prospective randomized multicenter	Change in dyspnea symptom scores. Death, rehospitalization, and ER visit for HF.	N=77 pts. with HF NYHA I–IV, > 20 years, hospitalized for acute HF with symptoms or signs; with NT-proBNP ≥400 pg/mL or BNP ≥100 pg/mL	N= 38 pts The apps were connected to monitoring devices; pts. could enter information on vital signs, HF symptoms, diet, medications, and exercise regimen and received daily feedback or alerts on their input.	N = 38 pts. Pts. could only enter their blood pressure, heart rate, and weight using conventional, non-Bluetooth devices and could not receive any feedback or alerts from the app	Dyspnea, fatigue, ankle edema, and palpitations	4 weeks	The apps were automatically paired with Bluetooth-connected monitoring devices, including a BP monitor, weight scale, and body water analyzer. The intervention group received feedback and alerts from the app.	Dyspnea symptom score reduction significantly better in the intervention group than in the control group (mean –1.3, SD 2.1 vs mean –0.3, SD 2.3; P=0.048). Body water composition significantly improved within the intervention group (baseline level mean 7.4, SD 2.5 vs final level mean 6.6, SD 2.5; P=0.003). No significant differences regarding deaths and hospital visits.
Zaman et al, 2023 [19]	10. 2020 to 11. 2021	Retrospectivematched 1:1.	ER visits. Hospital admissions Associated costs.	N=146 pts.with HF NYHA I–IV Inclusion: newly diagnosed HF, LVEF < 50%.	N=73 pts. RM (Luscii platform) + self-reporting of symptoms and pill use + messages to clinicians + standard care.	N=73 pts. Standard care.	BP, HR, body mass.	3 months use of RM + 3 months follow-up.	Data sent to a cloud-based server, pts. could add text to their measurements. Clinicians could send messages to pts.	RM group had fewer ER visits (16 vs 46), less admissions (4 vs 21), and lower per-total costs than control.

Notes: * *Based on clinical trial data from trials.gov.*
Abbreviations: BP, blood pressure; HR, heart rate; QoL, quality of life.

Thus, health care providers have the luxury to choose the type of device and modality of transmission based upon the patient's clinical status and technological awareness, as well as institutional capability and resources[11] and in line with the trend toward a personalized approach to HF monitoring (eg, through taking into account factors such as severity of HF, geographical distance between patients and their providers, patient's capacity for self-management, etc).[42] The financial aspects (payments and insurance) of RM programs should also be considered and calls have been made for the necessity of a reimbursement code for RM.[14] The technology and infrastructure, and also the human factor incur costs to be taken into account.

Patient adherence represents a significant aspect of successful RM programs. Technology use depends on acceptance from patients.[64,65] Adherence was observed to impact the frequency of RM, which decreased with time.[66] Also, patients who displayed good adherence to RM were more likely to be in better health—possibly due to their increased adherence to their medication regimens as well.[66] Thus, it was particularly those patients struggling with their medical and lifestyle regimens that seemed to be more in need for RM. Other factors that may impact adherence include performance expectancy / self-efficacy with technology, effort expectancy, social influence / family status,[67] and concerns regarding privacy (especially among older patients).[65] Patients were more likely to use RM technology when they perceived that this way they can avoid multiple trips for medical consults and when they felt safe regarding the privacy of their data.[68] Mental health issues such as depression have also been linked to adherence. Unfortunately patients with depression have typically been excluded from research studies, based on the assumption that these patients are less likely to adhere to their prescribed RM and medication regimens.[43]

In addition to the exclusion of specific groups of patients as outlined above, a limitation of this review paper is that it was not able to focus on specific patient groups (eg, patients with reduced LVEF, patients with specific comorbidities, etc.), on specific outcomes (eg, days without hospitalizations, days alive, etc.), or to determine the relative contribution of each measured physiological parameter to the prediction model (eg, weight versus BP versus 3-lead ECG). Moreover, the present review is limited by a potential publication bias and lack of data on long-term outcomes.

Conclusion

The present literature review examined research data collected during or post pandemic to determine if RM programs for patients with HF are significantly associated to positive outcomes. While the literature published before the pandemic rendered mixed results, all the 19 studies being analyzed found that RM is associated with beneficial effects regarding re-hospitalizations and/or deaths, as well as outcomes such as increase engagement in health behaviors, medication adherence, symptom reporting, or health related quality of life.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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