

The effects of a nurse-led smartphone-based intervention after coronary artery bypass grafting: A randomised controlled trial

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ABSTRACT

Background: Patients after coronary artery bypass grafting often face suboptimal recovery, including pain, reduced quality of life, and haemodynamic instability, worsened by limited self-care knowledge and inadequate post-discharge support. Nurse-led smartphone-based interventions may offer a scalable solution for resource-limited settings.

Objective: To evaluate the effects of a nurse-led, smartphone-based educational and follow-up intervention on pain, quality of life, and haemodynamic stability in patients undergoing elective coronary artery bypass grafting.

Design: Single-blind, randomized controlled trial.

Settings: A tertiary cardiac surgery center in Shiraz, Iran, from July 2024 to April 2025.

Participants: Eighty-four adults undergoing elective coronary artery bypass grafting, randomized (1:1) to intervention or control groups, with 80 completing the study (40 per group).

Methods: The intervention group received a three-phase programme: (1) pre-operative education via videos, messages, and a face-to-face session; (2) in-hospital education and daily symptom monitoring for pain and self-care; (3) 30-day post-discharge follow-up with weekly nurse-led calls and real-time messaging. Controls received standard care with one handout. Outcomes included pain (visual analog scale), quality of life (SF-36 Health Survey), and hemodynamic indices (blood pressure, heart rate). Pain and haemodynamic indices were assessed at baseline, three times daily for four days in the general ward following post-intensive care unit discharge (12 time points), and weekly post-discharge (days 7, 14, 21, 30; 4 time points), totaling 17 assessments. Quality of life was assessed at baseline and 30 days post-discharge. Data were analyzed using Mann–Whitney U tests, t-tests, and repeated-measures analysis of variance.

Results: The intervention group had lower pain scores (in-hospital: 3.96 ± 0.42 vs. 4.29 ± 0.35 , $p < 0.001$, $d = -0.85$, 95% CI -0.50 to -0.16 ; post-discharge: 1.45 ± 0.38 vs. 2.01 ± 0.50 , $p < 0.001$, $d = -1.26$, 95% CI -0.76 to -0.36) and reduced post-discharge blood pressure and heart rate. Total quality of life scores showed no significant between-group differences at 30 days (adjusted ANCOVA: adjusted mean difference = 0.15, 95% CI -1.27 to 1.57 , $p = 0.832$), while the pain domain improved significantly in the intervention group ($p = 0.002$, $r = -0.35$). Group-by-time interactions were significant for pain and haemodynamic outcomes ($p < 0.05$).

Conclusions: This nurse-led, smartphone-based intervention reduced pain, improved pain-related quality of life, and stabilized haemodynamic parameters post-coronary artery bypass grafting. Easily integrated into nursing practice, it supports recovery in resource-limited settings and merits further study.

Registration: Registered at the Iranian Registry of Clinical Trials, IRCT20240426061574N1, registered June 05, 2024, <https://irct.behdasht.gov.ir/search/result?query=IRCT20240426061574N1>.

Social media abstract: Nurse-led smartphone intervention reduces pain and stabilizes haemodynamics in post-coronary artery bypass grafting patients over 30 days.

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What is already known

- Recovery after coronary artery bypass grafting is often complicated by pain, reduced quality of life, and haemodynamic instability.
- Nurse-led interventions can improve postoperative outcomes, but evidence on smartphone-based approaches remains limited.
- Mobile health studies for cardiac recovery show inconsistent findings, often lacking cultural adaptation or scalability in resource-limited settings.

What this paper adds

- A culturally tailored, protocolised nurse-led smartphone messaging intervention demonstrated feasibility and acute-phase benefits (pain reduction, haemodynamic stabilization) in a resource-constrained setting.
- Pain-domain quality-of-life improvements were observed, with no overall quality-of-life differences at 30 days.
- This low-cost, scalable intervention using accessible messaging platforms supports acute recovery and integration into nursing practice in resource-limited contexts.

1. Background

Coronary artery disease impacts an estimated 200 million individuals globally, with its prevalence having surged by 100% over the past 30 years (Virani et al., 2020). In Iran, it contributes to nearly 50% of annual deaths (Sarrafzadegan and Mohammadifard, 2019). Coronary artery bypass grafting is a cornerstone treatment for advanced coronary artery disease, effectively reducing mortality and improving prognosis by restoring myocardial blood flow (EL-Andari et al., 2025). The post-operative period poses challenges—pain, reduced quality of life, haemodynamic instability, and psychological distress—that hinder recovery and burden healthcare systems (Minami et al., 2023; Montrief et al., 2018).

Pain is defined as an unpleasant sensory and emotional experience linked to tissue damage (Raja et al., 2020). Postoperative pain is common after coronary artery bypass grafting, with moderate to severe acute pain in the first 24–72 h from surgical trauma, and chronic pain in 30–50% of patients due to inflammation and nerve injury (Bjornnes et al., 2016; Richebé et al., 2018). This pain restricts respiratory function, limits mobility, and exacerbates haemodynamic parameters, such as elevated heart rate and blood pressure, creating a cycle of physiological stress (Jalili et al., 2024). Psychological factors, including anxiety, fear, and depression, amplify pain perception and are often rooted in patients' limited self-care awareness and apprehension about complications (AbuRuz and Al-Dweik, 2022). Haemodynamic instability, driven by pain and psychological stress, further complicates recovery, as heightened cardiovascular responses exacerbate pain (Babamohamadi et al., 2021). These issues highlight contradictions in the literature: some studies emphasize pharmacological management while overlooking psychological mediators, revealing a gap in integrated approaches (Aburuz et al., 2022; Kathania et al., 2021). For instance, while pharmacological interventions reduce acute pain, they often fail without addressing anxiety, leading to inconsistent outcomes across trials (de Andrade et al., 2024).

Quality of life, encompassing physical, emotional, and social dimensions, is frequently compromised after coronary artery bypass grafting (Jamaludin, 2019). Patients exhibit reduced physical activity, struggle to resume social roles, and experience persistent emotional distress, with suboptimal quality of life reported in the first year post-surgery (Muthukrishnan et al., 2023). Literature suggests that patients' self-care knowledge and ongoing monitoring by healthcare teams significantly influence postoperative outcomes and quality of life, as many lack the skills to manage symptoms or adhere to recovery protocols (Gohari et al., 2022; Kim et al., 2022; Schneider et al., 2024).

However, evidence reveals inconsistencies: while some nurse-led programmes enhance self-efficacy and adherence, others report limited effects due to methodological flaws, such as small samples or lack of cultural tailoring, underscoring the need for context-specific designs (Ni et al., 2022; Salarvand et al., 2024).

Nurses, as primary patient advocates, are well-positioned to deliver education and enhance self-care awareness, starting preoperatively to improve patients' understanding of the surgery and recovery expectations (Kalani et al., 2021). Several studies have reported potential benefits of nursing interventions on pain, quality of life, and other clinical outcomes in patients undergoing coronary artery bypass grafting; however, success varies: complex app-based interventions often fail due to high dropout rates (40–60%) from usability issues in older adults (Cajita et al., 2018), while simple messaging platforms succeed through better accessibility, cultural tailoring, and lower technical barriers; dropout <20% (Wu et al., 2023). This variability underscores why culturally adapted, low-complexity tools are more effective in resource-limited settings, as they reduce barriers and enhance adherence (Li et al., 2024). Despite this, current post-discharge education and care are often unstructured, with limited follow-up, leading to poor self-care, reduced treatment adherence, and feelings of abandonment (Elsayed and Gaballah, 2024; Tabas et al., 2020). Moreover, staff shortages, shift constraints, and a lack of real-time tools hinder consistent nurse-led post-discharge interventions (Gohari et al., 2022; Shaikha et al., 2021).

Smartphones are mobile devices with internet connectivity and multimedia capabilities that enable communication through text, voice, images, and videos. Smartphones offer a scalable solution to enhance nursing capacity by enabling rapid, tailored communication via images, videos, and voice messages, strengthening structured care delivery (Ma et al., 2022; Temple-Oberle et al., 2023). Nurse-led smartphone interventions harness multimedia messaging to deliver structured, patient-centered care, enabling real-time monitoring, personalized education, and consistent follow-up (Li et al., 2024). Taken together, interventions tend to succeed when delivery is low-complexity, accessible, and culturally tailored with consistent nurse contact, whereas high-friction apps underperform due to usability burdens and retention challenges in older adults; our design therefore prioritizes low complexity and a consistent attention dose appropriate for a public, resource-constrained tertiary context.

Mobile health applications and standard messaging platforms can support nurse-led, smartphone-based post-discharge care, but applications' complexity, reliability issues, and development demands—especially challenging for older adults—contribute to high dropout rates and usability concerns, explaining failures in non-tailored interventions (Cajita et al., 2018; Cruz-Cobo et al., 2022; McBride and LeVasseur, 2017). Nurse-led interventions via accessible messaging platforms and voice calls allow real-time monitoring, personalized education, and consistent follow-up to support self-care and psychological needs, though evidence remains limited by small samples and lack of cultural tailoring, which correlates with success in resource-limited settings (de Jong et al., 2020; Li et al., 2024). Mobile health in cardiac surgery improves self-efficacy, resilience, lifestyle, and quality of life, but mixed psychological and adherence outcomes reflect methodological gaps, including limited attention to acute pain and cultural adaptation in resource-limited settings (Salarvand et al., 2024; Wu et al., 2023).

Research is scarce on how nurses can use smartphone messaging to deliver care, follow up, and targeted education after coronary artery bypass grafting—insights vital to assessing their potential to improve recovery and outcomes (Cruz-Cobo et al., 2022; Ni et al., 2022). These gaps highlight the need for nurse-led interventions that leverage simple, accessible smartphone messaging platforms to provide culturally tailored education, continuous follow-up, and timely support for patients after coronary artery bypass grafting. Therefore, this study pragmatically aimed to evaluate the effects of a protocolised, nurse-led smartphone messaging and follow-up intervention on pain, quality of

life, and haemodynamic stability in patients undergoing elective coronary artery bypass grafting, with a focus on feasibility and scalability in a resource-constrained context rather than technological novelty.

2. Methods

2.1. Design

This study was a two-arm, single-blind, randomized controlled trial (RCT) with a pre-test/post-test design, conducted from July 2024 to April 2025. The trial was registered with the Iranian Registry of Clinical Trials (IRCT20240426061574N1).

2.2. Participants

Eligible participants were adults undergoing their first elective coronary artery bypass grafting at Shahid Beheshti Hospital, Shiraz, Iran, a tertiary referral center for cardiac surgery. Inclusion criteria included: 1) full consciousness (Glasgow Coma Scale score of 15); 2) access to a smartphone with internet connectivity for the patient or an active caregiver (present during pre-operative education and available for ≥ 23 days post-discharge); and 4) literacy (patient or caregiver); patients were excluded if they: 1) had an emergency coronary artery bypass grafting; 2) had psychiatric disorders such as generalized anxiety or major depression; 3) were receiving treatment for their psychiatric disorders; and 5) had no access to a standardized home blood pressure monitor.

2.2.1. Sample size estimation

The sample size for testing the null hypothesis, based on study variables for this randomized controlled trial, was determined using G*Power software (version 3.1.9.7). The calculation was informed by prior work reporting a moderate effect size (Cohen's $d = 0.5$) for pain outcomes in patients undergoing cardiac surgery (Jalili et al., 2024). To detect a similar effect in our primary outcome variable, quality of life, we assumed a two-group design with a significance level (α) of 0.05 and statistical power of 0.80. This yielded a sample size of 72 participants (36 per group), as required. Accounting for an anticipated attrition rate of 15%, based on typical dropout rates in similar clinical studies (Esmaili et al., 2022), the target sample size was increased to 84 participants in total (42 per group).

2.2.2. Randomization and masking

Participants were allocated in a 1:1 ratio to either the intervention group, which received a nurse-led, smartphone-based educational and follow-up intervention, or the control group, which received only standard care. Randomization was conducted using block randomization with a block size of four. The randomization sequence was generated using an online random number generator (<https://www.sealedenvelope.com/simple-randomiser/v1/lists>) by an independent research coordinator not involved in participant recruitment or data assessment. To maintain allocation concealment, the sequence was secured in sequentially numbered, opaque, sealed envelopes prepared in advance by the independent Researcher A. Following baseline data collection, the independent researcher, Researcher B, who was blinded to the randomization sequence, opened the envelopes in the order of participant enrollment to assign participants to their respective groups. All outcome assessors remained blinded to group assignments to reduce the risk of bias during data collection and analysis.

2.3. Study intervention

The intervention was a nurse-led, smartphone-based educational and follow-up intervention programme. The intervention programme was designed and developed by a multidisciplinary team (one cardiac surgeon, two nurse educators, two cardiac intensive care nurses). It

integrated evidence-based guidelines (Akar et al., 2024; de Waard et al., 2021; Mares et al., 2018; Wu et al., 2023). Pilot-tested with five patients for usability and cultural appropriateness, the intervention consisted of 7 multimedia videos (5–10 min each, MP4 format) delivered via a smartphone-based messaging platform, supplemented by bidirectional communication and telephone follow-ups. The intervention was delivered by a researcher with approximately 10 years of experience in cardiac surgery operating rooms, cardiac intensive care units, and post-surgical patient care, who was not involved in data collection. This researcher underwent training and was supervised by a member of the research team, a nursing professor, to ensure standardized delivery of the intervention. Details of the multimedia video content are shown in Table 1.

2.3.1. Phase 1: pre-operative

One week before surgery, while patients were not hospitalized, the intervention commenced via the messaging platform. Multimedia videos one to four (covering pre-operative preparation, surgical procedures, and immediate post-operative care) were delivered, featuring evidence-based content, professional narration, and patient-centered visuals to enhance comprehension while minimizing distress. An optional animated video, adapted from reputable cardiac surgery resources and dubbed into Persian, was provided at the patient's request. Supplementary materials, including text-based explanations, images, and additional videos, were shared through the platform to address patient needs. Patients could initiate queries via the messaging platform (median response time: 8 h, range: 4–12 h, 8 AM–4 PM), and the researcher would respond to text or voice messages as needed to ensure clarity. A 1-GB internet data package was provided to ensure accessibility. Two days before surgery, upon hospital admission, the researcher conducted a face-to-face session (approximately 30 min) to summarize the content, address patient questions, and reinforce understanding, and further leveraged the messaging platform for ongoing communication.

2.3.2. Phase 2: in-hospital (post-ICU to discharge)

Following extubation and transfer to the surgical ward (mean: 2 days post-surgery), the intervention continued via the messaging platform. Multimedia videos five to seven (covering post-surgical care in the ward, pain management, and post-discharge care; 5–10 min, MP4 format) were sent to the patient and their active family caregiver, supplemented by text-based and visual materials on pain management and home care. On days 3–5, the researcher conducted a 30-minute face-to-face session with the patient and family caregiver to review post-discharge content and address questions. The researcher collected qualitative feedback from patients and caregivers during face-to-face sessions to assess engagement with the smartphone-based materials, supplemented by quantitative logs. Patients were encouraged to re-watch videos and access materials via the messaging platform. The researcher responded to patient- or family-initiated queries through the platform (median response time: 8 h, range: 4–12 h, 8 AM–4 PM) using text or voice messages, with ongoing support available post-discharge during working hours.

2.3.3. Phase 3: post-discharge (30 days)

Follow-up included four telephone calls (days 7, 14, 21, 30; mean: 12.8 ± 2.7 min, range: 10–15 min) to assess pain (visual analog scale), blood pressure, and heart rate using standardized home monitors. Pre-discharge training ensured accurate measurements (5-minute rest, averaging two readings 1 min apart). Calls were scheduled 9 AM–1 PM, with flexibility. Weekly reminders (Mondays, via messaging platform) reinforced self-care (wound care, nutrition, medication, non-pharmacological pain relief), addressing 2.3 ± 1.1 patient-initiated queries/week (median response time: 8 h, range: 4–12 h).

2.3.4. Control group

The control group received routine institutional care provided to all

Table 1

Details of the multimedia video content for the nurse-led coronary artery bypass grafting educational intervention.

Video	Duration	Title	Contents
1	5 min	Pre-operative preparation	- Preparations the night before and morning of surgery - Patient-centred guidance to reduce anxiety - Assign homework: review the preparatory checklist via the messaging platform
2	5 min	Preparing for CABG surgery	- Overview of patient preparation steps - Introduction to the medical equipment used - Assign homework: review equipment guides via the messaging platform
3	5 min	CABG surgical procedure	- Explanation of CABG stages: anesthesia, surgery, recovery - Patient-centered visuals to enhance understanding - Assign homework: review procedure summary via messaging platform
4	7 min	Post-operative care in the ICU	- ICU care: regaining consciousness, deep breathing, coughing - Managing dry mouth/lips, mobility, and compression stockings - Transition to surgical ward, dietary guidelines - Assign homework: practice breathing exercises, review dietary guide via messaging platform
5	10 min	Post-surgical care in surgical ward	- Transition to the surgical ward, respiratory physiotherapy - Post-operative mobility, chest care, bathing, wound care - Use of elastic stockings, introduction to rehabilitation - Assign homework: practice mobility exercises, review wound care guide via messaging platform
6	7 min	Pain management after CABG	- Managing chest, wrist, forearm, and surgical site pain - Pharmacological (analgesics, topical anesthetics) and non-pharmacological (music therapy, massage, relaxation, acupuncture) strategies - Pain assessment scale, pain control steps - Assign homework: practice relaxation techniques, review pain management guide via messaging platform
7	7 min	Post-discharge care after CABG	- Activity, restrictions, diet, wound care, medications - Exercise, home care, prayer, travel, sexual activity - Assign homework: review post-discharge care plan, engage with follow-up queries via messaging platform

Note: All videos were developed with evidence-based content, professional narration, and patient-centered visuals. Abbreviation: CABG, coronary artery bypass grafting.

patients undergoing coronary artery bypass grafting at the study center: discharge education by the cardiac rehabilitation unit, a 5-page illustrated handout (surgical procedure, pain management, self-care, warning signs), and two nurse-led telephone follow-ups at 2 and 4 weeks for symptom review and reinforcement. This protocol is applied uniformly. An active control was not implemented due to nursing staff shortages (ratio > 1:15 in post-surgical wards) and ethical constraints in a public tertiary center, where withholding enhanced education would

compromise care equity. This design reflects real-world practice in resource-limited settings (Esmaili et al., 2022; Gohari et al., 2022).

2.4. Measures

2.4.1. Demographic

Demographic data (age, sex, marital status, education, occupation) were collected using a standardized questionnaire and extracted from medical records.

2.4.2. Outcomes

2.4.2.1. Quality of life. Quality of life was assessed using the SF-36 Health Survey (Ware, 1993), a 36-item questionnaire evaluating eight domains: physical functioning, role limitations due to physical/emotional health, energy, emotional well-being, social functioning, pain, and general health. Scores range from 0 to 100, with higher scores indicating a better quality of life. The Persian version was psychometrically tested (Montazeri et al., 2005).

2.4.2.2. Pain. Pain was measured using the Visual Analog Scale, a 10-cm line ranging from 0 (no pain) to 10 (worst pain imaginable), validated for pain measurement (Begum and Hossain, 2019). The Persian version showed high reliability (Cronbach's $\alpha = 0.88$) (Fadaeizadeh et al., 2009).

2.4.2.3. Haemodynamic parameters. Systolic/diastolic blood pressure, as well as heart rate were measured using standardized, calibrated devices. In-hospital measurements employed hospital monitors, while post-discharge assessments used home monitors. Participants were trained pre-discharge to ensure accurate measurements (5-minute rest, two readings 1 min apart, averaged).

2.5. Data collection

Eligible patients were approached during pre-operative visits by Independent Researcher B, who explained the study's objectives, procedures, and potential risks, and obtained written informed consent from participants. Then, Independent Researcher B assigned participants to either the intervention or the control group.

Data were collected at specific time points to capture quality of life, pain, and haemodynamic parameters. Baseline measurements (T1) were collected pre-operatively (during the last visit before hospital admission for surgery), before randomization, when participants were unaware of their group allocation. Quality of life (SF-36) was assessed via an online link at T1 and 30 days post-discharge (T17), with Independent Researcher C providing telephone assistance to ensure comprehension without influencing responses. Pain (visual analog scale), systolic/diastolic blood pressure, and heart rate were measured at: 1) baseline (T1); 2) in-hospital phase (days 1–4 post-transfer to surgical ward, every 8 h during morning, afternoon, and evening shifts, totaling 12 time points: T2–T13, with T2: day 1 morning, T3: day 1 afternoon, T4: day 1 evening, T5: day 2 morning, T6: day 2 afternoon, T7: day 2 evening, T8: day 3 morning, T9: day 3 afternoon, T10: day 3 evening, T11: day 4 morning, T12: day 4 afternoon, T13: day 4 evening); and 3) post-discharge (days 7, 14, 21, 30: T14–T17, with T14: day 7, T15: day 14, T16: day 21, T17: day 30). In-hospital measurements (T1–T13) utilized standardized hospital devices, while post-discharge measurements (T14–T17) used home monitors with standardized protocols. Independent Researcher C collected post-discharge data via telephone follow-ups, recording pain, blood pressure, and heart rate in a secure digital checklist. Due to the nature of the intervention, participant blinding was not maintained post-allocation; outcome assessors remained blinded, and validated tools with standardized instructions were used to mitigate reporting bias. The 30-day follow-up was selected to target the acute postoperative phase,

where pain, hemodynamic instability, and initial quality of life factors, such as symptom experience and self-efficacy, are most pronounced, enabling a preliminary assessment of intervention feasibility and short-term effects before longer-term studies (Bjørnnes et al., 2016; Jalili et al., 2024; Kim et al., 2022).

2.6. Analysis

Data distribution was assessed using Shapiro–Wilk tests to evaluate normality for all outcome variables. For quality of life (SF-36, non-normal distribution), Mann–Whitney U tests were used to compare between-group differences at baseline (T1) and 30 days post-discharge (T17). Wilcoxon signed-rank tests were used to assess within-group changes in SF-36 scores from T1 to T17. Effect sizes ($r = Z/\sqrt{N}$) were calculated for significant findings. Additionally, overall SF-36 total scores were analyzed using ANCOVA with baseline SF-36 total as a covariate to account for baseline differences. For pain (visual analog scale), systolic/diastolic blood pressure, and heart rate (normal

distribution), independent t-tests were used to compare between-group differences at each time point (T1, T2–T17). Repeated Measures ANOVA with the Greenhouse–Geisser correction was used to evaluate group-by-time interactions for pain, blood pressure, and heart rate across the time points (T1, T2–T17). Effect sizes (Cohen's d) were computed for significant t-test and ANOVA results. Normality was verified using the Shapiro–Wilk test, and homoscedasticity was confirmed using Levene's test and residual plots. The Benjamini–Hochberg procedure was applied to adjust for multiple testing across the SF-36 domains. An intention-to-treat analysis with last-observation-carried-forward was used to handle missing data, given minimal dropout (4 participants). Descriptive statistics (mean, standard deviation, frequency) summarized demographic and clinical characteristics. Chi-square or Likelihood Ratio tests (for expected cell counts <5) were used to compare categorical variables. All analyses were conducted using SPSS version 26, with a significance threshold of $p < 0.05$.

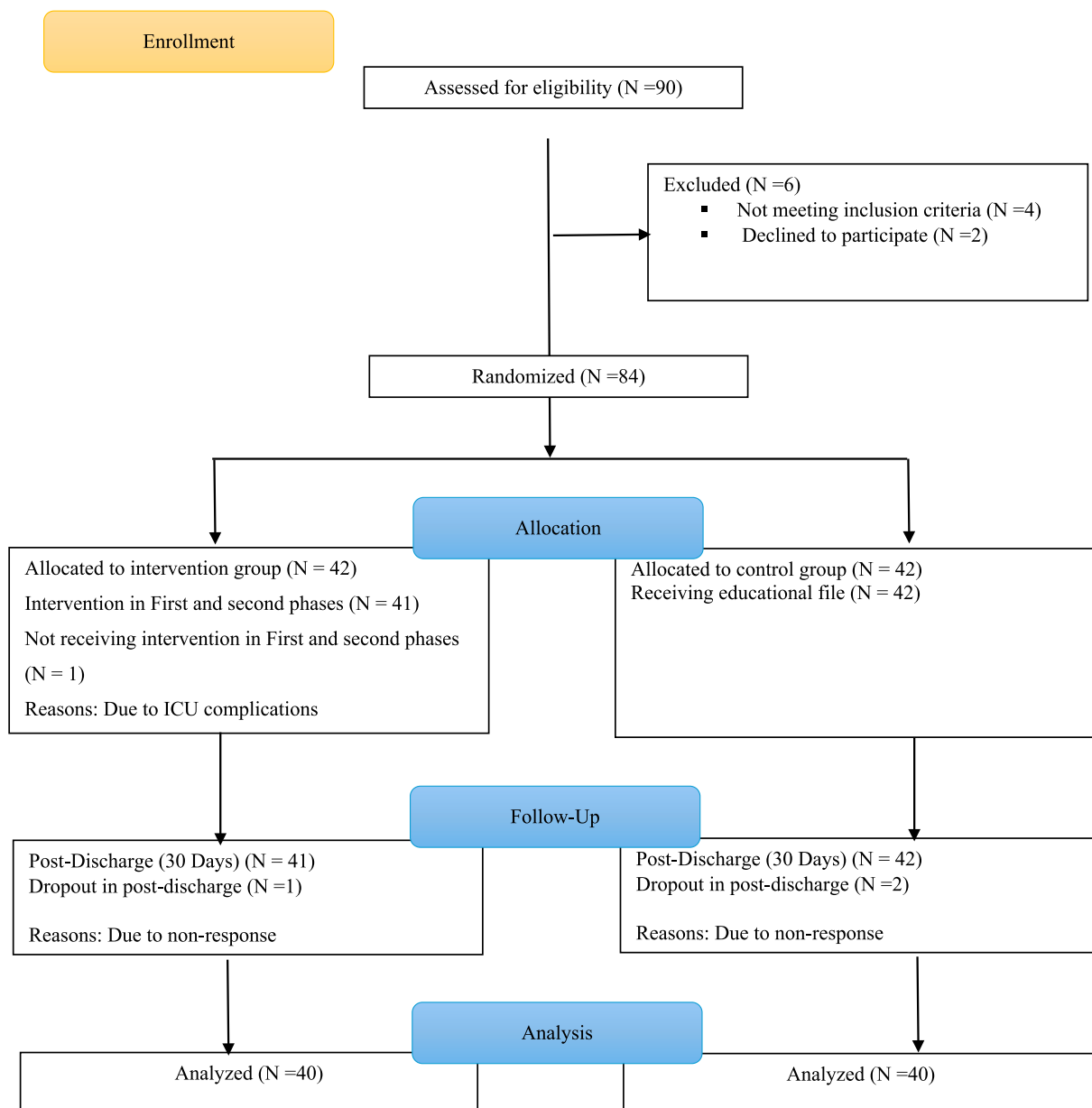


Fig. 1. Participant flow diagram (CONSORT 2025).

2.7. Ethics approval and informed consent

The study adhered to the Declaration of Helsinki (Shrestha and Dunn, 2019). Written informed consent was obtained, with the right to withdraw. The data were anonymized and stored on a password-protected server, ensuring compliance with international data protection standards. The study was approved by the Ethics Committee of Shahid Sadoughi University of Medical Sciences (IR.SSU.REC.1402.145).

3. Results

3.1. Participant flow

Of 90 screened patients, 84 (93.3%) were enrolled and randomized to the intervention (n = 42) or control (n = 42) groups. Six patients were excluded (2 declined participation, 4 did not meet the inclusion criteria). One participant from the intervention group was lost during the in-hospital phase (due to ICU complications), and three participants (1 intervention, 2 control) were lost post-discharge (due to non-response), resulting in 80 participants (40 per group) for analysis. The CONSORT flow diagram is presented in Fig. 1.

3.2. General characteristics

The general characteristics of the participants are summarized in Table 2. The intervention and control groups were comparable in terms of age (p = 0.558), sex (p = 0.626), education (p = 0.083), occupation (p = 0.148), type of coronary artery bypass grafting (p = 0.796), history of previous hospitalization for major surgeries (p = 0.637), history of diabetes (p = 0.823), history of hypertension (p = 0.651), and ejection fraction (p = 0.849), indicating successful randomization. All participants were married, precluding statistical comparison for marital status.

3.3. Engagement and adherence

Platform logs confirmed 98.5% message delivery success; all participants installed the application. Phase 1 video views averaged 89%. Patient/caregiver response rates were 88% at day 7 and 75% at day 30. No app-related dropouts occurred.

3.4. Quality of life (SF-36)

SF-36 total and domain scores showed non-normal distribution (Shapiro-Wilk, $p < 0.001$). Mann-Whitney U tests revealed no significant between-group differences in total SF-36 scores at baseline (intervention: 37.63 ± 9.68 vs. control: 38.70 ± 11.53 , $p = 0.697$, 95% CI for unadjusted mean difference – 5.81 to 3.67) or day 30 (32.00 ± 3.62 vs. 31.86 ± 2.62 , $p = 0.840$, 95% CI for unadjusted mean difference – 1.27 to 1.55). The pain domain improved significantly in the intervention group (mean rank 47.0 vs. 34.0, $p = 0.002$, $r = -0.35$, 95% CI for difference 5.2 to 14.8). No other domains showed significant group differences (Table 3). To account for baseline differences, overall SF-36 total scores at day 30 were additionally analyzed using ANCOVA with baseline SF-36 total as a covariate. The estimated marginal means were 32.00 (95% CI 31.00 to 33.01) for the intervention and 31.85 (95% CI 30.85 to 32.85) for the control. The adjusted mean difference was 0.15 (95% CI – 1.27 to 1.57), $p = 0.832$, indicating no significant between-group difference. The model showed a non-significant covariate effect for baseline ($p = 0.830$) and a very small group effect (partial $\eta^2 = 0.001$). Levene's test indicated unequal variances ($p < 0.001$).

3.5. Pain (visual analog scale)

The Shapiro-Wilk test confirmed normal distribution ($p > 0.05$). Independent t-tests showed no significant between-group difference at

Table 2

General characteristics of participants.

Variable	Intervention (n = 40)	Control (n = 40)	P-value ^a
Age, n (%)			
40–49	3 (7.5%)	4 (10%)	0.558
50–59	9 (22.5%)	12 (30%)	
60–69	17 (42.5%)	18 (45%)	
70–79	10 (25%)	6 (15%)	
80–85	1 (2.5%)	0 (0%)	
Sex, n (%)			
Male	27 (67.5%)	29 (72.5%)	0.626
Female	13 (32.5%)	11 (27.5%)	
Education, n (%)			
Illiterate	15 (37.5%)	7 (17.5%)	0.083
Primary	17 (42.5%)	22 (55%)	
Secondary	1 (2.5%)	5 (12.5%)	
Diploma	7 (17.5%)	5 (12.5%)	
Higher	0 (0%)	1 (2.5%)	
Occupation, n (%)			
Homemaker	12 (30%)	11 (27.5%)	0.148
Employed	23 (57.5%)	17 (42.5%)	
Retired	5 (12.5%)	12 (30%)	
Type of CABG, n (%)			
On-pump	22 (55%)	24 (60%)	0.796
Off-pump	18 (45%)	16 (40%)	
History of previous hospitalization for major surgeries, n (%)			
Yes	15 (37.5%)	13 (32.5%)	0.637
No	25 (62.5%)	27 (67.5%)	
History of diabetes, n (%)			
Yes	14 (35%)	15 (37.5%)	0.823
No	26 (65%)	25 (62.5%)	
History of hypertension, n (%)			
Yes	20 (50%)	22 (55%)	0.651
No	20 (50%)	18 (45%)	
Ejection fraction, n (%)			
Low (< 40%)	8 (20%)	7 (17.5%)	0.849
Normal (40–55%)	24 (60%)	26 (65%)	
High (> 55%)	8 (20%)	7 (17.5%)	

^a P-values from Chi-square or Likelihood Ratio tests.

baseline (T1: 0.26 ± 0.00 vs. 0.26 ± 0.00 , $p = 1.000$) or day 1 evening (T3: 5.50 ± 0.50 vs. 5.73 ± 0.55 , $p = 0.062$). Significant differences were observed at all other time points (T2, T4, T5–T17, $p < 0.05$), with lower pain scores in the intervention group (Fig. 2A). Repeated Measures ANOVA revealed a significant group-by-time interaction ($F(2.893, 222.772) = 2.898$, $p = 0.038$, $\eta^2 = 0.036$, Greenhouse–Geisser correction). In-hospital phase (T2–T13): 3.96 ± 0.42 vs. 4.29 ± 0.35 , mean difference – 0.33, 95% CI – 0.50 to – 0.16, $d = -0.85$. Post-discharge phase (T14–T17): 1.45 ± 0.38 vs. 2.01 ± 0.50 , mean difference – 0.56, 95% CI – 0.76 to – 0.36, $d = -1.26$. Mean pain scores are summarized in Table 4.

3.6. Systolic blood pressure

The Shapiro-Wilk test confirmed normal distribution ($p > 0.05$). Independent t-tests showed no significant between-group differences at baseline (T1: 128.18 ± 10.18 vs. 128.13 ± 10.23 , $p = 0.418$) or most in-hospital time points (T2–T8, T10, $p > 0.05$). Significant differences were observed on day 3 evening (T9: $p = 0.036$), day 4 (T11–T13: $p \leq 0.004$), and all post-discharge time points (T14–T17: $p < 0.01$), with lower

Table 3

Comparison of SF-36 domain mean ranks between intervention and control groups.

Domain	Time	Intervention (n = 40)	Control (n = 40)	P-value ^a	Effect size (r) ^b
Physical functioning	T1	39.76	41.24	0.773	–
	T17	38.23	42.78	0.318	–
Role limitations (physical)	T1	40.00	41.00	0.646	–
	T17	40.50	40.50	1.000	–
Pain	T1	38.31	42.69	0.373	–
	T17	47.00	34.00	0.002	–0.35
General health	T1	41.54	39.46	0.684	–
	T17	42.96	38.04	0.330	–
Vitality	T1	39.20	41.80	0.591	–
	T17	41.64	39.36	0.582	–
Social functioning	T1	39.04	41.96	0.562	–
	T17	43.20	37.80	0.233	–
Role limitations (emotional)	T1	40.00	41.00	0.646	–
	T17	40.50	40.50	1.000	–
Mental health	T1	39.78	41.23	0.777	–
	T17	42.23	38.45	0.409	–

^a P-values from the Mann–Whitney *U* test.

^b Effect size ($r = Z/\sqrt{N}$) to be calculated for significant findings ($P < 0.05$).

values in the intervention group (Fig. 2B). Repeated Measures ANOVA revealed a significant group-by-time interaction ($F(7.124, 548.538) = 6.225, p < 0.001, \eta^2 = 0.075$, Greenhouse–Geisser correction). In-hospital phase (T2–T13): 120.55 ± 2.85 vs. 121.94 ± 2.22 , mean difference -1.39 , 95% CI -2.53 to -0.25 , $d = -0.54$. Post-discharge phase (T14–T17): 118.48 ± 4.44 vs. 122.37 ± 2.77 , mean difference -3.89 , 95% CI -5.54 to -2.24 , $d = -1.05$. Mean values are summarized in Table 4.

3.7. Diastolic blood pressure

The Shapiro–Wilk test confirmed normal distribution ($p > 0.05$). Independent t-tests showed no significant between-group differences at baseline (T1: 78.23 ± 7.46 vs. $79.65 \pm 8.17, p = 0.085$) or most time points (T3–T13, T15–T17, $p > 0.05$), except for day 1 morning (T2: $p = 0.004$) and day 7 post-discharge (T14: $p = 0.016$), with lower values in the intervention group (Fig. 2C). Repeated Measures ANOVA revealed a significant group-by-time interaction ($F(8.826, 679.616) = 2.977, p = 0.002, \eta^2 = 0.037$, Greenhouse–Geisser correction), indicating differential changes in diastolic blood pressure between groups over time. In-hospital phase (T2–T13): 80.09 ± 2.39 vs. 79.30 ± 2.45 , mean difference 0.79 , 95% CI -0.27 to 1.85 . Post-discharge phase (T14–T17): 77.75 ± 3.04 vs. 78.87 ± 2.10 , mean difference -1.12 , 95% CI -2.45 to 0.21 . Effect sizes (Cohen's *d*) were not calculated for the in-hospital ($p = 0.147$) or post-discharge ($p = 0.060$) phases due to non-significant t-test results. Mean diastolic blood pressure is summarized in Table 4.

3.8. Heart rate

The Shapiro–Wilk test confirmed normal distribution ($p > 0.05$). Independent t-tests showed no significant between-group differences at baseline (T1: 85.68 ± 7.45 vs. $88.58 \pm 7.43, p = 0.452$) or most in-hospital time points (T2–T10, $p > 0.05$). Significant differences were observed on day 4 (T11–T13: $p \leq 0.023$) and all post-discharge time points (T14–T17: $p < 0.01$), with lower heart rates in the intervention group (Fig. 2D). Repeated Measures ANOVA revealed a significant group-by-time interaction ($F(4.706, 362.330) = 2.366, p = 0.043, \eta^2 = 0.030$, Greenhouse–Geisser correction). In-hospital phase (T2–T13): 94.31 ± 4.89 vs. 96.35 ± 5.35 , mean difference -2.04 , 95% CI -4.35 to 0.27 . Post-discharge phase (T14–T17): 78.55 ± 4.62 vs. 82.97 ± 3.25 , mean difference -4.42 , 95% CI -6.41 to -2.43 , $d = -1.11$. This

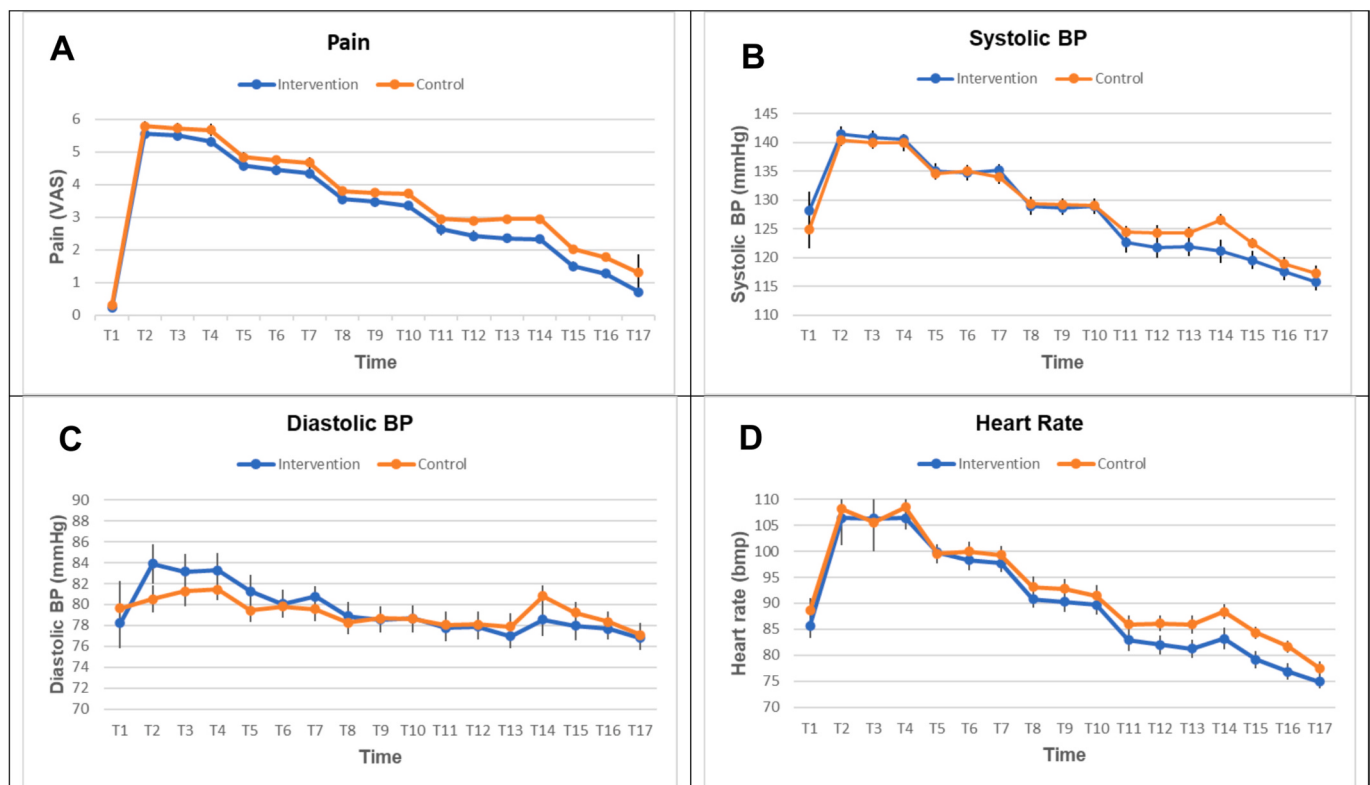


Fig. 2. Longitudinal changes in pain, blood pressure, and heart rate. (A) Pain (visual analog scale) scores over time (T1, T2–T17) for intervention (blue) and control (orange) groups, with 95% confidence intervals. (B) Systolic blood pressure (mmHg) over time. (C) Diastolic blood pressure (mmHg) over time. (D) Heart rate (bpm) over time. Significant between-group differences ($p < 0.05$) are reported in the text and Table 4. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 4

Comparison of pain, blood pressure, and heart rate between intervention and control groups across time points.

Outcome	Time	Intervention (n = 40) M ± SD	Control (n = 40) M ± SD	P-value ^a (t-test)	Effect size ^b (d)	F ^c (time * group)	P-value (ANOVA)	Partial η^2
Pain visual analog scale (VAS)	Baseline (T1)	0.26 ± 0.00	0.26 ± 0.00	1.000	–	2.898 (2.893, 222.772)	0.038	0.036
	Phase 2 Avg (T2–T13)	3.96 ± 0.42	4.29 ± 0.35	<0.001	–0.85			
	Phase 3 Avg (T14–T17)	1.45 ± 0.38	2.01 ± 0.50	<0.001	–1.26			
Systolic blood pressure (mmHg)	Baseline (T1)	128.18 ± 10.18	128.13 ± 10.23	0.418	–	6.225 (7.124, 548.538)	<0.001	0.075
	Phase 2 Avg (T2–T13)	120.55 ± 2.85	121.94 ± 2.22	0.017	–0.54			
	Phase 3 Avg (T14–T17)	118.48 ± 4.44	122.37 ± 2.77	<0.001	–1.05			
Diastolic blood pressure (mmHg)	Baseline (T1)	78.23 ± 7.46	79.65 ± 8.17	0.085	–	2.977 (8.826, 679.616)	0.002	0.037
	Phase 2 Avg (T2–T13)	80.09 ± 2.39	79.30 ± 2.45	0.147	–			
	Phase 3 Avg (T14–T17)	77.75 ± 3.04	78.87 ± 2.10	0.060	–			
Heart rate (bpm)	Baseline (T1)	85.68 ± 7.45	88.58 ± 7.43	0.452	–	2.366 (4.706, 362.330)	0.043	0.030
	Phase 2 Avg (T2–T13)	94.31 ± 4.89	96.35 ± 5.35	0.079	–			
	Phase 3 Avg (T14–T17)	78.55 ± 4.62	82.97 ± 3.25	<0.001	–1.11			

^a P-values from independent *t*-tests.^b Effect size (Cohen's *d*) calculated for significant *t*-test findings ($P < 0.05$).^c F (time × group), P-value (ANOVA), and partial η^2 from Repeated Measures ANOVA (Greenhouse–Geisser correction) for group-by-time interaction; Avg = average values across specified time points (Phase 2: T2–T13; Phase 3: T14–T17).

interaction indicated greater reductions in heart rate over time in the intervention group. Mean heart rates are summarized in Table 4.

4. Discussion

This study evaluated a nurse-led, smartphone-based educational and follow-up intervention for patients undergoing coronary artery bypass grafting, focusing on pain, quality of life, and haemodynamic parameters. The intervention significantly reduced pain scores across multiple time points (days 2, 7, 14, 21, and 30 post-discharge; $p < 0.05$, $\eta^2 = 0.15$), except on day 1 evening, likely due to standardized analgesic protocols. The intervention's components — education on pain management, deep breathing, positional changes, and timely help-seeking — likely enhanced patients' coping strategies and reduced anxiety, which exacerbates pain perception (Arrafi et al., 2022; Babamohamadi et al., 2021; Sinderovsky et al., 2023). This aligns with findings that smartphone-based perioperative nursing interventions have also been shown to improve pain self-management (Awaludin et al., 2022). A review study also highlighted that non-pharmacological approaches can provide pain relief without analgesic side effects, such as nausea or sedation (Niyonkuru et al., 2025). Another systematic review reported that numerous interventions, including nurse-led strategies combined with appropriate analgesic use, effectively reduced postoperative pain in cardiac surgery patients across reviewed studies (de Andrade et al., 2024). Methodological flaws in pain assessment highlight the need for more rigorous research. Our intervention used frequent, structured smartphone follow-ups to provide education, monitor pain, and offer real-time, tailored guidance, which may have contributed to the observed pain reduction.

The intervention significantly improved the pain domain of quality of life ($p < 0.05$, $\eta^2 = 0.15$), suggesting that targeted education effectively addressed pain-related quality of life, likely through enhanced self-efficacy and reduced anxiety. Symptom experience and self-efficacy are key predictors of quality of life in the acute postoperative phase, supporting the intervention's impact on this domain (Kim et al., 2022; Sadeghi et al., 2025). Overall quality of life showed no significant between-group difference at 30 days, consistent across non-parametric tests and adjusted ANCOVA. While most subdomains did not differ, the pain domain improved in the intervention group, aligning with

reductions in pain intensity. These findings suggest targeted benefits for pain, whereas broader quality-of-life recovery may require longer-term or multi-component support (Pačarić et al., 2020). This pattern highlights the need for extended follow-up (e.g., 6–12 months) or integrated psychological support to address global recovery, as short-term programmes may capture only the acute burden of coronary artery bypass grafting (Li et al., 2024).

Longer interventions (6–12 months) have demonstrated broader improvements in quality of life, suggesting that short-term programmes may be insufficient for comprehensive gains. Variations in quality of life outcomes across studies often stem from differences in follow-up duration, intervention design, or methodology, including quasi-experimental approaches (Li et al., 2024).

Hemodynamic parameters showed varied outcomes. Systolic blood pressure and heart rate significantly decreased ($p < 0.05$, $\eta^2 = 0.13$ for systolic blood pressure; $\eta^2 = 0.11$ for heart rate), particularly post-discharge (days 7, 14, 21, 30), but these differences should be interpreted cautiously given the short follow-up and mixed in-hospital findings (Chehri, 2022). Observed reductions (~4 mmHg in systolic blood pressure, ~4 bpm in heart rate) are modest and exploratory, and may reflect improved comfort and self-management, requiring confirmation in longer-term studies (Atia et al., 2023; Dyke et al., 2019). In contrast, diastolic blood pressure showed no consistent significant differences, except on day 1 in the morning, likely due to its sensitivity to chronic vascular factors, such as arterial stiffness, rather than to short-term educational interventions (Betz et al., 2018). Digital health interventions have similarly reduced systolic blood pressure, but diastolic changes often require longer-term or pharmacological approaches (Wu et al., 2023).

4.1. Limitations

This study has several limitations. First, being conducted at a single tertiary care center in Shiraz, Iran, limits generalizability to diverse healthcare settings. Second, variability in internet access and digital literacy, combined with missing granular analytics (e.g., dwell time, open rates, per-video completion), restricts conclusions about adherence; although observed delivery, viewing, and response rates suggest adequate exposure, future trials should integrate in-platform

engagement metrics (Cajita et al., 2018). Using messaging platforms instead of a dedicated application limited access to advanced features, such as automated reminders. Third, the 30-day follow-up was insufficient to capture long-term outcomes like quality of life, as coronary artery bypass grafting recovery extends over months, potentially missing delayed improvements. Fourth, minimal standard care in the control group may have exaggerated intervention effect sizes, though justified by resource constraints; differential attention and support (weekly contact plus messaging in the intervention vs. two calls in routine care) may have influenced outcomes (attention/support bias). Future trials should consider attention-matched comparators. Finally, participant blinding was unfeasible, so pain and quality of life were self-reported, introducing expectation and response bias despite validated tools; baseline psychological, literacy, and socioeconomic factors were also uncontrolled. Future studies should use longer follow-ups, robust engagement metrics, and multivariate adjustments to address these issues.

5. Conclusion

This study suggests that a nurse-led, smartphone-based intervention can reduce pain intensity, systolic blood pressure, and heart rate after coronary artery bypass grafting. However, no significant between-group differences were observed in overall quality of life or most subdomains. The pain domain of quality of life and pain intensity improved in the intervention group, while haemodynamic findings are exploratory and require longer-term evaluation. These results point to the value of low-cost, nurse-led, technology-supported strategies for early recovery, while emphasizing the need for more comprehensive, multi-phase follow-ups incorporating psychological support, family involvement, and interdisciplinary collaboration. Future research should include extended (6–12 month) follow-up, mental health assessments, integration with primary care, and robust randomized controlled trial designs to evaluate long-term benefits and scalability.

CRediT authorship contribution statement

Mohammadamin Mahmoodi: Writing – original draft, Methodology, Investigation, Conceptualization. **Mahnaz Antikchi:** Writing – original draft, Supervision, Investigation, Conceptualization. **Shaghayegh Saeidinasab:** Writing – original draft, Methodology, Investigation. **Fatemeh Bakhshi:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis.

Consent for publication

Not applicable.

Declaration of Generative AI and AI-assisted technologies in the writing process

Generative AI tools (Grammarly v1.233.1 and QuillBot, May 2025) were used only to enhance language and readability under full human supervision. All content was reviewed and revised by the authors, who remain fully responsible for the manuscript's accuracy and integrity.

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Declaration of competing interest

The authors declare no financial or nonfinancial conflicts of interest regarding the present research.

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Data availability

The datasets for the current study are available from the corresponding author upon reasonable request.

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