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Development and efficacy of mobile application to improve medication adherence for persons with cardiac disease

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OriginalArticle

Abstract

BACKGROUND: Patients with cardiovascular disease need to adhere to their treatment and care recommendations to prevent the progression of their condition and improve their quality of life. In this regard, this study was conducted to develop a mobile application and test its effectiveness in improving medication adherence among persons with cardiac disease.

METHODS: The study was conducted in two stages. The first stage involved the preparation of the "Mobile Application for Persons with Cardiac Disease" using the cascade model. In the second stage, 121 patients who were hospitalized in the cardiac intensive care unit of Ayatollah Taleghani Medical Education Center of Tehran from March to August 2023 were enrolled. The participants were randomly assigned to either the control group (63 people) or the intervention group (58 people). The study collected data using a medication adherence questionnaire on the 7th, 14th, and 21st day after discharge and compared the results with the control group. The data were analyzed using SPSS 20.

RESULTS: The average age of the control group was 56.75 ± 11.38 years, and the average age of the intervention group was 57.03 ± 11.55 years. The comparison of the average medication adherence with independent t-tests showed a significant difference between the intervention and control groups on the 7th, 14th, and 21st day after discharge (P<0.01). The results of the repeated measures test in each group also showed that the difference between the groups increased over time (P<0.001).

CONCLUSION: The results of the study showed that the mobile application is effective in improving medication adherence among heart patients.

Keywords: Mobile Applications; Medication Adherence; Heart Disease; Effectiveness

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Introduction

Cardiovascular disease is the most common cause of death in the world[1] and Iran[2]. It is responsible for one-third of deaths in America[3], 20% in Europe[4], and almost three-quarters of all deaths worldwide are due to coronary artery disease[3]. Medication adherence and care recommendations are crucial in the rehabilitation and prevention of disease progression in heart diseases[5,6].

Medication adherence is a critical issue in the management of cardiovascular diseases[7,8]. Adherence refers to how well patients follow the recommended treatment plan[9], including lifestyle changes and medication use, in collaboration with their healthcare provider[10,11]. However, adherence barriers to treatment by the patient make achieving care and treatment goals challenging[12-14]. These barriers are multi-faceted and are unlikely to be improved by a

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single-faceted intervention[15]. Therefore, it is essential to understand the socio-cultural contexts, recognize the challenges of changing lifestyles and beliefs, and recognize patients' limitations to develop appropriate interventions and support by policymakers and healthcare providers, especially nurses.

Unfortunately, in Iran, patients do not pay much attention to the doctor's orders and compliance with the treatment regimen[2,9]. This leads to irreparable problems in many patients, including those with cardiovascular diseases[16], blood pressure[17], diabetes[18], lung fibrosis[19], and cancer[20,21].

Several studies have investigated the factors that contribute to low medication adherence among Iranian patients, including complex procedures and long-term treatment of traditional medicine, insufficient knowledge about traditional therapies, and medication-related factors such as side effects and the complexity of the regimen[22].

Treatment and care recommendations play a significant role in the management of cardiovascular disease and stroke[5,10,23]. Following these recommendations has been reported to have significant benefits, including improved patient outcomes and quality of care. Evidence-based approaches to managing patients with heart failure are crucial for improving patient outcomes and quality of care[5]. To improve medication adherence among cardiac patients, cardiac rehabilitation programs that emphasize self-care are highly recommended, especially for patients with acute myocardial conditions[5].

One of the successful ways to promote treatment adherence is through effective training[5]. According to reports, providing training sessions for staff and patients in different healthcare settings, including pediatrics, diabetes, and home care, can enhance clarity of roles and responsibilities, improve patients' comprehension of their participation, and increase awareness of contextual and cultural issues. Furthermore, training can increase patients' self-confidence and commitment to the process of participation and medication adherence[5]. Providing effective education to patients is recognized as one of the effective ways to ensure compliance with treatment[9]. According to reports, patient education can enhance patients' self-management and treatment adherence, facilitate their understanding of their conditions, compliance with care plans, and reduction of disease complications and re-admission[24]. Furthermore, it can reduce the time of hospitalization, re-hospitalization, and the cost of treatment[9,17,25]. The traditional methods of training include face-to-face training, lecture method, and the use of pamphlets and paper sheets[9]. Nevertheless, with the advancement of technology and the use of virtual space, new technologies such as mobile phones and virtual reality have emerged as effective methods of education[9,16,26].

The use of mobile phones for education has both advantages and disadvantages[27]. One of its advantages is the availability of information without space and time limitations, the possibility of using it for training from virtual space, and fast communication[2,20,24,26,28-30]. However, technical problems in the programs, inappropriate content[9], and lack of skill in using it can be considered obstacles in using this technology in education. While mobile applications have been proposed as a solution to improve treatment compliance[24], more than half of the programs and contents are not properly available or do not have the desired specialized content[16,21]. To address this issue, preparing programs with specialized and reliable content can be an effective method of educating patients and society. The present study aimed to prepare and evaluate the impact of training software on compliance with the treatment of cardiac patients.

Materials and Methods

Study Design

The study was conducted in two phases using an interventional approach. The objectives of each stage were as follows: 1) Preparation of training software for heart patients, and 2) Evaluation of the impact of using the prepared software on medication adherence in heart disease. In the first stage, a smartphone-based program was prepared for teaching heart patients in two parts: educational content and self-assessment of heart disease, using the cascade model. In the second stage, after approving the software, it was implemented with 121 participants from hospitalized patients in the cardiac intensive care unit of Ayatollah Taleghani Medical Education Center of Tehran from March to August 2023. At this stage, the data were collected using the patient treatment compliance questionnaire on the

7th, 14th, and 21st days after discharge. Then, the data were analyzed and compared.

Ethical considerations

This study is based on a research project approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, which was assigned ethics code IR.SBMU.SME.REC.1401.103 The researcher obtained electronic consent from all participants in the study and will ensure the confidentiality of the data. This study was registered on Iranian Registry of Clinical Trials (IRCT) with code IRCT20210131050189N4.

Creating a mobile application for cardiac patients

The development of a program using the cascade model involves seven stages, including initial analysis, system analysis, design, programming, testing (alpha and beta), implementation, and modification. The first step in preparing any program is the initial analysis and determination of the need or problem, considering the purpose of the design. In the current study, the purpose of the design was to promote adherence. In the system analysis phase, practicality and possible solutions were checked by asking the following questions:

- Can technical solutions be provided for the problem?
- Does the product in question solve the problem?
- How much does it cost to prepare the desired product?
- How much time is needed to produce it?

An expert panel was held with the presence of 15 nursing professors with experience working in the heart department and cardiologists. The purpose of the expert panel was to discuss the development of software for heart patients. During the meeting, the assumption of providing health and care for all humans and the history of producing and using similar software in this field were considered. Justified answers were given to the above questions in the system analysis stage. Then, the content of the mobile application was approved by reviewing previous studies and prioritizing the content with the opinions of the same professors and nurses. In the design of the software, visual appeal, up-to-date information, and simple language for everyone's understanding were emphasized.

Content of the mobile application

The content of the program included self-care education regarding heart failure, cardiovascular diseases, coronary artery occlusion, high blood pressure, cardiac catheterization, cardiac rehabilitation, and a self-assessment form for heart disease risk factors. In each section, key points related to the cause of the disease, underlying factors, symptoms of the disease, common treatments, and ways to prevent the progression of the disease were presented. In the self-assessment form section for heart disease risk factors, the users' risk factors were examined step by step, and feedback was given to them regarding lifestyle modification and disease prevention. If there was a high risk of heart disease, they were advised to refer to a cardiologist for further examination.

After designing the desired system, the programmers wrote a program corresponding to the initial plan. The written program was tested in two parts, alpha and beta, to examine errors and weaknesses and check the user's acceptability of the program.

During the alpha phase of program development, the program was tested by 16 experts, including cardiologists and nurses who are members of the academic staff with experience in the heart department. The users had an average (SD) age of 37.93 (7.02) years. Additionally, the program was evaluated by 4 mobile phone programming experts with an average (SD) age of 35 (7.87) years. The results of the evaluation are shown in Table 1.

During the beta phase, the program was evaluated by 33 non-technical users over 18 years of age. The users had an average age of 41.42 (11.14) years. The users were surveyed about the applicability, convenience, and simplicity of the software. The results of the survey are shown in Table 2.

During the implementation and modification stage, the software was under constant supervision and monitoring after being made available to the public. The software was improved by making content changes and corrections due to scientific developments. The defects in the software were removed and updated to ensure that the software was effective in promoting medication adherence in heart patients.

Table 1. Findings from the alpha test of the training software

Evaluation items in the alpha test	Participants Programmers		Specialists	
	Mean	Standard Deviation	Mean	Standard Deviation
Do you think the visual status of the program is appropriate?	4.75	0.5	4.6875	0.60
Do you think the graphic design of the program is suitable?	4.5	1	4.5625	0.73
Can the program change the attitude towards the importance of the topic (observing health tips and maintaining health)?	3.75	0.5	4.6875	0.60
Can the program create motivation to observe health tips and maintain health?	4.5	0.57	4.375	0.89
Are the resources used in the program appropriate?	4.5	0.57	4.5625	0.73
Total	4.4	0.63	4.57	0.70

Table 2. Findings from the beta test of the training software

Evaluation items in the beta test	Mean	Standard Deviation
In your opinion, how specialized is the content of the program?	4.79	0.48
Do you think the content of the program is enough?	4.61	0.61
Do you think the visual status of the program is suitable?	4.85	0.44
In your opinion, is the appeal of the program appropriate?	4.76	0.56
Do you think it is good to transfer program content?	4.73	0.57
Do you think the program is useful?	4.73	0.57
Do you think the program is easy to use?	4.61	0.66
Don't you think the program environment is confusing?	4.73	0.63
Would you like to recommend the app to others to use?	4.79	0.55
How do you rate the program?	4.70	0.59
Total	**4.73**	**0.57**

Participants

The research was conducted in the cardiac intensive care unit of Ayatollah Taleghani Medical Education Center of Tehran from March 2023 to August 2023. Out of 402 patients hospitalized in the research environment, 216 patients met the inclusion criteria, and 126 of them were included in the study using convenience sampling. The inclusion criteria were being over 18 years old, being literate, having access to a smartphone, and the patient's desire to install the "Heart Patient Education Program." The exclusion criteria were deleting the app from the mobile phone or not responding to the follow-up during the study. Out of 126 patients who participated in the study, 1 patient was excluded due to the cancellation of the program, and 4 patients were excluded due to unwillingness to complete the questionnaire.

The study involved 121 participants who were divided into two groups: control (63 people) and intervention (58 people). The control group received usual face-to-face training, while the intervention group received the prepared software along with the usual face-to-face training. The participants were divided into the two groups using white and black or colored cards, respectively. The data was collected using the "Treatment Compliance Questionnaire." Treatment compliance was checked and compared on days 7, 14, and 21 after discharge.

The Medication adherence questionnaire

The Medication Adherence Questionnaire was developed by Kripalani et al. in 2009 and includes 12 statements with 4 options each based on a 4-point Likert rating. The questionnaire assesses two subscales: medication adherence (8 statements) and prescription renewal (4 statements). The total score range for the questionnaire is between 12 and 48, with lower scores indicating greater adherence. The scores can be analyzed both continuously and dichotomously (12 or >12)[27]. The validity and reliability of the tool have been confirmed in Iran by Sadeghi et al., with a reported Cronbach's alpha of 0.86[9].

Data Analysis

The collected data were analyzed using the Statistical

Package for Social Sciences version 20 software (SPSS v.20) by IBM Corp. The independent two-sample t-test was used to compare the mean of quantitative variables in the intervention and control groups, while the repeated measure test was used to compare the repeated data. The frequency distribution of qualitative variables was compared using either the chi-square test or Fisher's exact test.

The normality of the frequency distribution of quantitative variables was assessed using the non-parametric Kolmogorov-Smirnov test, and the equality of variance between groups was evaluated using the Levene test. A significance level of 0.05 was used for all tests.

Results

The study's findings, as presented in Table 3, indicate that the demographic characteristics of the participants were similar across the two control and intervention groups. The average age (SD) of the control group was 56.75 ± 11.38 years, and the intervention group was 57.03 ± 11.55 years, which did not differ significantly. The mean number of hospital days for the control group was 1.94 ± 1.23 days, and for the intervention group, it was 1.53 ± 0.98 days, which was not significantly different. There was no significant difference between the two groups in terms of gender and hospitalization cause.

The comparison of the average medication adherence between the intervention and control groups was conducted using an independent t-test. The results showed a significant difference in adherence on different days after discharge. On the 7th day after discharge, the mean medication adherence of the intervention group (28.26 ± 4.89) was significantly higher compared to the control

Table 3. Demographic characteristics of the research participants

Demographic Characteristics		Group Control		App		Homogeneity Test
		Mean	Standard Deviation (SD)	Mean	Standard Deviation (SD)	
Age (Year)	Female	56.85	10.84	59.12	10.73	t= -0.13
	Male	56.68	11.90	55.34	12.07	df= 119
	Total	56.75	11.38	57.03	11.55	P= 0.89
Hospitalized day		1.94	1.23	1.53	0.98	
		Count	percent %	Count	percent %	
Hospitalized day	1.00	33	52.4%	39	67.2%	χ^2= 6.09 df=1 P= 0.19
	2.00	13	20.6%	13	22.4%	
	3.00	9	14.3%	2	3.4%	
	4.00	4	6.3%	2	3.4%	
	5.00	4	6.3%	2	3.4%	
	Total	63	100	58	100	
Gender	Female	26	41.3%	26	44.8%	χ^2= 0.15 df=1 P= 0.69
	Male	37	58.7%	32	55.2%	
	Total	63	100	58	100	
Cause of Hospitalized	AF	8	12.7%	15	25.9%	χ^2= 6.56 df=3 P= 0.08
	Pace	10	15.9%	3	5.2%	
	MI	17	27.0%	12	20.7%	
	HF	28	44.4%	28	48.3%	
	Total	63	100	58	100	

Table 4. Comparison of treatment adherence in intervention and control groups

Group		Mean	SD	t	Df	P value
Medication Adherence at 7th Day	Control	25.18	5.25	-3.343	112	0.001
	intervention	28.26	4.59			
Medication Adherence at 14th Day	Control	27.09	3.18	-3.089	112	0.003
		29.11	3.77			
Medication Adherence at 21th Day	Control	27.51	3.27	-3.370	112	0.001
		29.67	3.56			

group (25.18 ± 5.25) (P<0.01). Similarly, on the 14th day after discharge, the intervention group (29.11 ± 3.77) had significantly higher adherence compared to the control group (27.09 ± 3.18) (P<0.01). On the 21st day after discharge, the intervention group (29.67 ± 3.56) had significantly higher adherence compared to the control group (27.51 ± 3.27) (P<0.01)(Table 4). The repeated measures test also showed that the degree of medication adherence between the intervention and control groups was significant on different days (7, 14, and 21 after discharge) with P<0.001. The difference between the two groups increased gradually over time (Figure 1).

Discussion

The present study's findings suggest that using mobile phone software to teach cardiac patients has a positive impact on medication adherence (P<0.01). Santo et al. also reported the positive effect of mobile phone programs on improving compliance with heart patient treatment, emphasizing the importance of program attractiveness and design[24].

The use of mobile health interventions has been reported to improve adherence to long-term therapies in chronic conditions, including cardiovascular diseases[31]. Mobile health technology can improve cardiac rehabilitation, increase medication adherence, and improve exercise tolerance in patients with cardiovascular diseases[32]. Interventions including SMS may increase medication adherence in adults with cardiovascular diseases[33]. SMS as a mobile health tool has been found to be effective in improving the outcomes of cardiovascular disease treatments[34].

Sharma et al. evaluated the usefulness of mobile phone applications in improving medication adherence in cardiac and diabetic patients[35]. The current study found that the mobile phone educational program was attractive, easy to use, and understandable for the public, as evaluated by experts. The study's results are consistent with previous research that has shown the positive impact of mobile phone applications on medication adherence in chronic conditions, including cardiovascular diseases[36-38].

Santo et al. highlighted the usefulness of mobile applications in recalling medication and care orders[39]. Ying Lin and colleagues discovered that mobile applications are appropriate for training patients with heart failure, as demonstrated in their study[2]. John Bostrom and colleagues reported the usefulness of mobile phone software in the rehabilitation of people with cardiovascular diseases, emphasizing the importance of appropriate program content[40]. Sadeghi et al. found that teaching patients using software with up-to-date and specialized content is an effective way to improve compliance with treatment[9]. According to a systematic review by Armitage et al.,

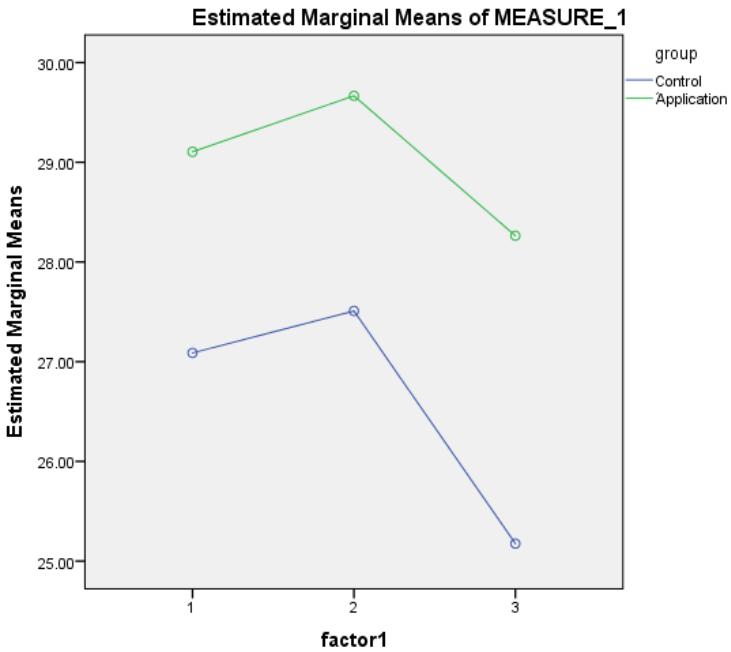

Figure 1. The result of repeated measure test

interventions based on smart treatment adherence programs can be useful in improving patients' medication adherence[41].

A systematic review by Akinosun et al. found that digital interventions can improve healthy behavioral factors such as physical activity, healthy diet, and medication adherence[42]. Athilingam's 2016 report revealed that there were 7 billion mobile phones in the world that year, and nearly 95% of the world's population used them. With rapid technological advancements, this number has probably increased since then. Considering the widespread availability of mobile phones and the increasing popularity of smartphones, as well as the results of current research and similar studies, it is clear that smartphone-based programs have a significant impact on empowering heart patients.

Furthermore, this technology can be utilized for self-care and enhancing medication adherence for other chronic diseases like diabetes, cancer, and hypertension[26]. To ensure that smartphone-based programs are effective and user-friendly, it is crucial to involve experts in the relevant fields in all design stages, including program content. Additionally, to improve motivation to use these programs, they should be simple, practical, and attractive to the general public. Furthermore, cultural factors should be considered when assessing the effectiveness of smartphone-based applications on various diseases in different societies and cultures.

Conclusion

Research has shown that mobile phone software can improve the compliance of heart patients. However, it is crucial to use software that has the necessary appeal and approved content to ensure its effectiveness.

Limitations

The use of smartphone-based applications is influenced by various factors, such as culture, which can affect the generalizability of the results. Therefore, it is crucial to investigate the effectiveness of smartphone-based programs in other diseases, as well as in different societies and cultures.

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Conflict of interest

The authors declare that have no conflict of interest.

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Author's Contributions

- R G formulates the research question that represents the systematic review objective
- R G and R K: did transcultural translation and validation process
- R G, A MH and S S: Data gathering
- R G and R K: provide proposal and reports
- R G and R K: Data analysis
- All authors have read and approved the manuscript

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