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# Effectiveness of telemonitoring on clinical outcomes in patients with heart failure: a randomized clinical trial

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**Given the advancements in information technology in recent years, there is a possibility of implementing technology-based interventions to train, monitor clinical outcomes, and improve patients with heart failure (HF) 's self-care abilities. This study was conducted to determine the effectiveness of telemonitoring on clinical outcomes of patients with HF. In this parallel randomized clinical trial with blinded outcome assessment and data analysis, 136 patients with HF were allocated to intervention or control groups. The intervention group received structured telemonitoring, education, and weekly follow-up for eight weeks. Self-care (primary outcome) was measured using the European Heart Failure Self-Care Behavior Scale, and medication adherence (secondary outcome) was assessed using the Medication Adherence Rating Scale at baseline and four weeks post-intervention. A total of 136 patients were enrolled, and 123 completed the study (intervention = 61; control = 62). Baseline demographic characteristics and outcome measures were comparable between the two groups. Following the intervention, self-care scores significantly improved in the intervention group compared with the control group ($p < 0.001$), with a large effect size (Cohen's d = − 1.26; 95% CI − 1.64 to − 0.87). Medication adherence also showed a significant improvement in the intervention group compared with the control group after adjusting for baseline values ($p < 0.001$), with a moderate-to-large effect size (Cohen's d = 0.73; 95% CI 0.37 to 1.10). Structured telemonitoring was associated with improvements in self-care and medication adherence in patients with HF. These findings suggest that technology-based follow-up programs may support better patient engagement and clinical outcomes. Further studies are needed to confirm the long-term benefits and sustainability of these interventions.**

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**Keywords** Heart failure, Adherence, Self-care, Telehealth, Telemonitoring, Randomized clinical trial

Heart failure (HF) is a major health complication in developed and developing societies[1]. This disease causes a malfunction of the heart as a physiological blood circulation pump[2]. It is a lifelong condition in which the heart muscle cannot pump enough blood to meet the needs of the body tissues for nutrients and oxygen[3]. More than 64 million individuals worldwide are affected by this disease[4]. Moreover, approximately 6.2 million adults in the United States suffer from HF[5]. According to the available statistics, its current prevalence in Iran equals 3500 patients per 100,000 individuals[6]. The prevalence of this disease has increased due to factors such as the aging of the population, increased survival rate following coronary events, hypertension, and the advancement of diagnostic and surgical techniques[7].

This disease is mainly characterized by shortness of breath, fatigue, and fluid retention in the body[8]. Sufferers struggle with numerous physical symptoms that negatively impact their quality of life (QoL) and result in their frequent clinical visits[9]. HF treatment guidelines recommend pharmacological and non-pharmacological therapy to manage this disease[10]. A complex and diverse drug regimen is used in pharmacological therapy[11].

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The medications prescribed to these patients reduce the risk of hospitalization and mortality and lead to better management of HF symptoms[12]. Non-pharmacological therapy also plays a vital role in treating patients with HF[13]. Self-care is an effective non-pharmacological treatment method to prevent readmission and improve patients' health[14].

Self-care refers to a set of knowledge and skills for caring for oneself and is considered a means of maintaining individuals' health and self-esteem[15]. Self-care behaviors of patients with HF include consistent medication intake, adherence to medication regimens, following a diet, engaging in physical activity, monitoring weight, and managing fluid intake[16], among which medication adherence is considered one of the most imperative self-care behaviors[17]. The rate of medication adherence in patients with HF is low[18], which can increase the burden on healthcare systems and re-hospitalization and decrease patients' QoL[19]. This disease ranks first concerning re-hospitalizations. The causes of re-hospitalization include poor self-care, non-adherence to medication, insufficient patient training, lack of follow-up of patients after discharge, and symptom recurrence[20].

One of the most efficient approaches to reducing the re-hospitalization rate, controlling costs, increasing the access of patients with chronic disorders to care services, and reducing the incidence of these adverse outcomes is to use an innovative control and telemonitoring program, which provides care for patients beside their families and at their residences[21].

A recent systematic review and meta-analysis of mobile telemonitoring applications revealed that, while effects on mortality and QoL among HF patients varied across studies, these approaches significantly reduced hospitalization rates. This highlights the potential of mobile-based treatments to help with ongoing patient management[22]. To this end, various applications such as video conferencing, e-mails, smartphones, and other communication methods are used to transfer information[23]. Therefore, telemonitoring can provide an appropriate infrastructure for patient training and has the potential to improve self-care[24].

According to Riegel's Middle-Range Theory of Self-Care of Chronic Illness (2012), self-care in chronic diseases such as HF involves maintaining, monitoring, and managing one's health behaviors. This theoretical framework provides a foundation for understanding how structured interventions, such as patient education and telemonitoring, can enhance patients' ability to adhere to treatment, recognize early symptoms, and adjust daily behaviors, ultimately improving clinical outcomes and QoL[25].

Finally, one of the needs of patients with chronic heart disorders, of which HF is one of the most important cases, is to provide a long-term program for training and monitoring the physical condition of patients. Most studies, especially local ones, have taken a descriptive approach to self-care and medication adherence. Therefore, the need to implement telemonitoring as a constant intervention to assess patients' condition, examine their specific needs, and provide them with educational content is an essential intervention for patients with HF in Iran. To the best of our knowledge, there are limited Iranian studies investigating the effect of structured telemonitoring interventions on self-care and medication adherence in patients with HF, and none have examined a comprehensive remote education and follow-up program as implemented in this trial. Therefore, in the present study, we assessed the efficacy of telemonitoring on self-care as the primary outcome and medication adherence as the secondary outcome in patients with HF.

## Materials and methods

### Study design

This study was a single-masked, parallel randomized clinical trial (RCT) with a pre- and post-test design, in which the efficacy of telemonitoring in patients with HF was assessed in intervention and control groups (the latter receiving routine education). This study fully adhered to Consolidated Standards of Reporting Trials (CONSORT) guidelines (Supplementary Material 1) and was conducted in 2024. Participant recruitment was conducted from March 2024 to August 2024 at the HF clinics of Shahid Modarres and Imam Hossein Hospitals in Tehran.

### Setting and participants

The study population comprised individuals with persistent HF who were referred to the HF clinics at Shahid Modarres and Imam Hossein Hospitals in Tehran, met the inclusion criteria, and provided informed consent to participate. The sample size was calculated at approximately 61 individuals in each group using Pocock's formula $\left(n = \frac{\left(z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 \left(S_1^2 + S_2^2\right)}{(\bar{x}_1 - \bar{x}_2)^2}\right)$ and the data from Yanicelli et al.'s study[26], taking into account the first type error of 0.05 and 90% power. However, considering the 10% attrition probability, the sample size was calculated as 68 individuals (136 participants in total)

### Inclusion criteria

The inclusion criteria were as follows: age range of 18–80 years, chronic HF diagnosed and confirmed by a cardiologist, Class II and III HF based on the New York Heart Association (NYHA) functional classification, access to the Internet and a smartphone and confirmed ability to use it, which was assessed through a brief structured demonstration and orientation session, and absence of other chronic disorders such as cancer, depression, mental disability, or vision/hearing problems. A combination of patient self-reporting and medical record review was used to identify comorbidities.

### Exclusion criteria

The exclusion criteria included incomplete questionnaires obtained from the participants, encountering severe physical problems or death during the study, hospitalization for any reason or a change in the treatment process,

unwillingness to continue cooperation, and participation of members of the intervention or control group in other educational programs during the study.

## Randomization and blinding

A convenience sampling approach was used. Block randomization was used to randomly assign participants to intervention and control groups. The statistical consultant used blocks of four to create the random allocation sequence, resulting in 34 quadruple blocks for the entire sample of 136 people. To ensure appropriate concealment of the allocation sequence during participant enrollment, the allocation sequence was hidden in opaque envelopes.

Because of the nature of the telemonitoring intervention, participants and intervention providers were aware of group allocations, but the data analyst and outcome assessor were blinded. Thus, the study used a single-blind design.

## Primary and secondary outcomes

The primary outcome of the study was self-care, and the secondary outcome was medication adherence.

## Tools

Data collection tools included three questionnaires: a demographic information questionnaire, the European Heart Failure Self-Care Behavior Scale (EHFSCBS), and the Medication Adherence Rating Scale (MARS).

## Demographic information questionnaire

The study participants' demographic and clinical features were assessed using this questionnaire, which included questions about age, gender, marital status, education level, ejection fraction, and the frequency of hospitalizations for heart failure (HF).

## European heart failure self-care behavior scale (EHFSCBS)

It is a 12-item questionnaire based on a 5-point Likert scale. The range of responses varies from Totally true to Not true at all, and the range of scores is between 12 and 60[27]. In Negarandeh et al.'s study, the reliability of the EHFSCBS was evaluated using the test–retest method on 20 samples, and its interclass correlation was calculated as 0.85; this indicated that the questionnaire had a desirable level of reliability[28]. We assessed the questionnaire's face validity (qualitative) and content validity (quantitative and qualitative) separately and determined the reliability at 0.82 using Cronbach's alpha.

## Medication adherence rating scale (MARS)

This questionnaire comprises 10 dichotomous items with yes/no response options, scored as 0 for "no" and 1 for "yes." Items 1, 2, and 8 assess intentional and unintentional medication non-adherence, respectively. The total score ranges from 0 to 10, with scores of 0–5 indicating poor adherence and scores of 6–10 indicating high adherence[29]. Although standard cut-off points were used for descriptive purposes, medication adherence was analyzed as a continuous variable to preserve sensitivity and avoid information loss. Allahbakhshian et al. reported the reliability of the medication adherence instrument as 0.68 based on Cronbach's alpha and 0.89 using the test–retest method[21]. In the present study, face validity (qualitative) and content validity (quantitative and qualitative) were assessed separately, and reliability was assessed using Cronbach's alpha, which was 0.86.

## Research process

Patients were assigned to either the intervention or control group at the beginning of the research. Patients in the control group received standard care, which is routinely provided to HF patients in Iranian hospitals. This consisted of brief, unstructured verbal instructions from nurses or physicians at the time of hospitalization or discharge, covering general topics such as medication use, dietary advice, physical activity limitations, and follow-up appointments. No structured educational materials, messaging, or weekly phone calls were provided during the study period. Standard care was not standardized across patients and did not include systematic follow-up or tailored instructions.

In contrast, during the monitoring and follow-up phase, patients in the intervention group were given structured instructional materials. In a manner akin to a review study, a thorough literature review was used to develop the instructional content. Online databases, including PubMed, Scopus, Web of Science, and Google Scholar, were thoroughly searched for recent peer-reviewed studies and pertinent national and international clinical recommendations for managing HF. Heart failure, patient education, self-care, illness management, and nursing interventions were important keywords utilized in searches. Additionally, guidelines from reputable organizations, such as the European Society of Cardiology (ESC) and the American Heart Association (AHA), were examined.

A preliminary draft of instructional material covering key HF self-management topics was created based on the retrieved evidence. First, the content's qualitative face validity was assessed. A qualitative Content Validity Index (CVI) method was then used to evaluate content validity. Ten specialists in cardiovascular nursing and HF treatment evaluated the information at this point for relevance, clarity, and scientific accuracy. The necessary changes were made to improve the accuracy, comprehensiveness, and clarity of the educational materials, informed by experts' input. Patients were not involved in the content validation process.

To conduct the study, after recruiting patients who met the inclusion criteria, the researcher obtained oral and written consent from them and, soon after, administered the pre-test questionnaires to each participant. In order to avoid a long-term gap between the sample selection process and the completion of the pre-test questionnaires with the initiation of the intervention, the researcher conducted the study in smaller groups

due to the large sample size and the time-consuming sampling process and the possibility of dropping samples; 136 patients were divided into three groups of 48, 48, and 40 individuals (the smaller groups were multiples of four due to the quadruple blocking in the sampling method). After all qualified participants were recruited into smaller groups, they were assigned to the intervention and control groups in the order of their inclusion into the study, based on the blocking in the randomized sampling method and the study process initiated for them. Patients in the intervention group joined a channel on the "Bale" messaging platform to exchange information. For 8 weeks, every Saturday morning, patients received new HF educational content in a written file and an audio file on the channel, tailored to their ease of access. On Wednesdays, a limited number of common questions (3 or 4) related to the educational content at the beginning of the week were sent to each individual on the "Bale" messaging platform, and the patients had to respond to the questions until Friday night on the same messenger platform. The eight-week duration of the intervention was determined based on previous telemonitoring and telenursing studies in patients with HF, which suggest that short- to medium-term interventions (approximately 6–12 weeks) are effective for delivering educational content, supporting behavior change, and monitoring self-care outcomes while minimizing participant burden[28].

Afterward, the researcher evaluated patients' responses individually within a day and provided feedback on the "Bale" messenger platform, and if it was necessary to clarify the educational content for them, further explanations would be sent to them in the form of voice so that the educational content is clear (Supplementary Material 2). In this manner, group-based education sessions were conducted, and patients received individualized feedback on the educational content. In addition, the researcher conducted weekly follow-up phone calls with each patient. During these calls, patients were asked to report any HF-related symptoms experienced during the previous week, including shortness of breath, weight gain, lower extremity edema, palpitations, chest pain, nocturia, and other relevant symptoms. Patients were also asked to report their blood pressure, heart rate, body weight, and, in patients with diabetes, blood glucose levels. Based on the assessment of reported symptoms and vital signs, appropriate recommendations were provided to the patients during the same phone call. In cases of concerning or worsening symptoms, patients were advised to seek medical evaluation by a physician.

Patients in both the intervention and control groups completed the questionnaires again 4 weeks after the interventions were completed. To address ethical considerations, all educational content developed for the intervention group was compiled into an educational manual and provided to the control group participants after completion of the study.

### Ethical considerations

All participants provided written informed consent. Study participants received a clear articulation of the research background and aims from the research team. This study adhered to the ethical guidelines outlined in the World Medical Association Declaration of Helsinki and was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, with ethics code IR.SBMU.PHARMACY.REC.1401.247. The protocol was registered in the Iranian Registry of Clinical Trial Center with the following code: IRCT20230221057476N1.

### Statistical analysis

Statistical analysis was performed using SPSS version 19 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including mean and standard deviation for continuous variables and frequency and percentage for categorical variables, were calculated. Baseline demographic and clinical characteristics were compared between the intervention and control groups using the Chi-square test or Fisher's exact test for categorical variables and an independent t-test for continuous variables.

Within-group comparisons of self-care behavior and medication adherence scores were conducted before and after the intervention using paired t-tests. Between-group comparisons of outcome variables were performed using one-way ANOVA. Additionally, to compare post-intervention self-care and medication adherence scores between groups while adjusting for baseline values, analysis of covariance (ANCOVA) was applied. Effect size was calculated using Cohen's d with 95% confidence intervals (CI) to estimate the magnitude of the intervention effect. A per-protocol analysis was conducted, including only participants who completed the study ($n = 123$). A p-value of less than 0.05 was considered statistically significant.

## Results

### Participant flow

In the present study, 136 patients were enrolled, with 68 allocated to the control group and 68 to the intervention group. Six patients from the control group and seven patients from the intervention group were excluded. Ultimately, data from 123 patients were analyzed (Fig. 1: CONSORT Flowchart).

### Demographic characteristics

Initially, statistical analyses showed no significant differences between the two groups in demographic characteristics, indicating that the groups were homogeneous across the studied variables. Moreover, most study participants were male and married (Table 1).

### Primary outcome

The mean ± standard deviation of patients' self-care scores before the intervention was 29.91 ± 7.63 in the intervention group and 31.16 ± 7.05 in the control group. One-way ANOVA indicated no statistically significant difference between the two groups at baseline ($p = 0.350$).

After the intervention, the mean ± standard deviation of self-care scores was 24.01 ± 6.68 in the intervention group and 31.56 ± 6.72 in the control group. Within-group analysis using the paired t-test showed a significant

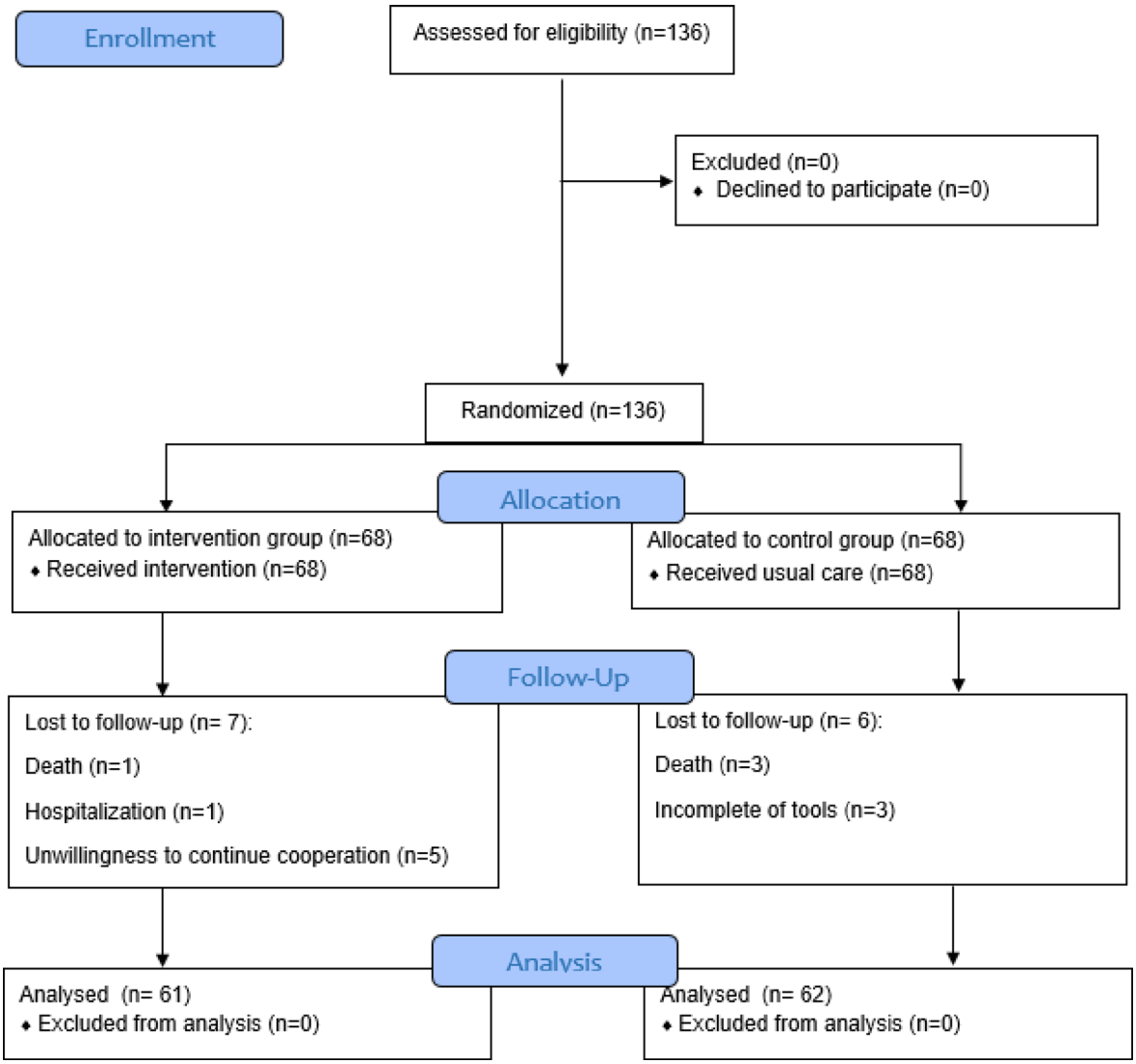


**Fig. 1**. CONSORT diagram.

improvement in the intervention group ($p = 0.001$), whereas no significant change was observed in the control group ($p = 0.646$).

To compare post-intervention self-care scores between groups while controlling for baseline values, analysis of covariance (ANCOVA) was performed. The results demonstrated a statistically significant difference between the two groups after adjustment ($p < 0.001$).

The magnitude of the intervention effect was large, with a Cohen's d of −1.26 (95% CI: −1.64 to −0.87), indicating a substantial improvement in self-care behavior in the intervention group compared with the control group (Table 2).

## Secondary outcome

The mean ± standard deviation of patients' medication adherence scores before the intervention was 2.85 ± 1.62 in the intervention group and 2.42 ± 1.42 in the control group, with no statistically significant difference between the groups at baseline based on one-way ANOVA ($p = 0.115$).

After the intervention, the mean ± standard deviation of medication adherence scores was 3.35 ± 1.57 in the intervention group and 2.22 ± 1.26 in the control group. Within-group analysis using the paired t-test showed a statistically significant improvement in medication adherence in the intervention group ($p = 0.019$), whereas no significant change was observed in the control group ($p = 0.339$).

To compare post-intervention medication adherence scores between the two groups while controlling for baseline values, analysis of covariance (ANCOVA) was performed. The results demonstrated a statistically significant difference between the groups after adjustment ($p < 0.001$).

The magnitude of the intervention effect was moderate to large, with a Cohen's d of 0.73 (95% CI: 0.37 to 1.10), indicating a meaningful improvement in medication adherence in the intervention group compared with the control group (Table 3).

| Variable | Classification | Intervention | | Control | |
|---|---|---|---|---|---|
| | | n. | % | n. | % |
| Age (year) | 20–35 | 9 | 14.8 | 7 | 11.3 |
| | 36–45 | 13 | 21.3 | 9 | 14.5 |
| | 46–55 | 4 | 6.6 | 17 | 27.4 |
| | 56–65 | 31 | 50.8 | 9 | 14.5 |
| | 66–75 | 4 | 6.6 | 20 | 32.3 |
| | total | 61 | 100 | 62 | 100 |
| | Mean± standard deviation | 13.08 ± 52.21 | | 15.26 ± 55.23 | |
| | Independent t-test | P=0.226 ; df=121 ; t= -1.218 | | | |
| Gender | Female | 16 | 26.2 | 21 | 33.9 |
| | Male | 45 | 73.8 | 41 | 66.1 |
| | Total | 61 | 100 | 62 | 100 |
| | Chi-squared test | P=0.433 ; df=1 ; 0.854 = $\chi^2$ | | | |
| Marital status | Single | 4 | 6.6 | 4 | 6.5 |
| | Married | 52 | 85.2 | 49 | 79 |
| | Widowed | 5 | 8.2 | 6 | 9.7 |
| | Divorced | 0 | 0 | 3 | 4.8 |
| | Total | 61 | 100 | 62 | 100 |
| | Chi-squared test | P=0.478; df=3; 3.172 = $\chi^2$ | | | |
| Educational level | Below diploma | 20 | 32.8 | 30 | 48.4 |
| | Diploma | 17 | 27.9 | 18 | 29 |
| | Academic education | 24 | 39.3 | 14 | 22.6 |
| | Total | 61 | 100 | 62 | 100 |
| | Chi-squared test | P=0.105; df=2 ; 4.652 = $\chi^2$ | | | |
| Number of hospitalizations due to heart failure | Mean± standard deviation | 1.07 ± 1.70 | | 0.97 ± 1.64 | |
| | Independent t-test | P=0.807; df=66 ; t=0.245 | | | |
| Ejection fraction | Mean± standard deviation | 12.41 ± 28.27 | | 10.75 ± 24.19 | |
| | Independent t-test | P=0.053 ; df=121 ; t=1.951 | | | |

**Table 1**. Demographic characteristics of patients with heart failure in two groups and the results of statistical tests.

| Group | Before | | After | | Paired t-test | | |
|---|---|---|---|---|---|---|---|
| | Mean | Standard deviation | Mean | Standard deviation | | | |
| Intervention | 29.91 | 7.63 | 24.01 | 6.68 | $p=0.001$ | df = 60 | t = 7.726 |
| Control | 31.16 | 7.05 | 31.56 | 6.72 | $p=0.646$ | df = 61 | t = 0.461 |
| One-way ANOVA/ ANCOVA (baseline adjusted) | F = − 0.881; df = 1; $p=0.350$ | | F = 48.36; df = 1; $p<0.001$[a] | | | | |
| Cohen's d (95% CI) | – | | − 1.26 (− 1.64 to − 0.87) | | | | |

**Table 2**. Mean and standard deviation of patients' self-care scores before and after interventions. [a]Adjusted for baseline.

| Group | Before | | After | | Paired t-test | | |
|---|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation | | | |
| Intervention | 2.85 | 1.62 | 3.35 | 1.57 | $p=0.019$ | df = 60 | t = 2.417 |
| Control | 2.42 | 1.42 | 2.22 | 1.26 | $p=0.339$ | df = 61 | t = − 0.964 |
| One-way ANOVA/ ANCOVA (baseline adjusted) | F = 2.53; df = 1<br>$p=0.115$ | | F = 16.45; df = 1<br>$p<0.001$[a] | | | | |
| Cohen`s d (95% CI) | – | | 0.73 (0.37 to 1.10) | | | | |

**Table 3**. The mean and standard deviation of medication adherence in patients before and after interventions. [a]Adjusted for baseline.

## Discussion

Comparing the mean self-care scores in the intervention group showed a significant improvement in patients' self-care; however, in the control group, the difference between pre- and post-test scores was not significant. Consistently, the study by Kiyarosta et al. (2020), entitled "The Effect of Using Smartphone Applications on Self-Care in Patients with Heart Failure," demonstrated that smartphone applications can enhance self-care, remote care, and telemonitoring in patients with HF[30]. Similarly, Negarandeh et al. (2019) reported that telemonitoring improved self-care behaviors in patients with HF[28]. Furthermore, Deckwart et al. (2023) showed that a holistic remote patient management approach can empower patients with HF and enhance their self-care behaviors. Based on these findings, it appears that patients who receive telemedical care demonstrate better adherence to heart failure self-care recommendations[31].

According to Riegel's Middle-Range Theory of Self-Care of Chronic Illness, our findings suggest that telemonitoring effectively supports patients' ability to maintain, monitor, and manage their health behaviors, which may explain the observed improvement in self-care scores[25,32].

By reviewing the studies, we can conclude that, as an effective way to control chronic diseases, especially HF, self-care has long been a focus of researchers and healthcare providers. Since HF is not treated like many chronic diseases, the primary purpose is to manage the patient's condition, which can be achieved through continuous care and monitoring and by promoting patient self-care behaviors. In the meantime, given the advances in technology and the valuable capabilities of information technology to improve the delivery of health services, this method can be used to monitor and manage patients' conditions and enhance their self-care. From the researcher's perspective, the consistency between the results of the aforementioned studies and the present study, as well as the observed improvement in self-care behaviors among patients in the intervention group, can be attributed to the nature of the training, the telemonitoring method, and the continuous follow-up of patients' conditions. The method employed in the present study for providing training, following up on care, and monitoring the treatment process represents one of its key strengths. It enables the delivery of services to patients regardless of geographic distance, maintains communication between patients and the care team, facilitates the supervision and monitoring of patients' conditions, and enhances patients' knowledge of disease-related self-care behaviors. Given that none of the reviewed studies contradict the present study's findings, telemonitoring may be effective in improving self-care among patients with HF.

Considering the sociocultural context of Iran, several factors may influence the effectiveness of telemonitoring interventions in patients with HF. Family support, literacy level, access to digital technology, and patient attitudes toward telehealth play an important role in adherence to self-care behaviors. In Iranian society, where family involvement in patient care has traditionally been high, remote monitoring can complement family support and increase patient engagement. Additionally, differences in digital literacy among patients may affect their ability to engage effectively with mobile interventions, underscoring the need for culturally appropriate educational content and instruction[33]. Although we did not directly measure family support or digital literacy in our participants, these factors are likely to have influenced engagement with telemonitoring and adherence to self-care behaviors in this Iranian population.

In the present study, medication adherence improved significantly in the intervention group after telemonitoring, whereas the control group experienced a decrease over the same period. These findings suggest that structured telemonitoring can help patients maintain or improve adherence, even in the context of chronic, complex conditions such as HF. The observed improvement, though moderate in effect size, highlights the potential clinical value of ongoing interaction, education, and follow-up in reinforcing medication-taking behaviors. In the review of previous studies, the only study with results that contrasted with the present study was that of Yanicelli et al. (2021), titled "Non-invasive Home Telemonitoring System for Heart Failure Patients"[26]. Several factors may influence the efficacy of interventions in improving medication adherence among patients in the intervention group. Although both studies were conducted over a 3-month period, Yanicelli et al.'s study analyzed data from 30 participants, whereas the present study included 123 individuals. With a larger sample size, the findings regarding medication adherence became significant in this study, suggesting that an even larger sample may be necessary to detect significant effects. Therefore, future studies are recommended to employ a larger sample and a longer intervention period. Notably, both studies found that medication adherence decreased over time in the control group, whereas patients in the intervention group did not experience such a decline, highlighting the potential impact of the researchers' interventions[26].

In the present study, the researcher's ongoing interaction with patients in the intervention group and their active engagement in self-care appeared to enhance medication adherence. Conversely, patients in the control group experienced a decrease in medication adherence over time, likely due to the absence of additional interventions. Furthermore, the study data showed that most patients in the intervention group had an academic education, whereas most patients in the control group had an education below the diploma level. Although the chi-square test indicated that the groups were homogeneous in terms of education, it should be noted that individuals with lower literacy levels are generally more vulnerable to deterioration in their health status.

Reviewing previous studies, the researchers also found results consistent with those of the present study. The results of Indraratna et al.'s (2022) clinical trial study titled "a smartphone-based model of care to support patients with cardiac diseases transitioning from hospital to the community (Tele Clinical Care)" have shown that one of the long-term benefits of Tele Clinical Care is improving medication adherence in HF patients[34]. The study by Najafi Ghezeljeh et al. (2018) showed that interventions and a smartphone-based application effectively improved medication adherence in patients with HF[21]. The study by Torkabad et al. (2020) showed that interventions improved medication adherence in patients with high blood pressure[35]. In Indraranta et al.'s study, the intervention implementation method and the follow-up duration differed from those in the present study. In the study by Najafi Ghezeljeh et al. (2017), although the target group and sample size were almost similar to the present study, and the approach in both studies was to investigate the efficacy of telemonitoring methods in

medication adherence, the intervention design and the implementation of the study were dissimilar[21]. The study by Torkabad et al. (2020) was conducted on another target group, which can justify the effectiveness of their intervention on medication adherence[35]. Due to the multiplicity of medications consumed and also the chronic and debilitating nature of the disease, HF patients may require broader interventions to change medication adherence behaviors. Based on the reviewed studies, further investigations are needed to assess the effects of telemonitoring on medication adherence in patients with HF.

It should be noted that the baseline mean medication adherence scores in both groups fell within the "poor adherence" range according to standard cut-off points. This finding is consistent with previous Iranian studies reporting generally low medication adherence among patients with chronic diseases[36]. However, dichotomizing adherence into "poor" and "high" categories may reduce sensitivity in detecting subtle changes. Therefore, in this study, adherence was primarily interpreted as a continuous variable.

### Limitations

This study has several limitations that must be considered. First, reliance on self-report measures of self-care and medication adherence may introduce reporting bias. Second, potential differences in digital proficiency among participants may have influenced their participation in the remote monitoring intervention. Third, although the posttest was conducted 4 weeks after the intervention, the relatively short follow-up period may not fully capture the long-term effects of remote monitoring on behavioral outcomes such as medication adherence. Additionally, the presence or absence of a persistent and competent caregiver may influence the results, which is beyond the researcher's control. Differences in participants' living conditions and access to equipment such as blood pressure monitors, scales, and glucometers may affect cooperation in weekly reporting. Thirteen participants were excluded during the study, which slightly reduced statistical power and potentially affected the results. A per-protocol analysis may overestimate the intervention effect compared with an intention-to-treat (ITT) analysis. Future studies are recommended to apply ITT principles and appropriate strategies for handling missing data. Participants were recruited through convenience sampling, which may limit the generalizability of the findings and introduce selection bias. Although random allocation to intervention and control groups helped mitigate concerns about internal validity, the results should be interpreted with caution when generalizing to broader populations of patients with heart failure. Furthermore, although the educational content was validated by experts, patients were not involved in the content validation process. Future studies may benefit from incorporating patient feedback during the development phase to enhance comprehensibility and patient-centeredness of educational materials. Because the control group did not receive structured weekly contact or messages, part of the observed effect in the intervention group may reflect an attention effect rather than the educational content or telemonitoring itself. Future studies may consider equalizing attention across groups to more accurately isolate the intervention effect. Finally, because the sample included only patients with NYHA class II and III HF, the results' generalizability to patients with NYHA class I and IV HF is limited.

## Conclusion

The present study suggests that structured telemonitoring, combined with education and regular follow-up, may improve self-care behaviors and medication adherence in patients with HF. Patients in the intervention group tended to show better self-care and enhanced medication adherence compared with the control group, highlighting the potential of technology-based interventions to support ongoing patient engagement and clinical management. While these findings are encouraging, the relatively short follow-up period and the study population's specificity necessitate cautious interpretation. Future research with longer-term follow-up, larger and more diverse patient populations, and consideration of contextual factors such as digital literacy and caregiver support is recommended to further evaluate the sustainability and generalizability of these interventions.

## Data availability

The datasets used and/or analyzed during the current study are available from the corresponding authors upon reasonable request.

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## References

1. Silavanich, V., Nathisuwan, S., Phrommintikul, A. & Permsuwan, U. Relationship of medication adherence and quality of life among heart failure patients. *Heart Lung.* **48** (2), 105–110 (2019).
2. Khorrami, E. R. & Zakeri, M. M. Factors affecting heart failure outcomes: A review article (2018).
3. Schwinger, R. H. G. Pathophysiology of heart failure. *Cardiovasc. Diagn. Ther.* **11** (1), 263 (2021).
4. Savarese, G. et al. Global burden of heart failure: A comprehensive and updated review of epidemiology. *Cardiovasc. Res.* **118** (17), 3272–3287 (2022).
5. Virani, S. S. et al. Heart disease and stroke statistics—2021 update: A report from the American Heart Association. *Circulation.* **143** (8), e254–e743 (2021).
6. Zahed Nakhjiri, L., Darvishpour, A., Pourghane, P. & Gholami Chaboki, B. Assessing the self-care status in older adults diagnosed with heart failure and hospitalized in the cardiovascular intensive care units of the public hospitals in the east of Guilan, Iran (2020). *Iran J. Nurs.* **34**(129), 67–81 (2021).
7. Jones, N. R., Roalfe, A. K., Adoki, I., Hobbs, F. D. R. & Taylor, C. J. Survival of patients with chronic heart failure in the community: A systematic review and meta-analysis. *Eur. J. Heart Fail.* **21** (11), 1306–1325 (2019).
8. Bragazzi, N. L. et al. Burden of heart failure and underlying causes in 195 countries and territories from 1990 to 2017. *Eur. J. Prev. Cardiol.* **28** (15), 1682–1690 (2021).
9. Arrigo, M. et al. Acute heart failure. *Nat. Rev. Dis. Primers.* **6** (1), 16 (2020).

10. Aghajanloo, A., Negarandeh, R., Janani, L., Tanha, K. & Hoseini-Esfidarjani, S. S. Self-care status in patients with heart failure: Systematic review and meta-analysis. *Nurs. open*. **8** (5), 2235–2248 (2021).
11. Aghakhani, N. et al. An investigation of arbitrary use of drugs in patients with congestive heart failure hospitalized in educational and treatment centers of urmia university of medical sciences. *Sadra Med. J.* **9** (1), 1–10 (2021).
12. McDonagh, T. A. et al. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: Developed by the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) With the special contribution of the Heart Failure Association (HFA) of the ESC. *Eur. Heart J.* **42** (36), 3599–3726 (2021).
13. Dugal, J. K. et al. Non-pharmacological therapy in heart failure and management of heart failure in special populations—A review. *J. Clin. Med.* **13** (22), 6993 (2024).
14. Kola, M. K. S., Jafari, H., Charati, J. Y. & Shafipour, V. Comparing the effects of teach-back method, multimedia and blended training on self-care and social support in patients with heart failure: A randomized clinical trial. *J. Educ. Health Promot*. **10** (1), 248 (2021).
15. Sayadi, A., Abedini, S., Abedini, S. & Kamal Zadeh, H. Self-care and health literacy in Iranian elderly: A review. *J. Mod. Med. Inform. Sci.* **9** (1), 80–89 (2023).
16. Ruppar, T. M., Cooper, P. S., Johnson, E. D. & Riegel, B. Self-care interventions for adults with heart failure: A systematic review and meta-analysis protocol. *J. Adv. Nurs.* **75** (3), 676–682 (2019).
17. Hood, S. R. et al. Association between medication adherence and the outcomes of heart failure. *Pharmacother. J. Hum. Pharmacol. Drug Therapy*. **38** (5), 539–545 (2018).
18. Kobraei, A. A., Adib-Hajbagheri, M., Karegar, K. & Miranzadeh, S. The effect of educational package on adherence to treatment and health literacy in patients with heart failure. *Feyz Med. Sci. J.* **26** (3), 302–310 (2022).
19. Wu, J-R. et al. A multi-component, family-focused and literacy-sensitive intervention to improve medication adherence in patients with heart failure–A randomized controlled trial. *Heart Lung*. **48** (6), 507–514 (2019).
20. Mehri, Z., Kheiry, F. & Rakhshan, M. Predictive influence of disease knowledge and hope on self-care behavior among adults with heart failure. *J. Educ. Health Promot*. **13** (1), 211 (2024).
21. Allahbakhshian, A. & Gholizadeh, L. Is beliefs about medication a factor in adherence to the medicine in patients undergoing coronary angioplasty? *Crescent J. Med. Biol. Sci.* (2020).
22. Del Rebolledo, M. et al. Effectiveness of mobile telemonitoring applications in heart failure patients: systematic review of literature and meta-analysis. *Heart Fail. Rev.* **28** (2), 431–452 (2023).
23. Faragli, A. et al. The role of non-invasive devices for the telemonitoring of heart failure patients. *Heart Fail. Rev.* **26** (5), 1063–1080 (2021).
24. Strandberg, S., Backåberg, S., Fagerström, C. & Ekstedt, M. Self-care management and experiences of using telemonitoring as support when living with hypertension or heart failure: A descriptive qualitative study. *Int. J. Nurs. Stud. Adv.* **5**, 100149 (2023).
25. Riegel, B., Jaarsma, T. & Strömberg, A. A middle-range theory of self-care of chronic illness. *Adv. Nurs. Sci.* **35** (3), 194–204 (2012).
26. Yanicelli, L. M. et al. Non-invasive home telemonitoring system for heart failure patients: a randomized clinical trial. *J. Telemed. Telecare*. **27** (9), 553–561 (2021).
27. Jaarsma, T., Strömberg, A., Mårtensson, J. & Dracup, K. Development and testing of the European heart failure self-care behaviour scale. *Eur. J. Heart Fail.* **5** (3), 363–370 (2003).
28. Negarandeh, R., Zolfaghari, M., Bashi, N. & Kiarsi, M. Evaluating the effect of monitoring through telephone (tele-monitoring) on self-care behaviors and readmission of patients with heart failure after discharge. *Appl. Clin. Inf.* **10** (02), 261–268 (2019).
29. Johnson, A. B. et al. Medication adherence rating of patients with hypertension in a tertiary care hospital. *World J. Pharm. Pharm. Sci.* **5** (2), 694–710 (2016).
30. Kiyarosta, N., Ghezeljeh, T. N., Naghashzadeh, F., Feizi, M. & Haghani, S. The effect of using smartphone applications on self-care in patients with heart failure. *Nurs. Pract. Today*. **7** (4), 311–321 (2020).
31. Deckwart, O. et al. Effects of remote patient management on self-care behaviour in heart failure patients: Results from the randomized TIM-HF2 trial. *Eur. J. Cardiovasc. Nurs.* **22** (8), 786–794 (2023).
32. Ho, P. M., Bryson, C. L. & Rumsfeld, J. S. Medication adherence: Its importance in cardiovascular outcomes. *Circulation* **119** (23), 3028–3035 (2009).
33. Negarandeh, R., Aghajanloo, A. & Seylani, K. Barriers to self-care among patients with heart failure: A qualitative study. *J. Caring Sci.* **10** (4), 196 (2020).
34. Indraratna, P. et al. A smartphone-based model of care to support patients with cardiac disease transitioning from hospital to the community (TeleClinical Care): Pilot randomized controlled trial. *JMIR mHealth uHealth*. **10** (2), e32554 (2022).
35. Torkabad, S. M., Bonabi, T. N. & Heidari, S. Effectiveness of smartphone-based medication reminder application on medication adherence of patients with essential hypertension: A clinical trial study. *J. Nurs. Midwifery Sci.* **7** (4), 219–225 (2020).
36. Rezaei, S., Vaezi, F., Afzal, G., Naderi, N. & Mehralian, G. Medication adherence and health literacy in patients with heart failure: A cross-sectional survey in Iran. *Health Lit. Res. Pract.* **6** (3), e191–e9 (2022).


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## Author contributions

Z.S.: Conceptualization, methodology, formal analysis, resources, data curation, writing-original draft, review and editing; M.BP.: Conceptualization, formal analysis, methodology, data curation, writing-original draft visualization; N.S.: Conceptualization, formal analysis, methodology, data curation, writing-original draft visualization; S.DN.: Conceptualization, methodology, data curation, visualization, review and editing; S.S.: Formal analysis, methodology, data curation, visualization, review and editing.

## Declarations

## Competing interests

The authors declare no competing interests.

## Additional information

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