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Pilot experience on utility of a digital home monitoring system to improve outcome in Indonesian heart failure patients

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Submitted to: JMIR Human Factors
on: September 28, 2025

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Abstract

Background: The risk of rehospitalization in heart failure (HF) patients has initiated various preventive efforts and to simultaneously improve the quality of life (QoL) of the patients. Self-monitoring at home is one option, and technology is increasingly being used for this purpose.

Objective: To reduce the risk of hospital readmission and maintain the QoL of HF patients through self-monitoring with the assistance of a digital application.

Methods: Starting with determining the need for HF services in National Cardiovascular Center Jakarta in 2024, an application called FineHeart was built and tested on HF patients in a quasi-experimental pilot study. After the User Acceptance Test was completed, HF patients were recruited as intervention group and control group participants. Quality of Life was measured with the Kansas City Cardiomyopathy Questionnaire (KCCQ) before and after the test. The readmission rate and 4 of the KCCQ parameters were analysed between the 2 groups.

Results: Of the 72 patients who met the inclusion criteria, thirty participated in the intervention group and thirty in the control group who had signed the consent form. In the intervention group, after 30 days, 22 people complied using the FineHeart application prototype (73.3%), six were readmitted (20%), and one died not because of HF (3.3%). In the control group, 10 were readmitted (33.3%), and three died because of HF (10%). There was a significant relationship between adherence to application usage and an increase in Quality-of-Life scores ($p<0.029$) and Overall Summary Score ($p<0.001$)), but not in Self-efficacy and Social Limitation Scores.

Conclusions: The findings of this study provide a potential benefit for HF patients to perform self-monitoring at home in collaboration with the hospital team by using FineHeart app. Patient adherence may reduce the risk of readmission and improve QoL. Multicenter studies on larger groups of patients are needed to confirm these preliminary results.

(JMIR Preprints 28/09/2025:84309)
DOI: https://doi.org/10.2196/preprints.84309

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to confirm these preliminary results.

Keywords

heart failure, self-monitoring, telehealth, digital application, readmission prevention, patient's quality of life.

Introduction

Heart Failure (HF) affects over 20 million people worldwide, with a 5-year mortality rate of 60-70% [1]. It is a major public health problem, particularly among the elderly, with a prevalence of 1-2% in developed countries [2]. This clinical syndrome has multiple underlying aetiologies, requiring clinical assessment and diagnostic tools to determine it cause [3]. Heart failure constitutes 1–2% of all hospital admissions and is the leading cause of hospitalization in the population >65 years, which leads it to be a significant health concern [4,5] and reduces quality of life (QoL) [6,7].

After being discharged from hospital there is a considerable risk of early readmission providing opportunities for the healthcare system, both official and informal, to reduce this risk [8]. There has been a consistent decline in the number of hospitalizations for heart failure over the years in other countries [9], but this remains a challenge in Indonesia [10,11].

Modern healthcare systems face a challenge in preventing hospital readmission [12]. The growing use of mobile technologies makes an effective post-discharge care strategy for heart failure patients possible [13]. This study aims to reduce the risk of hospital readmission and maintain the quality of life of heart failure patients through self-monitoring with the assistance of a digital application monitored by hospital staff.

Methods

This study used a mixed method: a qualitative study with in-depth interviews and document studies for system needs analysis and a quantitative study for assessing the acceptability and efficacy of digital application. The study was conducted from January 1st to November 30th, 2024.

The population for the qualitative study was health workers at the National Cardiovascular Center (NCVC) Harapan Kita Jakarta, Indonesia, including nurses and cardiologists. Information was collected to summarise the features needed in the application prototype. The development of the prototype was also based on the results of previous research with a machine learning method that found a prediction model for heart failure readmissions at the same site that was implemented in a prototype mobile application. Mobile health apps have been widely used in other countries [14-16].

The user acceptance test (UAT) was administered to both health officers and patients. The quantitative trial involved post-hospitalization patients with a primary diagnosis of I50 (ICD-10). Intervention group: participants filled out the Kansas City Cardiomyopathy Questionnaire (KCCQ) and were instructed on the use of the application prototype. A prototype link was given to patients/families or *caregivers*, equipped with user-friendly instruments: digital sphygmomanometers, digital body scales, and digital oximeters and were trained on how to use them. Patients filled out the application prototype according to the parameters requested daily for 30 days and could be monitored online by hospital nurses. If signs required a clinical response, indicated by the presence of green, yellow and red notifications on the application, they were followed up by nurses or cardiologists. After 30 days, participants were asked to fill out the KCCQ again. Control group: participants filled out the KCCQ questionnaire before discharge and 30 days after hospitalization. No monitoring was carried out at home; only the follow up schedule at the hospital was met as usual.

We used official and licensed 23 parameters of KCCQ from *Outcomes Instruments, LLC*,

which has been translated into Indonesian and has been tested for reliability and validity, focusing on four parameters that are closely related to *Public Health*: *Quality of Life*, *Self-efficacy, Social Limitation* and *Overall Summary Score.* All data obtained were analysed with Repeated measures ANOVA, multiple logistic regression and Chi-square test. Ethical approval was stated by the Research and Community Service Ethics Committee, Faculty of Public Health, Universitas Indonesia (Ket-718/UN2.F10.D11/PPM.00.02/2024) and by the Institutional Review Board of National Cardiovascular Center Harapan Kita (DP.04.03/KEP003/EC001/2024). The participants recruitment process was carried out with written informed consent.

Results

Qualitative study and development of mobile application prototype

The results of in-depth interviews with 10 respondents consisting of 3 heart specialists and 7 nurses, combined with document studies, showed that patient monitoring at home is still manual and inconsistent. Educational material documents do not cover all patient needs, monitoring materials do not cover the needs of health workers, patient profile data and health history are incomplete, and have not been adjusted to the NCVC Harapan Kita patient flow (Table 1).

Table 1. In-depth interviews and document studies result

Category	Subcategory	Existing condition	Improvement needed
INPUT	Facilities and infrastructure	This hospital already has a heart failure clinic managed by cardiologists and cardiac nurses with a system that is not yet integrated. Monitoring the health development of heart failure patients is only done every time the patient comes to the heart failure clinic or by phone by a nurse, and it is still not routine.	Monitoring is carried out continuously from a distance via media that can provide real-time information to hospital staff and provide a means of notification if there are signs of deterioration in condition.
		Recording the health progress of heart failure patients through the guidebook "*Catatan Harian Jantungku*" (My Heart Diary).	There is a system that can record all patient medical records without having to manually fill in the book by the patient/caregiver or hospital staff.
	Human resources	Two dedicated nurses only care for heart failure patients for services at the heart failure clinic.	There are dedicated nurses and administrative staff to monitor heart failure patients both online from home and in the outpatient department.
		There is no specific home care for heart failure patients. This care is still mixed with home care for other patients and depends on the availability of designated personnel.	Assigning staff who specialize in home visits for heart failure patients (primarily nurses and medical rehabilitation therapists).

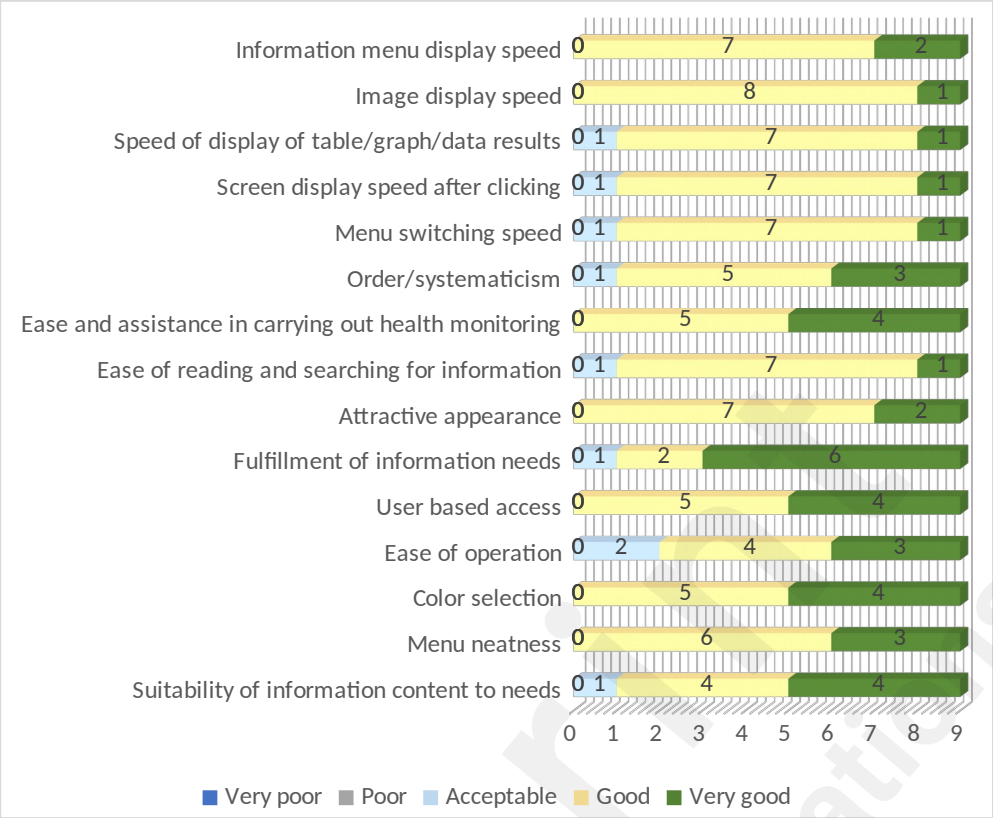
	Systems and technology	The direct registration system is in the outpatient registration section. The electronic medical data recording system is only done during check-ups at the outpatient department or heart failure clinic. The inpatient medical recording system is already electronic. There is no electronic recording for home monitoring.	There is an electronic recording system for self-monitoring at home that can be integrated with hospital medical records. The initial stage can be online data even though it is not yet integrated with hospital medical records.
PROCESS	Outpatient service flow in hospitals	Patients come to the HF clinic of their own free will, either according to the control schedule or if they have health problems, register at the counter and wait for their turn to be examined. The doctor checks and verifies previous medical data in the medical record, provides treatment and a control schedule or hospitalization if there are indications to be admitted, takes medication, and the patient goes home.	An online reminder is needed for patients to come to the hospital so that examinations and services can be carried out in one place and patients do not need to queue with other patients.
	Home service flow	Patients register for home care by calling the hospital. The hospital searches for available staff, makes an appointment for a visit, performs a physical examination, takes lab samples or performs a procedure, records it manually on paper, and reports it to the cardiologist.	There is a system that can notify hospital staff as a reminder of home visit schedules, or if there is a warning, staff can contact patients to offer home visits according to the doctor's instructions.
	Patient handbook	There is already a book: "*Catatan Harian Jantungku*" (My Heart Diary) which is held by the patient, filled in manually, and brought to the clinic during check-ups. Problems arise because the filling is irregular, and there is no historical data if the book is forgotten to be brought to the hospital.	There is a system that makes it easier for patients to fill in daily data, which can be read by hospital officers online without needing hard-copy books.
	Health education for patients at home	Available in "*Catatan Harian Jantungku*" (My Heart Diary) and the pocketbook "*Panduan Pasien Gagal Jantung*" (Heart Failure Patient's Guide).	Patients can read it online on the app, and it can be updated at any time by hospital staff.
OUTPUT	Feedback from patients at home	This relies on patients or caregivers contacting hospital staff by phone if their condition worsens or if they want a consultation rather than automatically.	It no longer depends on the patient's action but directly from the notification in the application.
	Response from hospital staff to patient's feedback	The hospital staff will respond via phone after getting patient information and consulting cardiologists. There is a time lag needed to get a response from the hospital	Shorten the time from notification to delivery of medical instruction information from doctor to patient.
	Report	Currently done manually in the patient visit report book at the HF clinic	No more manual. It is automatically displayed in the application, including the analysis.

By combining the required features with the implementation of a machine learning-based prediction model from previous research, a prototype of a mobile application called FineHeart was created.

Quantitative studies and prototype tests

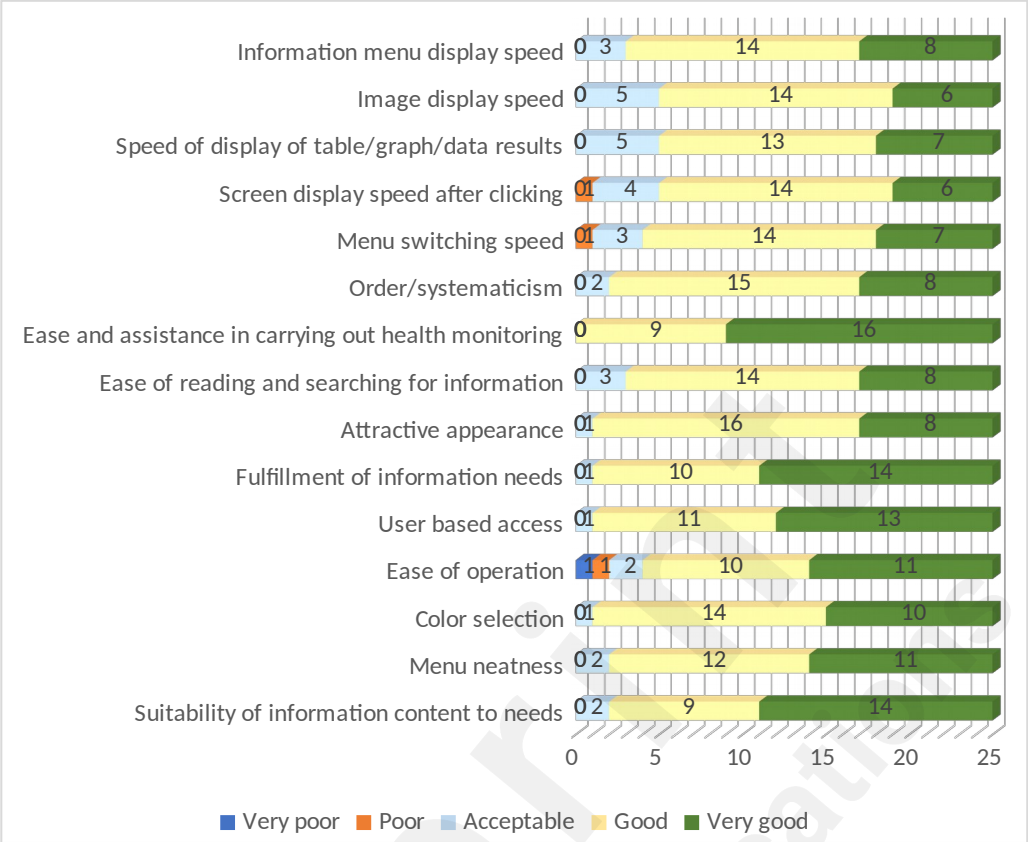
User Acceptance Test (UAT) in 9 health officers showed that the application prototype was complete and could be used by healthcare workers and patients at home. The results of UAT in 25 heart failure patients showed that patient acceptance of the FineHeart application prototype was predominantly good and very good (Fig 1 and 2).

Fig 1. User Acceptance Test result in health workers



The majority of the nine health workers UAT participants obtained good and very good results in all parameters.

Fig 2. User Acceptance Test result in HF patients.



The majority of the 25 patients who underwent UAT gave good and very good results in all parameters.

In the efficacy testing stage of the prototype application, of the 72 patients who met the inclusion criteria, eight were not willing to be the respondents; two were readmitted on day 1 post-discharge, one was a prolonged inpatient, and one died before the trial. Sixty patients signed the informed consent form. Thirty patients participated in the intervention group and thirty in the control group. Patients' characteristics are shown in Table 2. In the intervention group, after 30 days, out of 30 participants, 22 people complied using the FineHeart application prototype (73.3%), six were readmitted (20%), and one died not because of HF (3.3%). In the control group, 10 were readmitted (33.3%), and three died because of HF (10%) (Fig 3).

Table 2. Participants' baseline characteristicXVariables	**Intervention group (n=30)**	**Control Group (n=30)**	**p value**

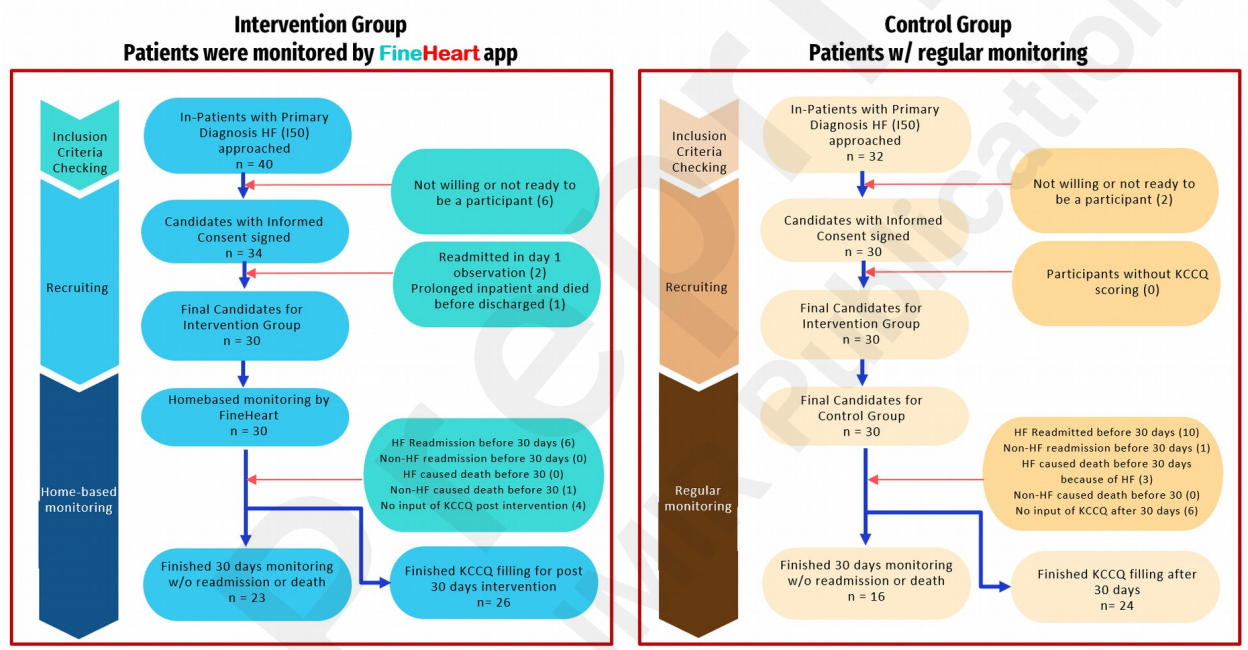
Age (years)	Mean (SD)	69.0 (4.3)	68.2 (4.1)	0.562
Gender	Male (%)	21 (70.0%)	18 (60.0%)	0.423
Marital status	Married (%)	27 (90.0%)	28 (93.3%)	0.634
Payer	Government health insurance (%)	29 (96.7%)	30 (100%)	0.317
Living partner	Yes (%)	30 (100%)	30 (100%)	1
Education	Elementary (%)	3 (10%)	9 (30%)	0.003
	Junior High School (%)	7 (23.3%)	0 (0%)	
	Senior High School (%)	14 (46.7%)	20 (66.7%)	
	University (%)	6 (20%)	1 (3.3%)	
Occupation	Unemployment (%)	16 (53.3%)	24 (80%)	0.067
	Self-employed (%)	5 (16.7%)	1 (3.3%)	
	Government/private sector employee (%)	9 (30%)	5 (16.7%)	
Religion	Muslim (%)	29 (96.7%)	27 (90%)	0.355
	Catholic (%)	1 (3.3%)	1 (3.3%)	
	Buddhist (%)	0 (0%)	2 (6.7%)	
Outpatient compliance	Regularly (%)	23 (76.7%)	12 (40%)	0.004
HF family history	Yes (%)	2 (6.7%)	4 (13.3%)	0.389
Smoking	Yes (%)	7 (23.3%)	9 (30%)	0.559
Alcohol	Yes (%)	1 (3.3%)	2 (6.7%)	0.554
Substance abuse	Yes (%)	1 (3.3%)	0 (0%)	0.313
Anemia	Yes (%)	2 (6.7%)	5 (16.7%)	0.228
Aortic valve disorder	Yes (%)	3 (10%)	0 (0%)	0.076
Asthma	Yes (%)	0 (0%)	0 (0%)	1
Cancer	Yes (%)	0 (0%)	0 (0%)	1
Arrhythmia	Yes (%)	4 (13.3%)	4 (13.3%)	1
Cerebrovascular accident/ stroke	Yes (%)	3 (10%)	1 (3.3%)	0.301
Coronary Artery Disease	Yes (%)	12 (40%)	7 (23.3%)	0.165
Dementia	Yes (%)	1 (3.3%)	0 (0%)	0.313
Diabetes Mellitus	Yes (%)	11 (36.7%)	17 (56.7%)	0.121
Dislipidemia	Yes (%)	7 (23.3%)	8 (26.7%)	0.766
Hypertension	Yes (%)	11 (36.7%)	12 (40%)	0.791
Liver disease	Yes (%)	0 (0%)	0 (0%)	1
Lung disease	Yes (%)	6 (20%)	2 (6.7%)	0.129
Protein Caloric Malnutrition	Yes (%)	0 (0%)	0 (0%)	1
Psychiatric Disorder	Yes (%)	0 (0%)	0 (0%)	1
Renal Disease	Yes (%)	11 (36.7%)	12 (40%)	0.791
Rheumatic disease	Yes (%)	4 (13.3%)	5 (16.7%)	0.718
Thyroid disease	Yes (%)	1 (3.3%)	1 (3.3%)	1
Cardiac devices	Yes (%)	1 (3.3%)	0 (0%)	0.313
Cardiac surgery	Yes (%)	1 (3.3%)	0 (0%)	0.313
CorAngioplasty	Yes (%)	4 (13.3%)	3 (10%)	0.686
Mechanical Ventilator	Yes (%)	0 (0%)	0 (0%)	1
ACE inhibitor	Yes (%)	10 (33.30%)	14 (46.7%)	0.291
ARB	Yes (%)	5 (16.7%)	8 (26.7%)	0.347
ARNI	Yes (%)	11 (36.7%)	4 (13.3%)	0.037

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SGLT2 inhibitor	Yes (%)	1 (3.3%)	0 (0%)	0.313
Diuretics	Yes (%)	23 (76.7%)	29 (96.7%)	0.023
Beta Blocker	Yes (%)	27 (90.0%)	27 (90.0%)	1
Spironolactone	Yes (%)	20 (66.7%)	24 (80%)	0.243
NYHA Classification	Class III (%)	15 (50%)	18 (60.0%)	0.492
	Class IV (%)	15 (50%)	12 (40%)	
LVEF	HFrEF (%)	25 (83.3%)	17 (56.7%)	0.041
	HFmEF (%)	1 (3.3%)	7 (23.3%)	
	HFpEF (%)	4 (13.3%)	6 (24%)	

ACE, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker; HF, heart failure; HFrEF, heart failure with reduced ejection fraction; HfmEF, heart failure with mid-range ejection fraction; HFpEF, heart failure with preserved ejection fraction; LVEF, Left Ventricular Ejection Fraction; NYHA, New York Heart Association; SGLT2, sodium-glucose cotransporter-2.

Fig 3. Participants recruitment process



The study included 30 HF patients for the intervention group and 30 patients for control group.

In terms of filling out the KCCQ post monitoring, from the intervention group, only 26 were filled in because one died and three did not fill in, while from the control group, only 24 were filled in because three died and three lost to follow-up. A comparison analysis between the intervention and control groups was performed for all KCCQ parameters (Table 3).

Table 3. KCCQ all scores in the intervention and control groups before and after 30 days of

post-discharge monitoring

Parameters	Intervention group (n=26)		Control Group (n=24)	
	Pre	Post	Pre	Post
Physical limitations (1a - 1f)	27.1±26.3	42.9±27.2	55.7±22.4	52.3±28.6
Symptom Stability (2)	42.5±31.6	59.6±33.2	68.3±30.0	52.1±31.2
Symptom Frequency (3,5,7,9)	34.0±23.3	53.5±29.5	49.7±25.3	53.9±30.2
Symptom Burden (4,6,8)	33.7±31.7	59.0±31.7	52.8±31.8	62.8±32.9
Total Symptom Score	33.9±26.1	56.2±29.6	51.3±27.6	58.4±31.0
Self-efficacy (9,10)	22.5±22.4	31.3±23.0	25.4±16.6	28.6±19.3
Quality of Life (12,13,14)	24.7±15.8	36.8±25.1	45.6±20.0	46.5±22.0
Social Limitation(15a-15d)	20.6±23.8	36.8±30.3	50.2±25.1	52.3±23.2
Clinical Summary Score	30.5±22.3	49.6±24.4	53.5±20.8	55.3±27.8
Overall Summary Score	26.6±15.3	43.2±22.6	50.7±18.0	52.4±23.6

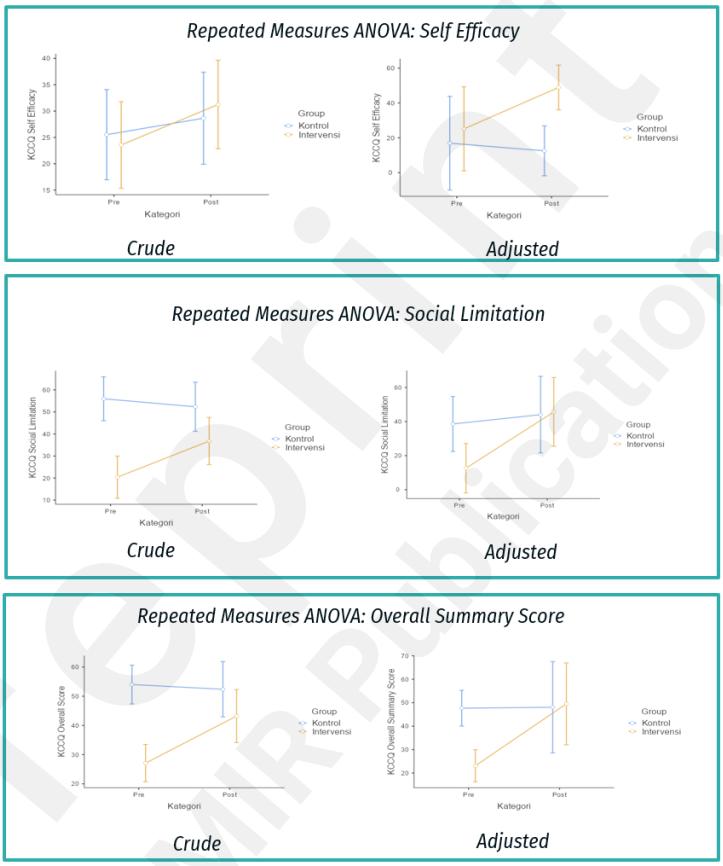
We conducted a multivariate analysis using Repeated Measures ANOVA to detect and adjust the influence of confounding variables on four outcomes: Self-efficacy, Social Limitation, Quality of Life, and Overall Summary Score. The analysis provides a comprehensive overview of the effects of the intervention by controlling for demographic, clinical, and social characteristic factors. The analysis for Quality of Life could not be continued due to the non-fulfilment of the assumption of variance homogeneity, as the results of the Levene test. Failure of this assumption indicates the existence of non-uniform variability among groups that can affect the validity of the analysis. However, the analysis of the other three outcomes still provides important information related to the effectiveness of the intervention and the influence of confounding factors so that it becomes a strong basis to support the validity of the research results (Table 4 & Fig 4).

Table 4. Analysis result of repeated measures ANOVA for Self-efficacy, Social Limitation and Overall Summary Score

Group	Category	Self-efficacy			Social Limitation			Overall Summary Score		
		Mean	SE	95% Confidence Interval	Mean	SE	95% Confidence Interval	Mean	SE	95% Confidence Interval
Crude										
Control	Pre	25.5	4.26	17.0–34.1	56	4.94	46.0 - 65.9	54	3.3	47.4–60.7
	Post	28.6	4.35	19.9–37.4	52.3	5.54	41.2 - 63.5	52.4	4.71	42.9–61.8
Intervention	Pre	23.6	4.09	15.3–31.8	20.4	4.75	10.9 - 30.0	27.1	3.17	20.7–33.5

	Post	31.3	4.18	22.8–39.7	36.8	5.32	26.1 - 47.5	43.2	4.52	34.1–52.3
Adjusted										
Control	Pre	16.9	12.22	-9.98–43.8	38.6	7.33	22.44-54.7	47.7	3.45	40.1-55.3
	Post	12.5	6.51	-1.8–26.9	44.1	10.22	21.56-66.6	48.1	8.83	28.6-67.5
Intervention	Pre	25.2	10.96	1.03–49.3	12.7	6.58	-1.83-27.1	23.1	3.1	16.3-29.9
	Post	48.9	5.84	36.08–61.8	45.6	9.17	25.46-65.8	49.5	7.92	32.1-67

Fig 4. Graph of repeated measures ANOVA for Self-efficacy, Social Limitation and Overall Summary Score



The results of the effect test between subjects showed that there was no significant difference between groups on the change in Self-efficacy score (F = 2.716, p = 0.128), in contrast to the Social Limitation score and Overall Summary Score, where there were several clinical factors that showed a significant influence.

Descriptive analysis showed that the intervention group had a higher trend of increasing Self-efficacy scores than the control group. Crudely, the mean Self-efficacy (Pre) score in the intervention group was 23.6 (95% CI: 15.3–31.8), increasing to 31.3 (95% CI: 22.8–39.7) after the intervention. In the control group, the average Self-efficacy (Pre) score was 25.5 (95% CI: 17.0–34.1) and

increased to 28.6 (95% CI: 19.9–37.4). After adjusting for the confounder variable, an increasing trend was still seen in the intervention group. The mean Self-efficacy (Pre) score in the intervention group was 25.2 (95% CI: 1.03–49.3), increasing to 48.9 (95% CI: 36.08–61.8) after the intervention. In the control group, the mean Self-efficacy (Pre) score decreased from 16.9 (95% CI: -9.98–43.8) to 12.5 (95% CI: -1.8–26.9) after the intervention.

Descriptive data also showed a difference in trend between the control group and the intervention for the Social Limitation score. Crudely, the mean Social Limitation (Pre) score in the control group was 56 (95% CI: 46.0–65.9) and decreased to 52.3 (95% CI: 41.2–63.5) after the intervention. In contrast, in the intervention group, the mean score increased from 20.4 (95% CI: 10.9–30.0) to 36.8 (95% CI: 26.1–47.5) after the intervention. After adjusting for the confounder variable, the upward trend in the intervention group remained more pronounced. The average Social Limitation (pre) score in the control group was 38.6 (95% CI: 22.44–54.7) and increased to 44.1 (95% CI: 21.56–66.6). In the intervention group, the mean score increased significantly from 12.7 (95% CI: -1.83–27.1) to 45.6 (95% CI: 25.46–65.8).

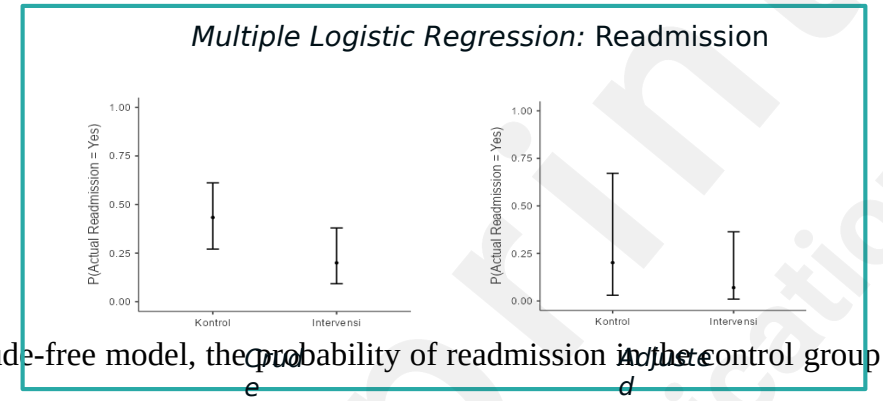
For Overall Summary Score, the mean crude score in the control group decreased from 54.0 (95% CI: 47.4–60.7) to 52.4 (95% CI: 42.9–61.8), while in the intervention group, the score increased from 27.1 (95% CI: 20.7–33.5) to 43.2 (95% CI: 34.1–52.3). After adjusting for the confounder variable, the control group showed a relatively stable mean score, from 47.7 (95% CI: 40.1–55.3) to 48.1 (95% CI: 28.6–67.5), while the intervention group experienced a significant increase from 23.1 (95% CI: 16.3–29.9) to 49.5 (95% CI: 32.1–67.0).

We also conducted multiple logistic regression analysis to evaluate the effect of application use on the incidence of hospital readmissions in heart failure patients, considering various confounder factors (Table 5 & Fig 5).

Table 5. Analysis result of multiple logistic regression for evaluating hospital readmission

Group	Crude		Adjusted	
	Probability	95% Confidence Interval	Probability	95% Confidence Interval
Control	0.433	0.2708-0.612	0.2014	0.03015-0.672
Intervention	0.2	0.0927-0.379	0.0702	0.00987-0.364

Fig 5. Graph of multiple logistic regression for evaluating hospital readmission



In the crude-free model, the probability of readmission in the control group was 43.3% (95% CI: 27.08–61.2%), while in the intervention group it was lower, which was 20% (95% CI: 9.27–37.9%). After adjustment, the probability of readmission in the control group decreased to 20.1% (95% CI: 3.02–67.2%), while in the intervention group it became 7.02% (95% CI: 0.99–36.4%).

A Chi-square test was carried out on the impact of application adherence with changes in 4 parameters of the KCCQ score. At this stage, the effect of patient adherence using the FineHeart application prototype was analyzed during self-monitoring at home. Patients were considered "high adherence" if they completed the application prototype according to the patient's characteristics at least 60% of the monitoring days (18 days). If it was less than 60%, it was considered "low adherence" (Fig 6 and Table 5).

Fig 6. Impact of the adherence to FineHeart app usage to readmission and the change of KCCQ score.

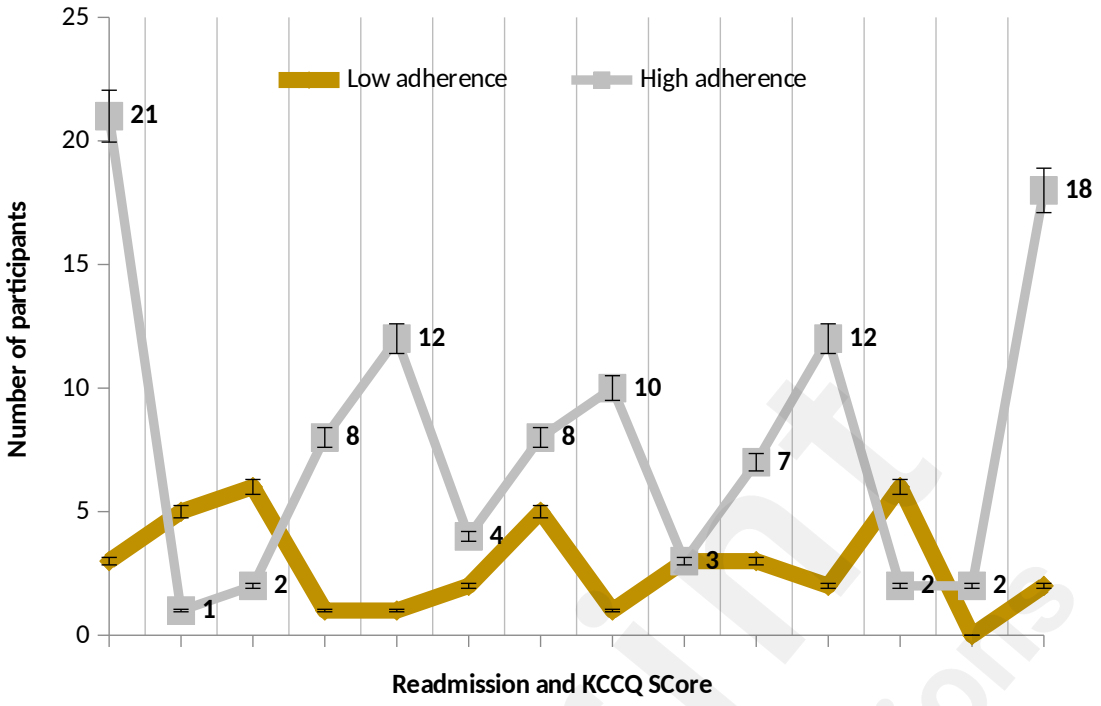


Table 6. Chi-Square Tests: Adherence vs Readmission and KCCQ Score.

	Readmission		QoL	Self-Efficacy	Social Limitation	Overall Summary Score
	Asymptotic Sig (2-sided)	Exact Sig. (2-sided)	Asymptotic Sig (2-sided)	Asymptotic Sig (2-sided)	Asymptotic Sig (2-sided)	Asymptotic Sig (2-sided)
Pearson Chi-Square	0		0.001	0.247	0.244	0.001
Likelihood Ratio	0.001		0.002	0.209	0.249	0.002
Fisher's Exact Test		0.002				
N of Valid Cases	30	30	30	30	30	30

There was a significant relationship between adherence to application prototype usage and an increase in Quality-of-Life scores and Overall Summary Score ($p<0.05$), but not in Self-efficacy and Social Limitation Scores.

Discussion

Heart failure patients home monitoring after discharge from the hospital is still done manually at NCVC Harapan Kita with media that does not fully support the remote monitoring program, so an appropriate digital platform is needed. Based on the results of the UAT of patients

and hospital staff, FineHeart is considered capable of meeting the needs of patients and hospitals.

In the efficacy testing stage of the prototype application, the challenge faced was that not all patients were willing to be recruited as respondents. The reason was that not all potential respondents were willing to carry out self-monitoring at home. Some of the reasons given by patients were poor understanding of how to use a mobile phone, no companion who was always near the patient, not willing to learn to use borrowed measuring instruments or feeling inconvenienced and unnecessary to carry out self-monitoring. This is good input for healthcare workers who manage heart failure patients. Education about the importance of self-monitoring is still inadequate and here the importance of the role of patient companions/care givers is seen [17]. In addition, the role of nurses is also very important in monitoring patient compliance by carrying out self-monitoring at home which can be done online through the application and communicating intensively with patients or caregivers [18-21].

In the intervention group, readmissions due to HF occurred in 20%. This figure is higher than the readmission rate in 30 days after hospitalization from NCVC's data in 2023, another study in Japan [22], but comparable with a study in USA [23].

For analyzing KCCQ scores changes in the intervention and control groups before and after 30 days of post-discharge monitoring, Repeated Measures ANOVA was chosen because it was able to evaluate the change in scores in each outcome thoroughly, both before and after the intervention, while considering the influence of other variables that could potentially confound the results (Fig 4). Repeated-measures ANOVA is utilized for comparing two or more treatment groups with outcomes assessed over time. This method's strength lies in its ability to simultaneously analyze the main effects of both time and treatment, as well as their crucial interaction, revealing whether treatments differentially impact outcomes over time. By accounting for the inherent correlation in repeated measurements, a hallmark of longitudinal studies, repeated-measures ANOVA offers a robust framework for testing multiple null hypotheses, including changes over time and differences between

groups. Furthermore, it incorporates mechanisms to address the sphericity assumption, ensuring the validity of results, making it a powerful and preferred tool for investigating dynamic changes in outcomes across different groups [24].

The lack of significant difference between groups on the change in Self-efficacy score could be attributed to the intervention's duration not being long enough and external influences like personal support systems. In contrast, the significant influence of clinical factors on the social limitation score and overall summary score suggests that the FineHeart application's features, such as continuous real-time health monitoring, integrated medical records, and dedicated support from nurses and administrative staff, provided more immediate and tangible benefits, effectively reducing social limitations and improving overall health management. These results indicate a tendency for increased effectiveness of implementation in the intervention group compared to the control group in increasing Self-Efficacy, but this still needs to be evaluated further with a larger sample size, since crude comparison before adjusting for confounding factors initially did not show any differences.

Social Limitation score analysis showed that the application-based intervention positively impacts the increase in Social Limitation scores in the intervention group. Although the statistical results have not shown significance on the direct influence of the group ($p = 0.176$), a more significant increase in scores in the intervention group compared to the control group indicates the effectiveness of this intervention.

Overall Summary Score analysis showed that the application-based intervention effectively improved the Overall Summary Score in the intervention group, although the direct influence of the group was not statistically significant ($p = 0.121$). The more remarkable improvement in the intervention group compared to the control group supports the potential of this intervention to improve patients' quality of life.

Multiple logistic regression results showed a promising trend towards decreased risk of readmission in the intervention group. These findings suggest potential application in supporting the

care of heart failure patients to reduce the risk of readmission, especially if supported by further studies with larger sample sizes and more detailed designs.

Chi-square test showed a significant relationship between adherence to application prototype usage. These findings contrast with previously reported studies that have used digital applications to enhance home monitoring of patients with heart failure [25,26].

Limitation

This study has several limitations. First, the small of sample size is a challenge, as some candidates were unwilling to be recruited as respondents. Some of the reasons were the lack of mobile phone usage capabilities, no companion at home, unwillingness to learn how to use the measuring equipment, and feeling no need to self-monitor. This is a good input for health workers who treat heart failure patients, where education on the importance of self-monitoring is still poorly understood. Here, the importance of the role of patient companions/caregivers can be seen [27]. In addition, the nurses' role is crucial to monitor patient compliance by conducting self-monitoring at home, which can be done online through an application and by communicating intensely with patients or patient companions [28]. Second, as shown in Table 2, the participants' characteristics were not homogeneous.

Conclusion

This study revealed that the FineHeart app has potential benefits for heart failure patients to perform self-monitoring at home in collaboration with the hospital team. Patient adherence may reduce the risk of readmission and improve quality of life. Although there are still limitations in this study, the prototype application that has been tested for its efficacy can be widely used, and its features can be further developed for the collaborative management of heart failure patients. More multicentric studies on larger groups of patients are needed to confirm these preliminary results.

Acknowledgement

The authors want to thank all the participants and the Heart Failure team of the National Cardiovascular Center Harapan Kita Jakarta that was involved in this study for the facilities, data and assistance provided.

Authors contributions

FEI, KNS, BBS, BSP, and IS conceptualized the study. HRW developed the mobile application. BBS and RS provided and arranged patient recruitment and follow-up. FEI and BS wrote the first draft and performed the data analysis. All authors contributed to results interpretation. RCCW, SDS and PMD critically reviewed drafts of the manuscript. All authors read and approved the final manuscript.

Funding information

This study was supported by Universitas Indonesia with grant number NKB-354/UN2.RST/ HKP.05.00/2024.

Conflict of interest

None declared.

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User acceptance test result in HF patients.

