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The effect of a smartphone-based application on the self-efficacy of heart valve surgery patients and their family caregivers` burden: a randomized clinical trial

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Abstract

Background Heart valve replacement has many complications that affect patients and their family caregivers. Increasing patients' self-efficacy in dealing with complications and reducing the care burden of their caregivers are among the critical factors that impact their quality of life. Today, smartphone Apps allow access to reliable information without time and place restrictions. It also facilitates teaching and learning through low-cost and easily accessible methods.

Objective This study was conducted to examine the effect of a smartphone App on the care burden of family caregivers and self-efficacy of patients undergoing heart valve surgery.

Methodology A randomized clinical trial study with a pre-test / post-test design was conducted. Sixty patients undergoing mechanical heart valve surgery were referred to the Shahid Modarres Hospital and PT clinic in Tehran, and their family caregivers were randomly divided into intervention and control groups. The App was installed on the patients' smartphones for educational purposes, and they were given 8 weeks to use it. Sullivan's cardiac self-efficacy questionnaire and Novak and Guest's care burden questionnaire were completed for patients and their caregivers in both groups before and after the intervention, respectively. Data was statistically analyzed using descriptive and inferential statistics through SPSS-18 software.

Findings There was no statistically significant difference between the two groups regarding demographic characteristics and the mean scores of self-efficacy and care burden before the intervention. However, after the intervention, the mean self-efficacy score increased to 47.43 ± 5.43 in the intervention group and 32.23 ± 3.25 in the control group, showing a significant improvement in patients' self-efficacy in the intervention group ($P < 0.001$). Although the mean self-efficacy score slightly increased in the control group, this increase was not statistically significant ($P = 0.094$). Furthermore, the mean score of care burden of caregivers after the intervention increased to 45.33 ± 6.34 in the intervention group and 53.86 ± 6.80 in the control group, showing a significant decrease in the care burden of caregivers in the intervention group compared to those in the control group ($P < 0.001$).

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Conclusion Based on the results, the designed smartphone App improved the self-efficacy of patients undergoing heart valve surgery while reducing the care burden of their family caregivers. Therefore, this App is recommended due to its effectiveness, ease of use, and low cost.

Trial registration Prospectively registered with the Iranian Registry of Clinical Trials on 11 March 2023; registration code: IRCT20210714051889N1.

Keywords Educational program, Smartphone App, Self-efficacy, Care burden, Heart valve surgery, Family caregivers

Introduction

The prevalence of cardiovascular diseases (CVD) (comprising CHD, HF, stroke, and hypertension) in adults aged 20 years and older was determined to be 48.6% (127.9 million) in a 2023 statistical update; this prevalence increases with age in both males and females [1].

Cardiovascular diseases are one of the leading causes of death worldwide [2]. Every year, more than 17 million people die due to cardiovascular diseases [2]. In Iran, 45% of deaths are due to cardiovascular diseases, and it is considered to be the first cause of death among adults [3]. Meanwhile, heart valve diseases are of great importance due to their chronic and progressive nature. Heart valve surgery is considered the last line of treatment for this disease [3]. In Iran, 23.8% of heart surgeries are related to heart valve repair or replacement [4]. Breathing problems, heart palpitations and atrial fibrillation, sleep problems, bleeding, changes in daily activities, risk of thromboembolism, endocarditis, and valve dysfunction are among the most critical complications of post valve surgery [5]. These complications weaken the quality of life of cardiac patients and require high self-efficacy to manage them [6, 7].

Self-efficacy is a broad psychosocial concept that is usually used in connection with the management of chronic diseases. It also plays a vital role in health-related behaviours and adherence to preventive programs [8]. Self-efficacy increases the patient's motivation, self-care, and quality of life. Since self-efficacy improves the patient's quality of life, it has attracted the attention of researchers and specialists in various fields [9]. Improving self-efficacy can help maintain health and well-being, increase patient compatibility, and reduce disability and treatment costs [8].

On the other hand, family is one of the important sources of support for patients undergoing heart valve replacement after returning home and going through post-surgery critical conditions [10]. Family caregivers play an important role in patients' physical and psychological support. They are considered one of the main pillars of the care system and contribute the greatest to patient care [11]. Managing chronic diseases at home is a complex issue that requires multidimensional care and services. Caring for chronic patients is associated with a high psychological burden for caregivers [12]. The term "care burden" is generally used to describe different aspects of stress and pressure that result from an imbalance between care demands and access to resources to meet them [13]. In this situation, family caregivers need rehabilitation nursing to help them meet the demands of the patients they care for [14]. Therefore, in line with holistic care, rehabilitation care is provided on a family-centred basis to the patient's family and the patient himself, considering the family's important role in the patient's rehabilitation [15].

Education is one of the most important methods to reduce the care burden [13], improve self-efficacy [16]. Therefore, providing various educational interventions emphasizing patient needs increases the patients' knowledge and helps them adapt to post-surgery conditions. Teaching communication and problem-solving skills to increase patients' ability to take care of themselves can also help reduce complications related to surgery and improve the knowledge of family caregivers, which is also considered a necessity [16]. Appropriate training and teaching approaches compatible with the patient's condition are also among the important interventions [15]. The World Health Organization defines digital health as " digital health is the field of knowledge and practice associated with the development and use of digital technologies to improve health." [17]. In recent years, the increasing use of smartphones and other technological tools and applications shows that health education through smartphones will be a significant force in health care [18].

Recently, the number of studies in this area has been increasing. The results of one study showed that a mobile-based health intervention led to significant improvements in self-care of patients with heart failure [19]. A systematic review and meta-analysis also found that multiple behaviors such as self-managements and cardiovascular risk factors can be modified in the short-term using mobile apps. The authors of the mentioned study stated that evidence for effectiveness requires larger, controlled studies with longer durations [20]. Another study also evaluated the impact of a self-management mobile phone application on patient adherence to hypertension treatment. The study showed that the application can be used as a successful tool for self-management of hypertension in patients

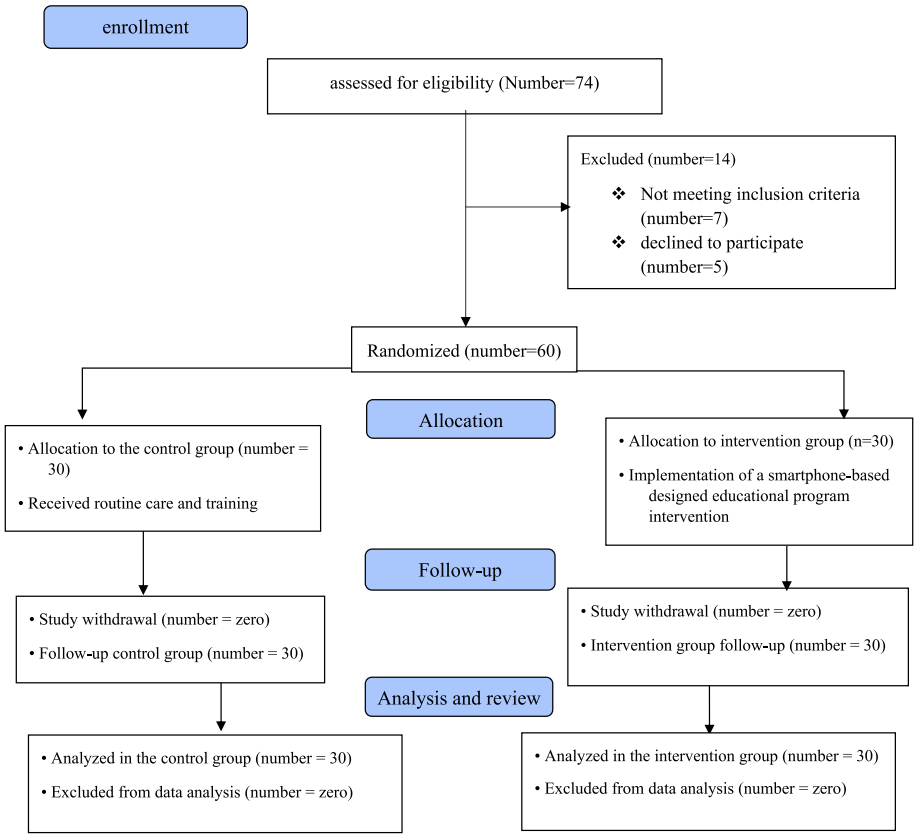

Fig. 1 Flowchart No. 1. Consort

attending public hospitals in developing countries [21]. Although mobile phone-based studies are frequently conducted in other patients with CVD, they have had very limited application in patients undergoing valve surgery.

Given the significance of readily available, ongoing education for cardiovascular patients and the proliferation of smartphone technology, and in the absence of prior research on designing and evaluating a smartphone application for educating patients undergoing heart valve surgery, we conducted a study aimed to evaluate the effects of a smartphone-based educational application on the caregiving burden of family members and the self-efficacy of patients who haveundergone heart valve surgery.

Materials and methods

This study is reported based on the Consolidated Standards of Reporting Randomised Controlled Trials (RCTs) of Social and Psychological Interventions (CONSORT-SPI) 2018 [22].

Study design

This parallel randomized controlled trial study with a pre-test / post-test design was conducted from 14 March 2023 to 20 December 2023 in a hospital affiliated with the Shahid Beheshti University of Medical Sciences, Tehran, Iran. The sample size consisted of 60 participants ($n=30$ in each group; intervention group (A) and control group (B)). Exclusions were made for ten participants throughout the study and follow-up period (Fig. 1).

Participants

The research population included patients undergoing mechanical heart valve replacement surgery and their family caregivers who visited the cardiac clinic for periodic examinations in Shahid Modarres Hospital, Tehran, Iran. The inclusion and exclusion criteria regarding patients and their formal caregivers are defined as follows:

Heart valve surgery patients

Inclusion criteria

The entry criteria for the patients included:

- an age range of 18 to 65 years,
- having an Android smartphone,
- undergoing mechanical heart valve replacement surgery for the first time,
- and not having auditory, visual,or tactile disorders.

Exclusion criteria

The exclusion criteria included:

- suffering from any other physical illnesses than heart valve disease,
- having well-known physical or mental disorders (i.e., dialysis, depression, schizophrenia),
- entering the acute phase of the disease,
- re-hospitalization, and death of the patient.

Caregivers

Inclusion criteria

The entry criteria for caregivers included:

- not being a member of a medical or treatment team,
- caring for a patient at least twice a week,
- being a first-degree family member of the patient,
- having at least a minimum level of literacy,
- and caring for a patient undergoing heart valve replacement surgery for the first time.

Exclusion criteria

The exclusion criteria were:

- Caregivers` patients dying during the study,
- previously participating in education sessions related to this research,
- taking care of another patient in addition to the patient suffering from heart valve surgery,
- having a known mental disorder,
- and being a healthcare worker.

Sample size

The sample size was calculated to be 52 people ($n=26$ in each group) using the Peacock formula $n = \frac{(Z_{1-\frac{\alpha}{2}}+Z_{1-\beta})^2(S_1^2+S_2^2)}{(\bar{x}_1-\bar{x}_2)^2}$ and information derived from the Ayer et al. (2021) study [23], considering 0.05 type 1 error and 90% power. However, after considering the 10% possibility of sample attrition, 60 people were considered for the study ($n=30$ in each group).

Randomization and blinding

Sampling was done using the convenient method, In the first stage of the study, random allocation was performed as block randomization in intervention and control groups. The statistical consultant obtained the random allocation sequence and the list of blocks based on the total sample size.In this study, the blocking method with the size of four was used to generate the random allocation sequence. According to the total number of samples required for the study, which was 60 individuals, the participants were placed in 15 quadruple blocks, including two groups of A (intervention) and B (control), obtained randomly. After generating a random sequence, sampling was implemented by concealment of the generated sequence; the random sequence was put inside opaque envelopes. For example, after randomly selecting the BBAB block, patients were assigned to the control, control, intervention, and control groups in the order of their entry, and the sampling process was carried out sequentially in the same way until the sampling was completed, and each patient's code was also assigned to his or her family member.

Educational material

The present study was conducted to design the content of smartphone educational applications. First, a literature review was conducted to extract related articles, books, programs, and academic booklets to determine the needs and interventions required for patients undergoing valve replacement surgery. Furthermore, to validate the educational program, its contents were given to five faculty members and specialists, including cardiologists, physiotherapists, nurses working in the cardiac department, CCU, and heart clinic, and five nursing professors who were experts in cardiac care. Consequently, their corrective comments and suggestions were considered and applied. After finalizing the content, a smartphone application was prepared with the help of experts in medical informatics and health information management. To check the face validity of the App, it was given to two patients and their opinions regarding the ease of use and satisfaction with the structure (shapes, word font, etc.) were considered and structural changes were made accordingly. Also, to assess the validity of the App's content (content Validity), it was given to three experts to examine it in terms of structure, content, and usability of the software, and their comments and suggestions were considered and used (Table 1).

Ethical considerations

This study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (code IR.SBMU.PHARMACY.REC.1401.166). To comply with the ethical principles, the patients entered the study voluntarily and were allowed to withdraw from the study at any time. Informed consent was also obtained from all patients. Confidentiality of personal data and information sources was also guaranteed, and the application was provided to the control group at the end of the study. It should be noted that this study was also registered in

Table 1 A summary of the application

Section	Content of the App	Aim	Method
1	Overview of heart valve failure and dysfunction, etiology, signs and symptoms, prevention and diagnosis Familiarity with medications, the need to use them, and their possible side effects The importance of careful use of drugs in case of disease exacerbation and prevention of re-hospitalization	To better understand the disease, its signs, symptoms, diagnosis, and the need to prevent it, Increase the knowledge of medications, their necessity, and their side effects	Using the smartphone application Question and answer during telephone follow-up
2	Explanation on how to properly take care of themselves and its aspects Explanation of the importance of managing patients' signs and symptoms in emergency cases Explanation of the importance and necessity of changing the patient's lifestyle, including following a proper diet, movement and exercise, following a medication schedule, quitting smoking, and controlling weight	Improving the patient's self-care ability Increasing the patient's knowledge and skill to control the condition	Using the smartphone application Question and answer during telephone follow-up
3	Discussion on how to adapt to the disease for patients	Promotion and improvement of strategies	Using the smartphone application Question and answer during telephone follow-up
4	Following up on the educational and support needs of the patient Answering the questions	Meeting the unique educational and support needs of patients and providing guidance	Using the smartphone application Question and answer during telephone follow-up

the Clinical Trial Registration Center of Iran with code IRCT20210714051889N1.

Intervention

At first, the patients completed the demographic information questionnaire and Sullivan's cardiac self-efficacy questionnaire (SCSES). Also, caregivers were asked to complete the Caregiver Burden Inventory (CBI) questionnaire. Then, the researcher installed an educational app on patients' smartphones in the intervention group. They were also taught in a session on how to use the application. Both groups also used the routine training programs provided by the cardiac clinic. During the intervention, the researcher contacted the participants through phone calls (one phone call every four weeks to check the program's content), and participants were told to ask their questions via a WhatsApp group. After 8 weeks of intervention, participants and their caregivers were asked to complete the self-efficacy and burden of care questionnaires.

Control

The control group was given routine training. This group did not receive additional training. The questionnaires were completed before and 8 weeks after the training. At the end of the study, the App was also provided to participants in the control group for ethical considerations.

Instrumentation

Data collection tools included a demographic information questionnaire, Sullivan's cardiac self-efficacy scale (SCSES), and Novak and Guest's care burden questionnaire. The following are the instruments utilized in this study:

Patients' demographic questionnaire

The first section was demographic characteristics, including age, gender, marital status, occupational status, education level and replaced valve type.

Caregivers' demographic questionnaire

Information included age, gender, relationship with the patient, marital status, education level and occupational status.

The Sullivan Self-Efficacy Questionnaire

The Sullivan Self-Efficacy Questionnaire has 16 questions that evaluate the patient's self-efficacy in terms of compliance with general care, control of disease symptoms, and adherence to medication regimen. This questionnaire is scored on a 5-point Likert scale, including completely (score 4), very (score 3), almost (score 2), a little (score 1), and not at all (score 0). The total score of this questionnaire is between 0–64, with higher scores indicating higher self-efficacy. Scores of 0–32 on this scale indicate low self-efficacy, and scores of 33–64 reflect high self-efficacy. Shamsizadeh (2012) confirmed the face and

content validity and reliability of this scale by reporting a Cronbach's alpha of 0.97 for the entire questionnaire [24].

Caregiver Burden Inventory (CBI)

The Novak and Guest's care burden questionnaire, created in 1989, has 24 items that measure the objective and subjective burden of care, emphasizing the subjective burden of care. This questionnaire has five subscales, including the time-dependent care burden, which examines the patient's dependence on the caregiver during the day and night (questions 1 to 5); the evolutionary care burden, which examines the patient's dependence on the caregiver and the caregiver's restriction in doing their works (questions 6 to 10), the physical burden of care that deals with the caregiver's physical health and problems that arise during the care provision (questions 11 to 14), the social burden of care that examines the expectations and pressures that the caregiver has but are not met (questions 15 to 19) and the emotional burden of care, which examines the emotional and spiritual problems that the caregiver faces during the care provision (questions 20 to 24). This questionnaire is based on a five-point Likert scale, including completely disagree (score 1), disagree (score 2), somewhat agree (score 3), agree (score 4) and completely agree (score 5). Higher scores indicate a greater burden of care [25]. Novak and Guest have investigated the psychometric properties of this questionnaire. The factor analysis conducted in their research showed that five subscales of time-dependent care burden, evolutionary care burden, physical care burden, social care burden, and emotional care burden predict about 66% of the total care burden variance. They also performed the reliability assessment for each subscale of this tool, showing a Cronbach's alpha value of 0.85 for the subscales of time-dependent care burden and evolutionary care burden and values of 0.86, 0.73, and 0.77 for the subscales of physical burden of care, social burden of care and emotional burden of care, respectively. Also, in the study of Abbasi et al. (2013) in Iran, Cronbach's alpha coefficient was calculated to be 0.9 for the whole questionnaire and 0.72 to 0.82 for its subscales [26].

Statistical analysis

Data were analyzed by descriptive (mean, standard deviation, frequency) and analytical statistics (Chi-square, Fisher's exact, paired t, and independent t-tests) using SPSS-18 software. The Kolmogorov–smirnov test was used to examine the distribution of self-efficacy and caregiving burden variables, and both variables had a normal distribution and the p-value was less than 0.05. Parametric tests were used to compare means. Also, this study had an adequate sample size (≥ 30 in each group), and thus, the normality estimates are justified by invoking the central limit theorem [27]. We applied chi-squared tests and independent sample t-tests to evaluate the qualitative and quantitative demographic and main study variables between the two groups. Paired sample t-tests were employed to compare the means of quantitative variables for intra-group comparisons. A significance level of < 0.05 was considered for evaluation.

Findings

Demographic characteristics

Based on the results, the mean age of the patients was 52.50 ± 10.13 years in the intervention group and 49.20 ± 10.12 years in the control group, and mean age of the participants ranged between 51 and 65 years. Also, most patients in the intervention group (70%) and control group (60%) were male. Majority of patients in the intervention group (93.3%) and control group (90%), were married. Moreover, 56.7% in the intervention group and 53.3% in the control group were self-employed. Mean age of caregivers in intervention group was 46.00 ± 10.84 and in control group was 44.06 ± 8.56. Half of the caregivers in both groups were male. Most caregivers were the patients' wives (60% in the intervention group and 63.3% in the control group). Most of them were married (83.3% in intervention and 90% in control group). No significant statistical difference was observed between the two groups in terms of all demographic characteristics of patients and caregivers (see Tables 2 and 3).

Heart valve surgery patients' self-efficacy

The mean and standard deviation of self-efficacy score before the intervention was 29.90 ± 4.60 in the intervention group and 30.26 ± 5.45 in the control group, and there was no statistically significant difference between the two groups in this regard according to the independent t-test ($p = 0.780$). However, after the intervention, the mean and standard deviation of self-efficacy score increased to 47.43 ± 5.43 in the intervention group and 32.23 ± 3.25 in the control group, and independent t-test showed a statistically significant difference between the two groups in this regard ($p < 0.001$). In other words, the self-efficacy of patients in the intervention group had increased after the intervention. Comparing the mean and standard deviation of self-efficacy scores before and after the intervention in the intervention group by the paired t-test indicated a significant difference between the pre-intervention and post-intervention score of self-efficacies in the intervention group ($p < 0.001$). But in the control group, this difference was not significant ($p = 0.094$), (Table 4).

Table 2 Frequency and percentage distribution of demographic characteristics of patients undergoing heart valve surgery in the study in two groups

Variable	Category	Test		Control	
		Number	Percentage	Number	Percentage
Age (years)	20–35 years	2	6.7	3	10
	36–50 years	10	33.3	12	40
	51–65 Years	18	60	15	50
	Standard deviation ± mean	52.50 ± 10.13		49.20 ± 10.12	
	*P**=0.212				
Gender	Man	21	70	18	60
	Woman	9	30	12	40
	*P***=0.589				
Marital status	Single	2	6.7	3	10
	Married	28	93.3	27	90
	*P***=1				
Job	Employee	1	3.3	2	6.7
	Freelance job	17	56.7	16	53.3
	Retired	2	6.7	4	3/13
	Worker	1	3.3	0	0
	Housewife	9	30	8	26.7
	*P***=0.865				
Education level	Elementary and the literacy movement	1	3.3	0	0
	Undergraduate	13	43.3	11	36.7
	Diploma	8	26.7	7	23.3
	Associate and Bachelor's Degrees	8	26.7	12	40
	*P***=0.606				
Replaced valve	Mitral	14	46.7	12	40
	Aorta	14	46.7	15	50
	Tricuspid	2	6.7	3	10
	*P***=0.864				

*Independent t-test results

**Fisher's exact test

Caregiver burden

The mean and standard deviation of care burden score among the family caregivers before the intervention was 53.60 ± 4.23 in the intervention group and 54.30 ± 6.81 in the control group. Independent t-test showed no statistically significant difference between the two groups in this regard ($p = 0.635$). However, after the intervention, the mean and standard deviation of care burden score increased to 45.33 ± 6.34 in the intervention group and 53.86 ± 6.80 in the control group, and independent t-test showed a statistically significant difference between the two groups in this regard ($p < 0.001$). In other words, the care burden of family caregivers had significantly reduced in the intervention group after the intervention. Comparing the mean and standard deviation of care burden score among family caregivers in the intervention group by paired t-test indicated a significant difference between the pre-intervention and post-intervention scores ($p < 0.001$). But in the control group, no significant difference was observed in this regard ($p = 0.157$), (Table 5).

Discussion

The results showed that the self-efficacy of patients undergoing heart valve surgery in the two intervention and control groups was not significantly different from each other before the intervention, but after the intervention, the self-efficacy of patients in the intervention group had significantly increased. Comparing the self-efficacy scores of patients before and after the intervention in the intervention group showed a significant difference between the pre-test and post-test scores. But in the control group, this difference was not significant.

In this regard, the research of Elsayed et al. (2024) suggested a deficiency in self-efficacy within the cardiac surgery patient population [28]. Dawa et al. [29] study indicated a heightened risk of burden among caregivers

Table 3 Frequency and percentage distribution of demographic characteristics of family members of patients undergoing heart valve surgery in the study in two groups

Variable	Category	Test		Control	
		Number	Percentage	Number	Percentage
Age (years)	20–35 years	6	20	4	13.3
	36–50 years	11	36.7	19	63.3
	51–65 years	13	43.3	7	23.3
	Mean ± standard deviation	46.00 ± 10.84		44.06 ± 8.56	
	*P**=0.447				
Gender	man	15	50	15	50
	woman	15	50	15	50
	*P****=1				
Relationship of family member to patient	Wife	18	60	19	63.3
	Boy	8	26.7	5	16.7
	Girl	2	6.7	3	10
	Father	2	6.7	2	6.7
	Brother	0	0	1	3.3
	*P***=0.88				
Marital status	Single	5	16.7	3	10
	Married	25	83.3	27	90
	*P***=0.706				
Education level	Elementary	1	3.3	0	0
	Undergraduate	8	26.7	9	30
	Diploma	8	26.7	10	33.3
	Associate's and Bachelor's degrees	13	43.3	11	36.7
	*P***=0.847				
Job	Employee	9	30	8	26.7
	Free	1	36.7	12	40
	Housewife	10	33.3	10	33.3
	*P****=1				

*Independent t-test

**Fisher's exact test

***Chi-square test

Table 4 Mean and standard deviation of self-efficacy of patients undergoing heart valve surgery before and after the intervention

Self-efficacy	Before the intervention		After the intervention		Paired t-test result		
Group	Average	Standard deviation	Average	Standard deviation			
Test	29.90	4.60	47.43	5.43	$P<0.001$	df = 29	t = −13.84
Control	30.26	5.45	32.23	3.25	0.094 = P	df = 29	t = −1.72
Independent t-test result	t = −0.28 df = 58 $P=0.780$		t = 13.14 df = 58 $P<0.001$				

due to their responsibilities. Furthermore, the study's findings indicated a high prevalence of caregiving burden among post-cardiac surgery patients [29]. The findings of a study conducted in 2019 by Bjørnnes et al. demonstrated the willingness of informal caregivers to assist in the postoperative care of their patients after cardiac surgery. Nevertheless, caregivers experience insecurity and a sense of being overwhelmed due to insufficient and unclear discharge instructions and inadequate follow-up support in the early post-discharge period at home [30].

Mobile devices are currently one of the most widely used technologies in the medical industry. The use of

Table 5 Mean and standard deviation of care burden score among the family caregivers of patients undergoing heart valve surgery before and after the intervention

Care burden	Before the intervention		After the intervention		Paired t-test result		
Group	Average	Standard deviation	Average	Standard deviation			
Test	53.60	4.23	45.33	6.34	$P<0.001$	df = 29	t = 5.57
Control	54.30	6.81	53.86	6.80	0.157 = P	df = 29	t = 1.45
Independent t-test result	t = −0.47 df = 58 $P=0.635$		t = −5.02 df = 58 $P<0.001$				

new educational methods such as smartphones can be effective in controlling diseases and their complications, especially in the elderly [31]. A comparative study conducted in 2016 by Voutilainen et al. demonstrated that e-learning achieved higher scores than conventional teaching methods [32]. In addition, research published in 2021 by Chen et al. suggested that mobile learning can enhance clinical nursing education [33]. Similar results were observed regarding the effectiveness of mobile phone-based interventions in improving self-efficacy in patients with thalassemia and gestational diabetes, such that these interventions were significantly associated with improving self-efficacy in this group of patients [34, 35]. Cai et al.`s study (2022) showed a significant increase in the physical activity, exercise self-efficacy and aerobic capacity of participants. Their study also showed a significant increase in the adherence to rehabilitation programs in the intervention group compared to the control group [36]. Ebrahimi et al. in their study showed that after the intervention, participants` self-efficacy improved in all dimensions, including personal responsibility for health, physical activity, nutritional behaviors, mental and spiritual growth, interpersonal relationships, and stress control [37]. The results of Cho and Lee`s (2021) study also showed that, using the smartphone application strategy was an effective way to promote self-efficacy and safe behaviors in patients attending outpatient clinics [38]. By conducting a single-group study on the elderly, Seo announced that the intervention and use of smartphone App was significantly effective in improving the quality of life, self-efficacy and psychological well-being of the elderly [39]. Aminuddin et al. [40] in a systematic review study conducted stated that, self-management interventions based on smartphones seem to have beneficial effects on self-efficacy, self-care behaviors and health-related outcomes of patients with type 2 diabetes. However, they argued that more research with appropriate design is needed to evaluate the effectiveness of smartphone-based self-care interventions for these patients [40]. From the researcher's point of view, the main reason for similar results of this study and other studies is the nature of education and the advantages of remote educational methods such as smartphone. In the current study, an up-to-date educational method was used that made it easy for individuals to access educational materials in a short period of time, eliminate the cost of transports and most importantly, not interfering with their life plan. There are many differences between the present study and the aforementioned studies, which is one of the strengths of this study. The present study's participants were only patients undergoing a single type of cardiac surgery, a key differentiating factor. Also, in the present study, a smartphone educational App was designed by cooperations of the researchers, a cardiologist, a physiotherapist, several nurses (working in cardiac department, CCU and heart clinic), and five nursing professors who were experts in cardiac care. Since we could find no study to show that education through smartphone does not affect the self-efficacy of patients, it can be said that the hypothesis of present study is confirmed and the designed educational App for smartphones is effective in increasing the self-efficacy of patients while reducing care burden for their caregivers. In this regard, Bahadri et al. (2023) conducted a study with the aim of comparing the impact of face-to-face and smartphone-based rehabilitation trainings on the care burden of caregivers of patients with chronic obstructive pulmonary disease, and found that rehabilitation training with smartphone was more effective than face-to-care training [41]. Research by Alhawiti indicated that implementing tele-nursing in elderly care during the COVID-19 pandemic resulted in substantial improvements in the knowledge and performance of caregivers, concurrently diminishing their perceived caregiving burden [42]. González-Fraile et al. (2021) acknowledged that remotely delivered interventions including support, education or both, with or without information, may slightly reduce caregivers' burden and improve their depression symptoms, but not compared to conventional treatment, waiting list or attention control. These interventions appear to make little or no difference in health-related quality of life [43]. Bani Ardalan et al. (1401) announced that intervention through training and telephone follow-up can be an effective and low-cost method in reducing the care

burden of caregivers of elderly patients diagnosed with stroke [44]. Teaching the patients and their caregiver is one of the most basic responsibilities of nurses, which can have a significant impact on the disease prevention and treatment [45]. The researcher believes that the main reason for the alignment of these studies and acquisition of similar results is the nature of education and the benefits of remote educational method such as smartphone Apps. Providing accurate information through any means can have an impact on people's knowledge and attitude, and can help family caregivers of patients, while getting to know more about the disease, learn how to care for the patients and increase their self-efficacy and resilience. This can also clear up ambiguities in their minds and make difficult tasks easier for them. In the current study, an up-to-date method was used, which made it easy for the individual to access educational materials at any time and place. It also provided the caregivers with more free times to do their personal work, eliminate the cost of travel and, most importantly, not interfering with their life plans. Caregivers could study the materials at times when their patients did not require care. This education method also helped the caregivers to, in addition to gaining more skills in caring for patient, they will learn about how to direct patient towards greater independence.

Limitation

One of the limitations of present study was the researcher's lack of control over the participants' study of educational materials, as they could only trust the participants' statements regarding the complete study of educational materials. Another limitation of this study was that it was conducted in a university-affiliated hospital. In this study, blinding was not applicable to educators, patients, and their caregivers. However, we tried to blind the analyst. Only one post-test was conducted in this study. Further follow-ups may be necessary to assess the impact of this educational intervention. Also, the current study was conducted on 18–65 years old literate people, so it can not be generalized to the whole society. The design and implementation of smartphone application in more advanced versions of devices required programming and online support, which was very costly for a senior student, so there was a limitation in designing a more advanced application.

Conclusions

The findings of present study, while confirming the research hypotheses, showed that the use of an educational program based on smartphone is effective in improving the self-efficacy of patients undergoing heart valve surgery, and also reducing the care burden of their family caregivers. This means that the use of this App, as one of the simple, cheap, applicable and effective nursing interventions, can be useful to improve self-efficacy of patients undergoing heart valve surgery, while reducing the care burden of their caregivers. Although in this study, self-care training was given to patients in all sessions, it seems that it was not enough, so it is better to use this method along with other new educational methods to achieve better results. Future research studies are suggested to include larger sample sizes and an educational intervention based on the use of comprehensive educational applications. Additionally, comparing different teaching methods helps us identify the most cost-effective form of education.

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Clinical trial number
The protocol of this study was registered on 11 March 2023 with the following registration code: IRCT20210714051889N1.

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There are no materials from other sources.

Authors' contributions
Sogand Sarmadi: Investigation, Methodology, Project administration, writing – original draft, Writing – review & editing. Neda Sanaie: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing. Mahsa Boozaripour: Investigation, Methodology, Writing – review & editing. Mohammad Zarei: Data curation, Formal analysis, Investigation.

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Data availability
The datasets generated and analyzed during the current study are not publicly available due to the necessity of ensuring participant confidentiality policies and the country's laws. Still, they are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The researcher obtained the ethical code (IR.SBMU.PHARMACY.REC.1401.166) from the Ethics Committee of Shahid Beheshti University of Medical Sciences, with the code IRCT20210714051889N1 in IRCT to conduct this study and permission to conduct the study was obtained from the Vice Chancellor for Research of Shahid Beheshti University of Medical Sciences. Participants provided written informed consent. They were informed of their right to withdraw from participation at any time during the research until publication. Data confidentiality was guaranteed and the results were made available to the participants upon request. Also, we confirm that all interventions were performed in accordance with relevant guidelines and regulations. The ethical principles of the Declaration of Helsinki were observed throughout the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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