


# BMJ Open Usability and feasibility assessment of a smartphone application (Suhriday) for heart failure self-care remote monitoring in an Indian tertiary health care setting: a pilot mixed-methods study

Bhuvana Kolar Bylappa <sup>1</sup>, Deepak Y Kamath,<sup>1,2</sup> Immaculate Sheela Josephine,<sup>2</sup> Jabraan Shaikh,<sup>3</sup> Anant Kamath,<sup>4</sup> Preethi Rioniz,<sup>1</sup> Shruthi Kulkarni,<sup>5</sup> Kiron Varghese,<sup>3</sup> Denis Xavier<sup>1,2</sup>

**To cite:** Bylappa BK, Kamath DY, Josephine IS, *et al.* Usability and feasibility assessment of a smartphone application (Suhriday) for heart failure self-care remote monitoring in an Indian tertiary health care setting: a pilot mixed-methods study. *BMJ Open* 2022;**12**:e056962. doi:10.1136/bmjopen-2021-056962

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2021-056962>).

Received 01 September 2021  
Accepted 03 August 2022



© Author(s) (or their employer(s)) 2022. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

For numbered affiliations see end of article.

## Correspondence to

Dr Bhuvana Kolar Bylappa; [bhuvana.bvn@gmail.com](mailto:bhuvana.bvn@gmail.com)

## ABSTRACT

**Background/objectives** Remote monitoring as a component of chronic heart failure (CHF) management programmes has demonstrated utility in reducing the risk of rehospitalisation and mortality. There is little evidence on mobile health app facilitated remote monitoring in India. We conducted a pilot usability and feasibility assessment of a smartphone-based application (Suhriday) to remotely monitor patients with CHF.

**Methods** We used a mixed-methods design. Usability testing consisted of the think-aloud approach followed by semistructured in-depth interviews (SSIs) and a satisfaction questionnaire. Feasibility testing was done using acceptability and user satisfaction questionnaires in addition to SSIs. We trained five purposively sampled patients with CHF (based on health literacy and gender) and their caregivers (n=10) in self-care monitoring and app use. Usability was assessed using metrics such as task completion, time required for task completion and user satisfaction using Brooke's System Usability Scale (SUS). Content analysis of the transcripts with deductive coding was performed for both usability and feasibility interviews. The number and types of medical alerts transmitted through the app were captured and escalated to the treating team.

**Results** Critical tasks involving (1) opening the app and identifying task list, (2) reporting blood pressure, weight, heart rate and fluid intake and (3) reporting symptoms were completed within 60 s by four patients. Median (IQR) SUS score was 85 (75–92.5) indicating high level of usability. There were 62 alerts from four patients over 4 weeks, with 36 (58.1%) excess fluid intake alerts and 16 (25.8%) blood pressure variations being the most frequent. One participant had challenges using the app and was monitored through active phone calls.

**Conclusion** Overall usability and satisfaction with Suhriday were good and we were able to remotely manage patients. However, patients with limited health literacy and those facing technological challenges required active structured telephone support.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ To the best of our knowledge, this is the first Indian study among patients with chronic heart failure (CHF) to assess usability and feasibility of smart phone-based application for remote monitoring.
- ⇒ The sampled participants were from diverse socio-economic backgrounds which helped us identify usability and feasibility problems.
- ⇒ This study is a stepping stone that has informed the design of a large trial with a complex intervention centred on mobile health and task sharing to improve self-care and outcomes in patients with CHF. Based on the characteristics of participant 4 in the pilot study who was unable to use the app successfully, we incorporated structured telephone and WhatsApp-based support as alternate options for remote monitoring.
- ⇒ Think-aloud approach was conducted for all five participants, however, semistructured in-depth interviews for usability and feasibility were only possible in three patients out of five. A usability study of the nurse interface was not done. Ideally, this interface would also need to be evaluated to ensure that it is simple and not time-consuming. Feasibility interviews had to be conducted telephonically due to the COVID-19 pandemic.
- ⇒ Although suggestions regarding the incorporation of a chat or video call option were made by a few participants, these features could not be included in the app due to financial constraints.

## INTRODUCTION

Heart failure (HF) is a rapidly growing cardiovascular disorder, which affects about 38 million individuals worldwide.<sup>1</sup> The INDIA Ukieri Study (INDUS) study estimated the prevalence of HF in India in 2016 as 1% of the total population; that accounts for nearly 8–10 million patients.<sup>2</sup> Self-care is essential for patients with HF and is comprised of

treatment adherence in addition to health maintenance behaviours. Patients need to learn to take medications as prescribed, understand how to monitor signs and symptoms of worsening HF, as well as what to do in response to such symptoms when they occur.<sup>3</sup> A cluster randomised controlled trial conducted in Ethiopia concluded that self-care education significantly improved self-care adherence score among patients with HF.<sup>4</sup>

The 2022 ACC/AHA/HFSA (American College of Cardiology/American Heart Association/Heart Failure Society of America) guidelines for the management of HF documented the role of interventions that aim to improve self-care knowledge and skill, and those that focus on enhancing medication adherence or reinforcing self-care with structured telephone support (STS) as being effective in patients with HF. In addition to improving HF self-care significantly, such strategies also reduce the risk of HF-related hospitalisation, all-cause hospitalisation and all-cause mortality. There is some uncertainty regarding improvement of self-care in patients with HF through educational interventions delivered through mobile health applications.<sup>3</sup> A systematic review and meta-analysis of the outcomes of STS or remote telemonitoring as the primary component of chronic HF (CHF) management in 8323 patients demonstrated a 34% risk reduction in all-cause mortality with telemonitoring. Additionally, STS and telemonitoring reduced HF-related hospitalisation by 23% and 21%, respectively.<sup>5</sup>

There is a dearth of evidence on mobile health app facilitated remote monitoring in India. Hence, we developed a mobile-based application named Suhriday ('Well Heart'), which has multiple capabilities including facilitating remote monitoring of patients with HF (details described below under the app section Functions). We intend to use it as a part of a complex intervention in a larger randomised controlled trial. Hence, we conducted a study to assess the usability and feasibility of smartphone-based application (Suhriday) in remotely monitoring patients with HF involving caregivers. The information from this pilot study will inform the mHealth component of a complex intervention to improve self-care in patients with HF.

## METHODS

We conducted a usability and feasibility testing of Suhriday, using a mixed-methods study. The mixed-methods approach which includes qualitative and quantitative methods provides a detailed understanding of user view of the app with regard to immediate engagement as well as attitude and perceptions with the continued use of the app.<sup>6</sup>

### Setting

This study was carried out in the Cardiology and Internal Medicine departments in both inpatient and outpatient wards of St. John's Medical College Hospital, a tertiary

care teaching hospital in South India from March to July 2020.

### Eligibility criteria, sampling

The participants for the study include patients with a clinical diagnosis of HF and at least 1 of their caregivers, who consent to use the smartphone app for 4 weeks at home. We excluded patients who in the opinion of the treating cardiologist had a survival prognosis at baseline of less than 3 months and those for whom an intervention procedure had been planned in the next 1 month. We conducted purposive sampling to ensure that at least one patient was female, one had inadequate health literacy and two were from semiurban or rural areas. The health literacy scale has three validated questions related to ability to read and understand medical records.<sup>7</sup> Based on the score obtained, health literacy can be classified as low, marginal or adequate.

### Suhriday APP

The mHealth application has been developed by One Health Solutions, a software company based in Bangalore, India. This application works on both Android and iOS. It uses JavaScript, Hypertext Markup Language and Cascading Style Sheets, and can be deployed for both desktop and mobile versions.

### Functions

The application is intended for care providers (nurses and treating physicians) to remotely monitor key parameters of patients with a primary diagnosis of HF who are on treatment. The application will also be able to generate reminders for medication adherence based on information entered by a healthcare provider nurse into the application at discharge. The patients or their caregivers, after measurement of key parameters (blood pressure (BP), heart rate, body weight and fluid intake) using validated instruments, will enter the same data into the app. The app also has a validated questionnaire for symptom/sign reporting.<sup>8</sup> It can identify and alert the study nurse when there are outlying values. The nurse will be able to view these alerts and escalate them so that the treating team can then take appropriate action (eg, order a titration of doses of high ceiling diuretics). The security features of this system include encryption of data on the device, user authentication and a secure Hypertext Transfer Protocol-based data transmission system. We used the Apache CouchDB database on a secure web server and the backend data were stored securely in the Cloud.

### Study procedures

#### Step 1: training a study nurse

We recruited a nurse with a master's degree. She was trained for 2 months on HF by three physician investigators using lectures and bedside demonstration to recognise worsening signs and symptoms as well as medications for HF. She was educated on the importance of self-care in HF including monitoring, maintenance and management. Furthermore, she was empowered to train patients

and caregivers to measure BP, fluid intake, check weight and use the Suhrday app (detailed in online supplemental appendix 1 table 1).

### Step 2: training for patients/caregivers

Patients and their caregivers were educated on salient aspects of HF self-care. Participants received training in measuring BP, fluid intake and weight from the study nurse. They were also trained to recognise worsening signs and symptoms of HF. Following this, detailed app training to perform the tasks assigned was provided to the participants (Tasks detailed in online supplemental appendix 1 (table 1)).

### Step 3: setting for usability testing at the patient interface

The patients/caregivers were asked to measure their BP, heart rate and body weight in the presence of the nurse. Then they were instructed to open the link from the message received, to download the app and open the application. The patients or their caregivers were asked to perform the think-aloud exercise while performing and completing the in-app tasks. (Usability measures definitions detailed in online supplemental appendix 1)

### Step 4: usability testing at the patient interface

To assess usability, we equipped five patients or their caregivers with the smartphone-enabled mHealth application, Suhrday and used the following methods:

#### *Think-aloud approach*

The purpose of this approach was to capture ease of use and an understanding of potential interface issues. Patients/caregivers were instructed to 'think aloud' (ie, verbalise their thoughts) as they interact with the Suhrday app while the mobile screens were recorded through the screen recorder option of Android phones. The study team observed and made notes about completeness of tasks with patients/caregivers. We measured effectiveness of task completion by noting whether tasks were (1) completed with ease, (2) completed with difficulty requiring intervention from the study nurse or (3) not completed. We also measured efficiency by noting time taken to perform tasks using the mobile screen and/or audiorecordings.<sup>9–11</sup>

#### *Qualitative semistructured in-depth interviews*

At the end of think-aloud approach, we interviewed the patient and caregiver as a dyad to capture the acceptability and barriers of the app and suggestions for improving its features. Details about qualitative data collection have been described below.

#### *Satisfaction measurement*

Patient and caregiver's satisfaction was measured utilising Brooke's System Usability Scale (SUS). The SUS has been evaluated for validity, reliability and sensitivity.<sup>12–16</sup> Scores were calculated according to Brooke's guidelines<sup>12</sup> and is detailed in online supplemental appendix 1.

### Step 5: feasibility study

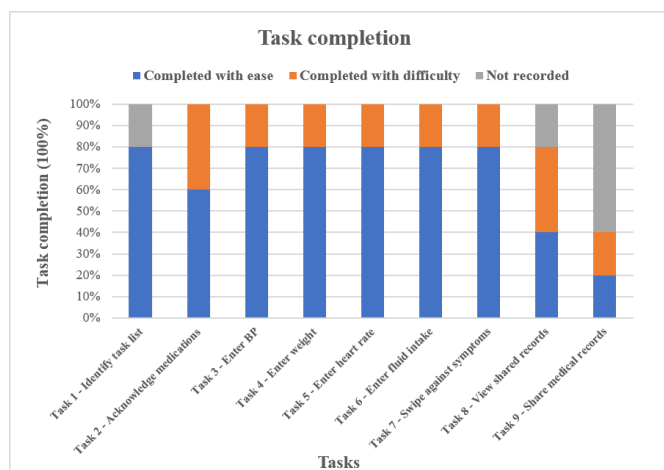
In the context of technology development is an analytical method used to determine if different components of a project can perform together in order to create a technically and operationally viable concept.<sup>17</sup> The guidance from the Medical Research Council, UK on the development and evaluation of complex interventions recommends an early phase of assessing feasibility prior to a full evaluation. Patients and their principal caregivers who participated in the usability testing were provided a smartphone enabled with the Suhrday app, a BP monitoring device and an Liquid-Crystal Display (LCD) weighing scale. They were asked to measure BP and body weight every morning for a minimum of 4 weeks and to report measured values using the application. In addition, they were asked to monitor and report symptoms or other signs through the app.

We provided the study nurse with a smartphone onto which the Suhrday application was installed. The study nurse monitored the patients for a minimum of 4 weeks and made telephone calls to address alerts received for variance in values of measurements and symptoms/signs (detailed in online supplemental appendix 1 (table 2)) in addition to weekly structured telephone follow-up calls. During the course of the study, the nurse maintained a paper dairy and an electronic diary (MS Excel Issue Tracker) to capture type of issue (medical or app-related), details of medical issues, person the issue was escalated to and description of resolution.

### Alerts and resolution process

The study nurse was the primary recipient of the alerts through the Nurse interface of the Suhrday app. She would call patients and ask them additional questions related to their symptoms from a preprepared list by the investigators. Salient data retrieved including present complaints, history, key investigation parameters and the current list of prescribed medications would then be informed to the study physicians. General medical escalations were attended by the Internist or the clinical pharmacologist (medically qualified in India), while HF symptom-related queries were escalated to the on-call Cardiology resident. If more information was required, the nurse would be asked to make an additional call to gather the same. Based on the physicians' assessment, the escalation would either be (1) resolved over the phone, (2) advised an outpatient visit for follow-up, (3) advised an emergency room visit or (iv) advised hospitalisation following an emergency room or outpatient visit.

A feasibility study conducted with qualitative research methods can help identify fundamental problems with the intervention workflow process or trial conduct.<sup>18</sup> Hence, after 4 weeks of continuous use of the application, we conducted semistructured feasibility interviews with the patients or their caregivers. We used a feasibility interview guide for this purpose (online supplemental appendix 1 —Feasibility interview guide). The interviews were



**Figure 1** Task completion rate for usability—effectiveness.

audiorecorded, transcribed and translated to English. Satisfaction was measured using the SUS instrument.

### Sample size, data collection and analysis

We carried out the usability and feasibility testing in five participants as it has been demonstrated that this can detect over 80% of usability problems.<sup>10</sup> For usability analysis, we noted effectiveness (task completion), efficiency (time required for task completion, noted through the screen recorder and/or audio recording) and user satisfaction (SUS score).<sup>6 9–12</sup> Interviews were conducted (for usability—in the Cardiology Research Office, for feasibility—telephonic) by DYK and BKB with the help of ISJ, and recorded using an audiorecorder. The interviews were transcribed verbatim and then translated into English by a research assistant. This was verified for content accuracy by either DYK or BKB. Transcripts were manually analysed using content analysis approach and deductive coding for acceptability and barriers related to app use, as well as suggestions for improving app functionality. For feasibility testing, while we intended to interview all five participants, we were only able to interview three due to the COVID-19 disruptions. Content analysis

codes from these interviews were categorised as those indicating the overall experience, interaction with study staff, impact of training on HF self-monitoring, satisfaction with the team and suggestions to improve the app. We measured user satisfaction using the SUS instrument at the end of the study. Components of acceptability (not validated) were measured using a Likert scale.

### Role of public and patient involvement

While the public was not involved in the study, patients and their caregiver's feedback on the utility and ease of app usability were investigated in detail as described in the results.

## RESULTS

We conducted this study from March 2020 to July 2020 and recruited five patients.

### Patient demographics and models of app use

Of the five patients, three were from urban areas, one from semiurban and one from rural India. Clinical features such as type of HF-reduced (HF<sub>r</sub>EF) or preserved ejection fraction, New York Heart Association class at recruitment and aetiology were captured (table 1).

### Usability, task completion

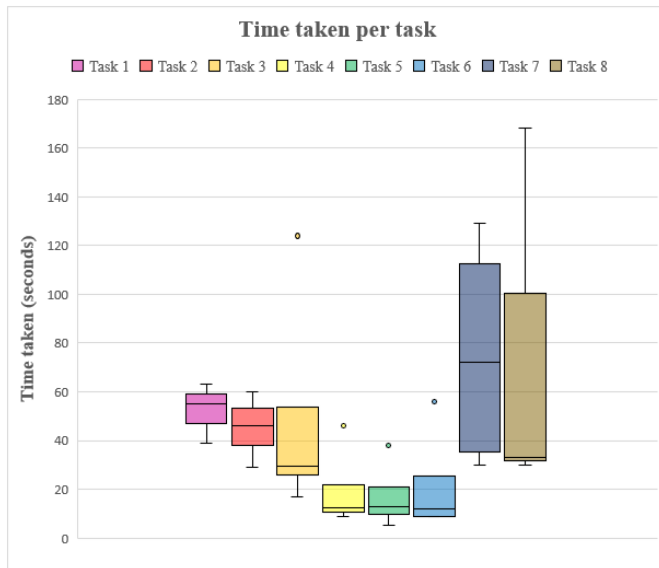
The task completion results are presented in figure 1. The critical tasks involving (1) opening the app and identifying task list (task 1), (2) BP, weight, heart rate and fluid intake reporting (tasks 3, 4, 5, 6, respectively) and (3) symptom reporting—understanding and reporting (task 7) were done easily. Majority of the tasks (tasks 1, 3, 4, 5, 6 and 7) were completed with ease by four (80%) of the participants. Task 8 (viewing shared medical records) and task 9 (sharing medical records) were reported as the most difficult to complete. Among five participants, two (40%) and one (20%) completed tasks 8 and 9, respectively, both of whom had adequate health literacy.

**Table 1** Patient demographics clinical features and models of app use

Patient demographics	Clinical features	Models of app use
Patient 1, 20–29 years, female	HFpEF, NYHA II, Hypertrophic obstructive cardiomyopathy	Patient directly trained and uses the app herself
Patient 2, 70–79 years, male	HFpEF, NYHA II, coronary artery disease, hypertension, type II diabetes mellitus	Patient maintains paper diary, sends photos of monitoring data through WhatsApp to caregiver, who reports it on app
Patient 3, 70–79 years, male	HF <sub>r</sub> EF, NYHA II coronary artery disease, hypertension, type II diabetes mellitus	Caregiver was trained initially; caregiver trained patient over 10 days, who later uses it himself
Patient 4, 50–59 years, male	HF <sub>r</sub> EF, NYHA II coronary artery disease, hypertension, type II diabetes mellitus, stroke	Initial apprehension and reluctance to use technology; Study nurse trained slowly, later was confident to use
Patient 5, 50–59 years, female	HFpEF, NYHA II hypertension, type II diabetes	Patient directly trained and uses the app herself

HFpEF, heart failure preserved ejection fraction; NYHA, New York Heart Association.





**Figure 2** Box and whisker plot for usability efficiency measure, IQR.

### Errors

One participant made the error of swiping across instead of tapping on task 2 (acknowledgement for medication reminder). Majority of the errors were faced with a single participant (participant 4, male, rural, inadequate health literacy), who completed task 2 with difficulty, as the drug names were not translated to his native language, Tamil. This participant also took seven attempts to complete task 3 (entry of BP values) due to the inability to locate the number mode after locating the area to enter the value as he forgot the instruction. He completed task 6 (entry of fluid intake the previous day) after three attempts due to difficulty in locating and placing the decimal point.

### Usability, time taken per task

The time taken per task results are presented in figure 2. For one participant (participant 3), we did not record the think-aloud approach through the screen recorder as the caregiver of the patient was not comfortable with it. We were not able to record the time taken to complete tasks through the audio recording, as the tasks were not performed systematically. The study team observed and made notes on completeness of tasks for this participant. Participant 4 who made the most errors took the longest time.

### Usability, satisfaction

The median (IQR) SUS score for usability of all the five participants was 85 (75–92.5), indicating high level of usability. Participant 4 however had a score of 32.5 indicating poor usability.

### Qualitative interview

Among five participants who completed think aloud process with the app, interviews were conducted with three participants (reasons explained in the Discussion

section) to determine acceptability, barriers of use and suggestions for improvement (table 2).

### Remote monitoring through Suhriday app

Overall, patients were managed remotely throughout the 4-week evaluation period with no unplanned rehospitalisations due HF or deaths.

### Alerts, number and type

There were a total of 62 alerts (detailed in online supplemental appendix 2 (table 1)) from four participants (snapshots of alerts in online supplemental appendix 2). Alerts related to fluid intake (58.1%), variance in diastolic BP (19.4%), HF symptom worsening (16.1%) and variance in systolic BP (6.5%) were received at nurse interface. Patients were counselled over the phone for fluid intake alerts. For alerts related to BP, the nurse ascertained whether patients were measuring it correctly. If the value was deemed accurate and uncontrolled, it was escalated to the study investigators. Patient 4 hardly used the app, but reported issues through STS. This was monitored actively by the study nurse and there were no HF related escalations over a 4-week period. Overall, five issues were remotely managed for three out of five patients. HF-related escalations led to up-titration of loop diuretics three times, and general medical queries were addressed for constipation and iron-deficiency anaemia.

### Resolution process and time (for alert-led issues and other medical issues)

The study nurse made 21 telephone calls to cardiologists and internists/clinical pharmacologist to resolve issues regarding HF symptom/sign related alerts, general medical queries, prescription confirmation and drug dose queries, as well as BP variations. Majority of the medical issues were resolved within 60 min.

### App issues at nurse interface

These were totally 29 in number. Difference in getting alerts with two different phones (8), log in issues (5), alert sync issues between two different phones (3), alert sync lag from patient to nurse (2) were the predominant issues at the nurse's interface. App issues at patient interface are summarised in online supplemental appendix 2 (table 2).

### Feasibility interview

We conducted telephonic interviews with three out of five participants (reasons explained in the Discussion section). Findings are in table 3.

### Feasibility, SUS, overall satisfaction, acceptability

Feasibility results among the three participants showed a median (minimum, maximum) SUS score of 92.5 (87.5, 100), which represents high usability with an overall satisfaction adjective rating of 'excellent' (2 participants) and 'best imaginable' (1 participant). In the context of acceptability, all three participants felt that they were confident in using the Suhriday app and would be able to

**Table 2** Acceptability and barriers of the app, suggestions for improving app features at baseline

Themes	Codes	Extracts
Acceptability of the app	Effective, useful for monitoring Very easy, very useful Monitor easily Useful reminder for medication taking, easy to use	‘This app is <b>very good</b> for like my kind of HCM people, congestive heart failure people. This is <b>very effective</b> and what I feel is every time it will be <b>like awareness</b> for you people, also for us also.’ (Patient 1, female) ‘This is there we can be with a <b>regular kind of checkup</b> day by day” “And this is <b>very easy to use</b> ’ ‘I guess this app is very useful to everyone <b>easily we can monitor</b> ’ (Patient 1, female) ‘The performance of the app is <b>very good</b> and the reaction time most the opening of the <b>app and individual components within</b> that are all <b>very good</b> ’ (Caregiver of Patient 3, male) ‘I open it and I go to all of the tablets and medication, which have to be taken, which are in red. I open each one of them and I complete them and click on save and this <b>hardly takes me any time</b> ’ ‘This was also fine the <b>weight reading, fluids intake</b> and all that was <b>fine</b> .’ (Caregiver of Patient 2, male)
Barriers of the app	Small font Unclear images	‘Instead of entering values in mobiles just I am telling see instead of entering <b>small small (font size) values</b> ’ (Caregiver of Patient 2, male) ‘This one is a bit of a problem, because for me <b>to type these numbers are really small</b> ’ (Caregiver of Patient 3, male) ‘It (discharge summary image) is very <b>unclear</b> ’ (Patient 1, female, high health literacy)
Suggestions for improving app functionality	Alarm feature Adjustment scale feature Help guide	‘It would be nice if anything turns red that the <b>phone rings or alarms</b> are there.’ (sic) (Caregiver of Patient 3, male) ‘These adjustment bars they are actually of no use. Because the spacing is really small.’ ‘The <b>scale (BP)</b> have (sic) to be completely <b>different representative</b> ’ (Caregiver of Patient 3, male) ‘The symptoms what I noticed was, if some patients who may want to understand, what is better, what is much worse mean’ ‘like on what basis do I tell much better? If there is a <b>help guide</b> or something like that’ (Caregiver of Patient 3, male)

BP, blood pressure.

teach others to do the same to a large extent (detailed in online supplemental appendix 1 (figure 1)).

## DISCUSSION

This is the first report from an Indian setting on how patients with HF respond to a remote monitoring application, pain points experienced, symptoms/signs that resulted in escalations and how they were resolved.

The usability assessment (think-aloud approach, in-depth interviews and SUS) of Suhriday demonstrated satisfactory usability for remotely monitoring among four of the five participants in our study. Most of the critical tasks were completed with ease (figure 1) which was comparable to the usability assessment of the HeartMapp study.<sup>19</sup> IQR for tasks 1, 2 and 3 were within 1 min and for tasks 4, 5 and 6 were well within half a minute. Our findings from table 2, figures 1 and 2 reflects that the app is easy to use.

However, participant 4 completed majority of the critical tasks with difficulty, took the longest time, made

many errors, and had poor usability in contrast to rest of the participants. This may be due to inadequate health literacy levels and educational attainment. Both patient and caregiver had initial apprehensions and were reluctant to use technology. Though they had smartphones, they were only accustomed to making calls. Although we trained them patiently and tried to build confidence, they could not sustain performing daily tasks and instead maintained manual records. Active STS was imperative in this case. The insights gained helped us plan contingencies for the randomised controlled trial, where we planned to incorporate active structured telephonic and WhatsApp-based support among patients who preferred not to use the app.

A decision-making algorithm for symptom management was developed based on the queries and alerts received. Escalations led to changes in prescriptions for participants 1 and 3. During the COVID-19 pandemic lockdown and heavy restriction imposed on movements, all patients were managed remotely through the app and by STS to

**Table 3** Feasibility of the app and impact of pilot intervention

Themes	Codes	Extracts
Overall experience using app	Good improvement, daily monitoring Good experience, maintained health well, reduced hospitalisation Very positive, friendly to use, part of routine	<p>'I have <i>good improvement</i> ma'am with this app. What exactly it is means (sic) like from this I came to know what is my blood pressure, <i>day to day routine</i> thing and the heart rate also <i>I maintained</i>.' 'Plus, the water intake and medicines like what time to what time like it will be mentioned in that.' (Patient 1, female)</p> <p>'In this critical situation (COVID-19 situation) this is the best option'. 'It has become a habit, daily everyday morning we have to do all these things' 'People are not able to come to the hospital so we can give him then through phone call or any video conference or video call something or this kind of app will be helpful in future also going forward' (Caregiver of Patient 2, male)</p> <p>'I got lot of <i>good experience</i>' '<i>I maintained myself very well</i>.' 'Usually, I used to get hospitalized a lot but now it has become less.' (Patient 1, female)</p> <p>'I would say the experience have been <i>very positive</i>. What I mean by positive is the app is really <i>friendly to use</i>.' 'And once you start using this, it becomes the <i>part of your routine</i>.' (Caregiver of Patient 3, male)</p>
Interaction with study staff	Change in treatment plan, helpful Provided solutions Dedicated, committed, knowledgeable, professional and patient -friendly	<p>'I was not keeping well, my legs got swollen, my stomach got swollen, so I used to contact mam' 'according to the doctors she <i>used to tell me the prescription</i>' 'There was <i>lots of help</i> sir' (Patient 1, female)</p> <p>'There were 3 or 4 occasions where the <i>issue was to be escalated</i> right' 'we contacted you and you <i>provided us with a solution</i>' (Caregiver of Patient 3, male)</p> <p>'<i>Dedicated</i> to this and <i>committed</i> and you were <i>very knowledgeable</i> and you were <i>highly professional and patient friendly</i>.' 'Immediate triage that is the most significant aspect of this.' (Caregiver of Patient 3, male)</p>
Impact of training on HF self-monitoring	Training on symptoms, signs of worsening led to awareness and improved self-monitoring	<p>'From this app I came to know that, particularly I <i>used to check</i> all these things (blood pressure, weight)' (Patient 1, female, high health literacy)</p> <p>'All the symptoms you people explained me from that I <i>got lot of education</i>'. 'I have <i>improved a lot</i> sir, like I used to know what exactly happens if I take lot of fluids.' (Patient 1, female)</p> <p>'It is improved. On daily basis also he is taking care of all' (Caregiver of Patient 2, male)</p> <p>'It had <i>great value</i>. I will tell you why doctor.' 'He used to drink as much water as possible' 'This <i>whole weight management aspect</i> we never actually took into consideration' 'swelling of legs as an <i>indicator to overall heart condition</i>' 'being aware of what is the <i>threshold level for BP</i>' (Caregiver of Patient 3, male)</p>
Satisfaction with the team	Suggestions and support to solve problems Quick resolution of problems, perfect	<p>'I had many times problems, I used to contact you, you will be suggesting, you will be contacting doctors, give me <i>proper prescription</i>' 'You have <i>supported me a lot</i>.' (Patient1, female)</p> <p>'<i>As soon as possible you used to contact</i> me and you used to suggest me' 'the <i>anxiety aspect was removed</i>.' 'I think it was <i>perfect</i>.' 'On a scale of ten I would give it 11' (Caregiver of Patient 3, male)</p>
After stopping app use	Self-maintenance	<p>'I'm noting down in a book and I'm WhatsApping (sic) you. <i>Everyday</i> I'm maintaining" '<i>In my one book I'm maintaining</i>.' (Patient 1, female)</p> <p>'I am doing. Up to date I am doing. Till today' (Patient 2, male)</p>
Suggestions to improve the app	Video call option Chat tool within app	<p>'If it is a <i>video call</i> it will be better' (Patient1, female)</p> <p>'Can't your app actually have a <i>chat interface</i> wherein I can post?' (Caregiver of Patient 3, male)</p>

BP, blood pressure; HF, heart failure.

manage issues. During remote monitoring, we did not have any unplanned hospital readmission or unplanned emergency/outpatient visit related to HF symptom/sign worsening when compared with a study by Heiney *et al* having one hospital admission and an emergency OPD visit during a 6-week study.<sup>20</sup>

During the feasibility assessment, interviewed participants expressed that the app was user-friendly, became part of their routine, helped maintain health and reduce hospitalisation. They also expressed that training led to awareness and improved self-monitoring. Participants opined that they were satisfied with the team's turn-around time to resolve issues quickly. Having video call option and chat tool within the app were a few suggestions made towards improving the app (findings from table 3).

The limitation of the study was that in-depth interviews for usability and feasibility were conducted in only three out of five participants. The usability interview for participant 4 could not be conducted initially due to in-hospital constraints, and later due to COVID-19-related disruptions. On the other hand, the feasibility interview was not conducted as he had not used the app. Another limitation was that no caregiver details were collected.

Users are the first citizens of a technology; hence their personal technological experiences are principally important.<sup>21</sup> Variations in age, gender, affluence and profession among patients and caregivers emerge as critically important factors in technological experience and engagement.<sup>22–23</sup> The issues that participant 4 faced, for instance, might be attributed to his social variables. Such cases are more likely to be encountered in communities where patients and caregivers are aged or ageing, and consequently, digitally unfamiliar. It is well evidenced in literature that ageing affects familiarity and fluency with digital devices,<sup>24</sup> and the digital divide hinders the elderly from using technology to enhance their quality of life.<sup>25–26</sup> Other studies<sup>27–29</sup> have shown evidence that factors such as self-efficacy, cognitive decline, declining motor skills and disorientation with hypertext structure heavily influence information and communication technologies (ICTs) among the aged.

This pilot study helped inform a randomised controlled trial designed to improve self-care and remote monitoring in HF patients using a smartphone application in a lower-middle-income country setting.

## CONCLUSION

This study demonstrated that Suhriday was acceptable and easy to use among most patients. Health literacy and preferences need to be considered while enrolling Indian patients into mHealth-based intervention programmes. This study has informed the design of an ongoing multi-centre trial with a complex intervention centred on mobile health and task sharing to improve self-care and outcomes in patients with CHF.

## Author affiliations

- <sup>1</sup>Pharmacology, St John's Medical College Hospital, Bangalore, Karnataka, India
- <sup>2</sup>Division of Clinical Research and Training, St John's Research Institute, Bangalore, Karnataka, India
- <sup>3</sup>Cardiology, St John's Medical College Hospital, Bangalore, Karnataka, India
- <sup>4</sup>National Institute of Advanced Studies, Indian Institute of Science, Bangalore, Karnataka, India
- <sup>5</sup>Medicine, St John's Medical College Hospital, Bangalore, Karnataka, India

**Acknowledgements** We would like to acknowledge Ms. Sangeetha and Ms. Radha from the Division of Clinical Research and Training, St. John's Research Institute for their assistance with transcribing interviews.

**Contributors** BKB, DYK, ISJ, JS, DX and SK contributed to the conception and design of the study. KV, JS, ISJ and BKB were involved in acquisition of data from recruited participants. BKB, PR and DYK performed the analysis. BKB, DYK, ISJ, JS, AK, SK and KV were involved in interpretation. BKB drafted the manuscript, with revisions from DYK, ISJ, JS, AK, PR, SK, KV and DX. DYK and BKB are the guarantors for the overall content of this article.

**Funding** This study was funded by the India Alliance-Department of Biotechnology (DBT)/ Wellcome Trust as an early career fellowship to DYK, Ref.no. IA/CPHE/15/1/502053.

**Disclaimer** The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

**Competing interests** None declared.

**Patient and public involvement** Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Not applicable.

**Ethics approval** We obtained ethical approval from the Institutional Ethics Committee of St. John's Medical College Hospital (Reference number: 124/2017) and written informed consent from all participants. Participants gave informed consent to participate in the study before taking part.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available on reasonable request. Currently, we have not deposited the raw data in an open access repository. However, we are willing to share the raw data with all interested investigators. Interested investigators may send an email to corresponding author with the brief write up of the research question, objectives and ethics approval for the proposal.

**Supplemental material** This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

**Open access** This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

## ORCID iD

Bhuvana Kolar Bylappa <http://orcid.org/0000-0002-7108-7524>

## REFERENCES

- 1 Ziaieian B, Fonarow GC. Epidemiology and aetiology of heart failure. *Nat Rev Cardiol* 2016;13:368–78.
- 2 Chaturvedi V, Parakh N, Seth S, *et al*. Heart failure in India: the INDUS (India Ukieri study) study. *J Pract Cardiovasc Sci* 2016;2:28–35.
- 3 Heidenreich PA, Bozkurt B, Aguilar D, *et al*. 2022 AHA/ACC/HFSA guideline for the management of heart failure: a report of the American College of Cardiology/American heart association



- joint Committee on clinical practice guidelines. *J Am Coll Cardiol* 2022;79:e263–421.
- 4 Dessie G, Burrowes S, Mulugeta H, *et al.* Effect of a self-care educational intervention to improve self-care adherence among patients with chronic heart failure: a clustered randomized controlled trial in Northwest Ethiopia. *BMC Cardiovasc Disord* 2021;21:1.
  - 5 Inglis SC, Clark RA, McAlister FA, *et al.* Which components of heart failure programmes are effective? A systematic review and meta-analysis of the outcomes of structured telephone support or telemonitoring as the primary component of chronic heart failure management in 8323 patients: abridged cochrane review. *Eur J Heart Fail* 2011;13:1028–40.
  - 6 Weichbroth P. A mixed-methods measurement and evaluation methodology for mobile application usability studies. *Architecture* 2019;43:45.
  - 7 Chew LD, Griffin JM, Partin MR, *et al.* Validation of screening questions for limited health literacy in a large VA outpatient population. *J Gen Intern Med* 2008;23:561–6.
  - 8 Chaudhry SI, Barton B, Mattera J, *et al.* Randomized trial of Telemonitoring to improve heart failure outcomes (Tele-HF): study design. *J Card Fail* 2007;13:709–14.
  - 9 Kushniruk AW, Patel VL. Cognitive and usability engineering methods for the evaluation of clinical information systems. *J Biomed Inform* 2004;37:56–76.
  - 10 Blank E, Tuikong N, Misoi L, *et al.* Usability of implementing a tablet-based decision support and integrated record-keeping (desire) tool in the nurse management of hypertension in rural Kenya. *Stud Health Technol Inform* 2013;192:1002.
  - 11 Georgsson M, Staggers N. Quantifying usability: an evaluation of a diabetes mHealth system on effectiveness, efficiency, and satisfaction metrics with associated user characteristics. *J Am Med Inform Assoc* 2016;23:5–11.
  - 12 Brooke J *et al.* SUS: a “quick and dirty” usability scale. In: Jordan PW, ed. *Usability evaluation in industry*. London; Bristol: Taylor & Francis, 1996: 189–94.
  - 13 Lewis JR, Sauro J. The Factor Structure of the System Usability Scale. In: *Proceedings of the 1st International Conference on human centered design: held as part of HCI international 2009*. San Diego, CA: Springer-Verlag, 2009: 94–103.
  - 14 Bangor A, Kortum PT, Miller JT. An empirical evaluation of the system usability scale. *Int J Hum Comput Interact* 2008;24:574–94.
  - 15 Jokela T, Iivari N, Matero J. The standard of user-centered design and the standard definition of usability: analyzing ISO 13407 against ISO 9241-11. In: *Proceedings of the Latin American conference on Human-computer interaction [Internet]*. New York, NY, USA: Association for Computing Machinery, 2003: 53–60.
  - 16 Georgsson M. Toward patient-centered, standardized, and reproducible approaches of evaluating the usability of mHealth chronic disease self-management systems for diabetes, 2018. Available: <http://urn.kb.se/resolve?urn=urn:nbn:se:bth-15140> [Accessed 04 Dec 2020].
  - 17 Matson J. Cooperative feasibility study guide, 2000. Available: <https://agris.fao.org/agris-search/search.do?recordID=US201300070988> [Accessed 20 Nov 2020].
  - 18 O’Cathain A, Hodinott P, Lewin S. Maximising the impact of qualitative research in feasibility studies for randomised controlled trials: guidance for researchers. *Pilot Feasibility Stud* 2015;1:1–3.
  - 19 Athilingam P, Labrador MA, Remo EFJ, *et al.* Features and usability assessment of a patient-centered mobile application (HeartMapp) for self-management of heart failure. *Appl Nurs Res* 2016;32:156–63.
  - 20 Heiney SP, Donevant SB, Arp Adams S, Adams SA, *et al.* A smartphone APP for self-management of heart failure in older African Americans: feasibility and usability study. *JMIR Aging* 2020;3:e17142.
  - 21 Oudshoorn N, Pinch T. How users matter: the co-construction of users and technology (inside technology) The MIT Press; 2003.
  - 22 Schäffer B. The digital literacy of seniors. *Res Comp Int Educ* 2007;2:29–42.
  - 23 Kamath A. “Untouchable” cellphones? Old caste exclusions and new digital divides in peri-urban Bangalore. *Crit Asian Stud* 2018;50:375–94.
  - 24 Mortara A, Vaira L, Palmieri V, *et al.* Would you prescribe mobile health apps for heart failure self-care? An integrated review of commercially available mobile technology for heart failure patients. *Card Fail Rev* 2020;6:e13.
  - 25 Blažič BJ, Blažič AJ. Overcoming the digital divide with a modern approach to learning digital skills for the elderly adults. *Educ Inf Technol* 2020;25:259–79.
  - 26 Niehaves B, Plattfaut R. Internet adoption by the elderly: employing is technology acceptance theories for understanding the age-related digital divide. *Eur J Inf Syst* 2014;23:708–26.
  - 27 Castilla D, Botella C, Miralles I, *et al.* Teaching digital literacy skills to the elderly using a social network with linear navigation: a case study in a rural area. *Int J Hum Comput Stud* 2018;118:24–37.
  - 28 Eshet-Alkalai Y, Chajut E. Changes over time in digital literacy. *Cyberpsychol Behav* 2009;12:713–5.
  - 29 Wang C-H, Wu C-L, . Bridging the digital divide: the smart TV as a platform for digital literacy among the elderly. *Behav Inf Technol* 2021;30:1–14.