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# Lymphedema self-management mobile application with nurse support for post breast cancer surgery survivors: description of the design process and prototype evaluation

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## Abstract

**Background** Self-management is the key to control breast cancer related lymphedema (BCRL). This study aimed to develop a mobile application with nurse support for lymphedema self-management and evaluate its usability from the patients' points of view.

**Methods** This applied developmental study was conducted on 87 women in a lymphedema clinic, Shiraz, Iran, May-November 2023. The study included three phases: development, distribution of the application and usability evaluation. In the development phase, the researchers developed application using the Java programming language. In distribution phase, the application was installed on the participants' phones. For usability evaluation, 87 patients completed the user satisfaction questionnaire after three months access to the application. Data was analyzed using descriptive and analytical statistics using SPSS software 22. *P*-value less than 0.05 was considered significant.

**Results** We designed a self-management application specific to BCRL that included ten unique modules mainly related to patient education, interaction with peers and nurse, self-management support, and settings. The application mean usability score was  $7.72 \pm 1.08$ . The usability dimensions of "screen" ( $8.06 \pm 1.02$ ) and "terminology and systems information" ( $7.29 \pm 1.62$ ) received the highest and lowest mean scores, respectively.

**Conclusion** The application has new features to meet more patients' needs compared to what other existing lymphedema self-management applications already have addressed. The findings showed that the participants rated the application usability at the "good" level that is similar to some previous studies. Considering the unique nature of the application and its favorable usability, we recommend its use for BCRL self-management.

**Keywords** Breast cancer lymphedema, Self-management, Mobile applications, Nurse, Breast cancer, Smartphone

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## Background

Breast cancer related lymphedema (BCRL) is one of the most problematic complications of breast cancer treatments and almost one out of every five patients experiences it [1]. Some treatments, including surgery with axillary lymph node dissection and radiation therapy, can cause disruption of lymphatic flow and abnormal accumulation of protein-rich fluid in the interstitial tissue and lymphedema [2]. It is also expected that in the coming years, with the increase in the use of perioperative adjuvant and neo-adjuvant therapies, the prevalence of BCRL will grow exponentially [3]. Symptoms of lymphedema, such as pain, infection and decreased function of the upper limb, have negative impacts on the person's performance and quality of life [4]. Without optimal management, lymphedema will progress, the risk of ulceration and infection will be increased and mental and physical health will be affected [5]. In addition, with long-term treatment, it will impose direct and indirect economic burden on the patients and healthcare system; including loss of productivity and income [6].

Self-management plays a critical role in improving and controlling symptoms throughout the life of patients with lymphedema [5]. It can improve long-term health outcomes and reduce the cost burden of lymphedema treatments on the persons and the society [7]. The results of a study showed that teaching BCRL self-management improved compliance with the treatment and independence in daily functions [8]. Therefore, adopting self-management behaviors is a lifelong commitment and the key to control and prevent the complications of lymphedema [9]. Hence, teaching methods of self-management to the patients is an essential part of prevention and control of lymphedema [10]. Nurses have important role in providing evidence-based self-management education and create a bridge from research to practice [11]. Studies have shown that the implementation of educational programs with nurse support is particularly important to ensure the success of long-term BCRL self-management [12, 13].

Mobile health (m-health) applications are the innovative and effective methods of providing health care. These applications enable effective communication between patients and the healthcare team and promote self-management behaviors [14, 15]. This is especially important in low-income communities and people who have less access to health care services [16]. Studies have shown that teaching lymphedema self-management techniques using mobile phone applications, in addition to saving time and financial costs, can reduce symptoms burden and edema volume in patients with BCRL [15, 17].

Application usability is one of the key factors that can predict the acceptance and success of the mobile applications [18]. Usability evaluation is used to investigate the

level of satisfaction and ease of use of a product based on the customer's experience of using the product [19]. The results of a national survey in the United States showed that nearly half of m-health application users stop using some applications for various reasons related to their poor usability [20]. Therefore, evaluating the usability of applications based on patients' viewpoints and developing applications with optimal usability should be considered [21].

Until now, various applications have been designed for lymphedema self-management, which mainly included educational videos [22]. Some also had other capabilities such as reminders [23] or communication with the doctor [15]. However, the number of nurse-supported applications to help patients in lymphedema self-management is limited [24]. Furthermore, some previous applications mostly addressed common complications of breast cancer surgery such as bleeding, infection and upper limb dysfunction and were not specific to BCRL management [22, 23]. Moreover, other applications for lymphedema management mainly focused on education of sports and brief tips related to lymphedema prevention [15, 25]. Additionally, a similar Iranian application on BCRL self-management offers training related to general health topics such as medication management, weight control, smoking cessation, and exercise after breast cancer surgery [26]. Therefore, in order to meet different needs of the patients, in the current study we designed an application specific to BCRL management, which benefits training based on complex decongestive therapy (CDT) techniques, the gold standard for lymphedema treatment. Furthermore, our application provides the opportunity for patients to interact with peers and the nurse therapist. Moreover, it helps patients to set individualized health-related goals, plan unique schedules of self-management activities, and view visual displays of the trend of changes in edema, which may reflect the effects of their self-management activities.

Review of scientific literature shows that the usability of small number of existing applications regarding BCRL has been tested, in which the sample sizes were small [24, 26, 27]. The small sample size can reduce the accuracy and generalizability of the findings. Therefore, it is necessary to evaluate the usability of mobile phone applications, including the application designed in the present study before distributing them. Therefore, the purpose of this study is to develop a mobile application with nurse support for lymphedema self-management and evaluate its usability from the patients' points of view.

## Methods

### Study design

This applied-developmental study was conducted between May and November 2023 in the Lymph Clinic of

Shahid Motahari Outpatient Center in Shiraz, Iran. The study consisted of three phases of development, distribution and usability evaluation of lymphedema self-management application.

#### **Development of the application**

During this phase, the requirements, contents, and functionality of the mobile application were determined. Then depicting the conceptual design, preparing the media and coding the application was done and the final prototype of the application was developed.

The researchers extracted lymphedema self-management content based on the related guidelines, reviewing existing applications on the lymphedema self-management and the field experts' viewpoints. Then an expert panel including a lymphatic therapist, a subspecialist of breast cancer surgery, a physiotherapist and three experts with PhD degrees in nursing reviewed the content. They evaluated the educational content in terms of its accuracy, safety, conciseness, clarity, and being pragmatic and scientific. The necessary corrections were made based on their opinions and the expert panel approved the initial draft of the applications' content. Then we focused on the conceptual design of the mobile application, including its environment and functions, and how to meet the patient's needs, effectively. In the next step, we recorded the sounds of the educational videos in a studio environment without any disturbing sounds and then we provided them with relaxing background music. Finally, a software engineer designed the application using the Java programming language for both Android and IOS operating systems. The expert panel examined the performance of the application in terms of its functions, and being innovative, patient-centered and user-friendly. Then the necessary corrections were made.

#### **Distribution of the application**

At this phase, the first researcher installed the mobile application on the participants' smartphones and taught them how to use it. In addition, she protected research data by blocking access to the platform with separate username and password for each patient. After installing the application on users' phones, its functionality was checked and its problems were fixed. The participants were asked to contact the researcher in case of problems in working with the application or if they have questions. In addition, the researcher periodically sent messages to them or made phone calls with them to ensure that they were using the application and had no problem working with it.

#### **Usability evaluation**

In order to evaluate the usability of the application, data related to users' points of view and their satisfaction of interaction with the application were collected.

#### **Participants and data collection**

The study sample included 90 women over 18 years old who had lymphedema after breast cancer surgery with axillary lymph node dissection. They were willing to participate in the study and had access to an Android or IOS mobile phone. The eligible patients were included in the study through the convenience sampling method for six months, from May to November 2023. The patients were excluded from the study at any time if they did not want to continue participating in the study.

After three months of access to the application, the patients completed an online questionnaire that was designed with Porsline. From 90 participants, 87 patients completed the questionnaires (96.6% response rate) and three of them were excluded from the study due to not answering the questionnaire. The research tool was the questionnaire for user interaction satisfaction version 5.5 (QUIS 5.5).

Chin et al. (1988) designed QUIS to evaluate the usability and user satisfaction of interaction with computer interface. This questionnaire contains five dimensions and 27 items. The dimensions include overall reactions to the application (six items), screen design (four items), terminology and systems information (six items), learning (six items) and system capabilities (five items). The questions are answered via a 10-point scale (from 0 to 9). The number 0 indicates the lowest level of usability and satisfaction, and the number 9 indicates the highest level [28]. Mean scores 0–3 are classified as weak, scores 3.1–6 are moderate, and scores 6.1–9 are classified as good usability [29]. Chin et al. reported the Cronbach's alpha coefficient of the questionnaire as 0.94 [28]. Moreover, Moulaei et al. confirmed the validity of the Persian version of the questionnaire using the content validity method and its reliability with Cronbach's alpha of 0.92 [30]. Furthermore, in the current study we confirmed its reliability by Cronbach's alpha of 0.94.

#### **Data analysis**

The data obtained in the research were analyzed by SPSS version 22 software and using the descriptive and analytical statistics. Because our study had a sample size of more than 50, we used the Kolmogorov-Smirnov test to check the normality distribution [31]. The results of this test showed that data related to age and type of surgery had a normal distribution, thus independent t-test was used to compare the usability based on age and type of surgery. However, data related to marital status, education level and place of residence (urban and rural) did

not have a normal distribution. Hence, we used Mann–Whitney U test to compare usability based on place of residence, and Kruskal-Wallis and Dunn's post-hoc test to compare usability based on marital status and education level. Moreover, we used Eta squared values to show the effect of the independent variable of education level on the dependent variables of questionnaire dimensions. The Eta squared values of 0.14, 0.06 and 0.01 were considered large, medium, and small, respectively [32].  $P < 0.05$  was considered statistically significant.

## Results

### Demographic findings of the participants

Patients participating in this study included 87 women with BCRL. Most of the participants had secondary education (36.8%), were over 50 years old (52.9%), married (74.7%) and lived in the city (80.5%). In addition, 50.6% of them had breast conservation surgery and 49.4% had mastectomy (Table 1).

### Mobile application prototype

Lymphedema self-management application contains ten modules mainly in four categories including education, interaction, self-management support, and settings. The education category includes three modules including “lymphedema reduction skills”, “arm circumference measurement”, and “lymphedema information”. The interaction category consists of three modules including “ask from the nurse”, “online self-help group”, and “application survey”. The self-management support category contains three modules including “lymphedema diary”, “calendar”, and “online exam”. In addition, in the settings category, people can change their username and password in the application. In addition to these modules, the first page of the application includes the welcome message, the introduction of the application, and personal information such as password, name, age, education level and place

of residence. The next is program menu, where different parts of the application are located (Fig. 1).

In the “lymphedema reduction skills” module, there are four lymphedema self-management educational videos based on the principles of CDT including massage, bandage, exercise and skin care. After watching and performing the activities of each video, patient clicks on “I did the activity” and the answer will be saved. In the “arm circumference measurement” module, there is a video to teach how to measure the arm circumference in terms of lymphedema, and the patient can notice the changes in the volume of arm edema over time by recording and saving the size of the points in a form in this section. The “lymphedema information” contains three educational videos about lymphatic system and its dysfunction, and lymphedema manifestations and risk factors.

The “ask from the therapist” module, allows users to ask their questions and a nurse will answer them within 72 h. The “online self-help group” provides a platform for participants to share their experiences regarding lymphedema and its management and help each other in this way. The supporting nurse is also present in the self-help group. After using the application for three months, the “application survey” including ten close-ended questions is activated to investigate the users' satisfaction with the application, and their opinions about its improvement.

In the “lymphedema diary”, people can report their self-management activities, make notes, set goals, and view the charts related to their exercise frequency, lymphedema changes and mood condition overtime. The “calendar” module provides the opportunity for users to specify the day and time to receive reminders to do the self-management practices, twice a week. In the “online exam” module, a number of multiple-choice questions about the contents of the educational videos are sent to people every month, and after the user selects the desired option, the correct answer is displayed along with the necessary explanations.

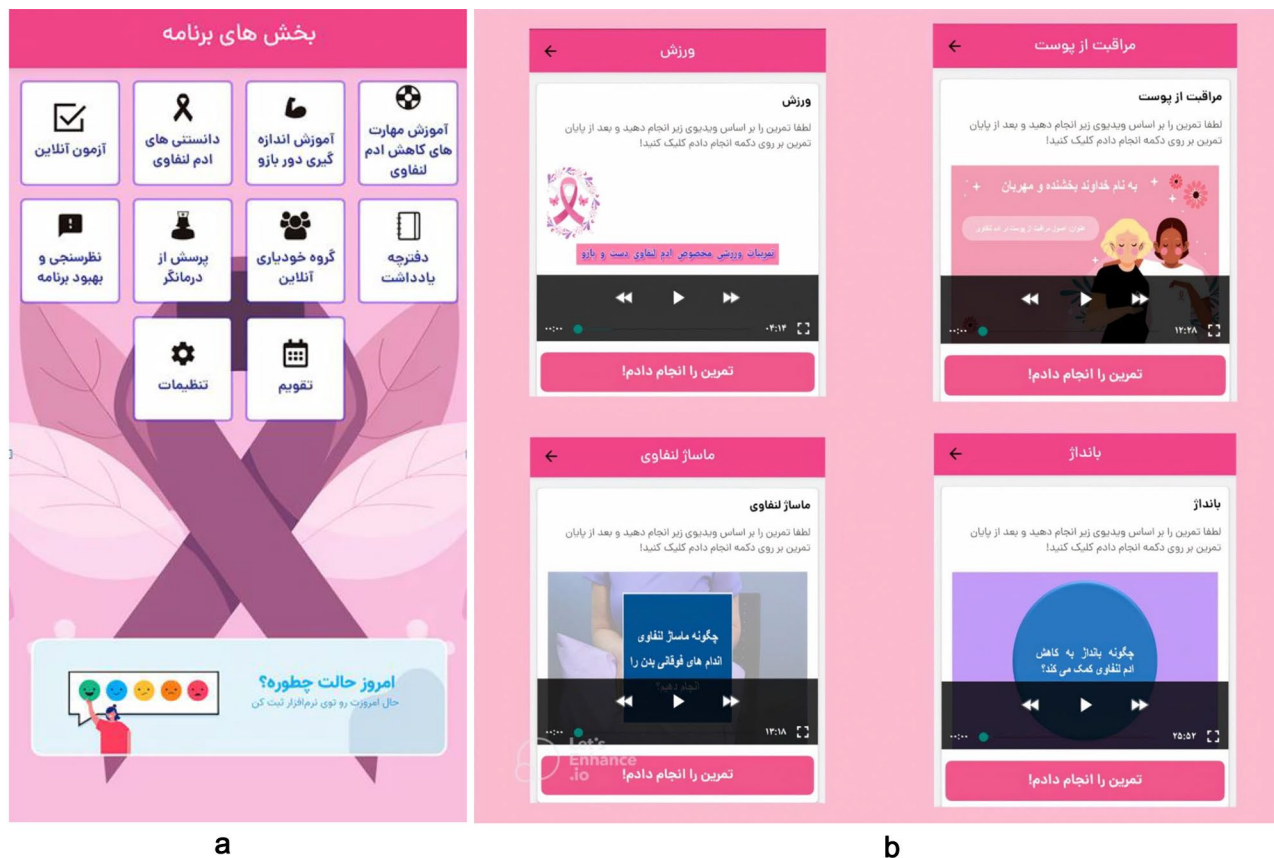
There is a question mark at the top of the page for each module and people can click on it to read the explanations about the module. In addition, in this application the nurse providing care has access to the patients' information and can monitor their lymphedema management practices and give the necessary feedbacks to them (Table 2).

### Usability evaluation findings

The mean usability score was  $7.72 \pm 1.08$  out of score 9. The highest mean application usability score was obtained in the dimension of “screen” ( $8.06 \pm 1.02$ ). Patients were less satisfied with the dimension of “terminology and systems information” with a mean score of  $7.29 \pm 1.62$  compared to other evaluated areas. In this area, the two items related to “error messages in the

**Table 1** Frequency distribution of demographic and clinical data of the study participants

Variable		Frequency (n = 87)	Percentage
Marital status	Single	5	5.7%
	Married	65	74.7%
	Widowed	15	17.2%
	Divorced	2	2.3%
Education	Primary	26	29.9%
	Secondary	32	36.8%
	Academic	29	33.3%
Age	30–49	41	47.1%
	≥ 50	46	52.8%
Place of residence	City	70	80.5%
	Village	17	19.5%
Type of surgery	Mastectomy	43	49.4%
	Conservative	44	50.6%



**Fig. 1** The display of some parts of the application: (a) Program menu; (b) “Lymphedema reduction skills” module [in Persian]

application” and “use of terms related to tasks” received a lower mean score compared to the other four items in this dimension (Table 3).

The findings showed that usability scores were not significantly different based on patients’ age ( $P=0.082$ ), type of surgery ( $P=0.329$ ) and marital status ( $P=0.884$ ). However, the place of residence was related to usability, so that patients living in the city ( $8.13 \pm 1.07$ ) were significantly more satisfied with the second dimension of the questionnaire (i.e. “screen”) than the patients living in the village ( $7.79 \pm 0.70$ ) ( $P=0.025$ ). Moreover, Kruskal–Wallis test showed that usability is different based on the level of education. Dunn’s post hoc test showed that the level of academic education has a significant difference with the primary ( $P=0.010$ ) and secondary ( $P=0.005$ ) education levels, so that people with academic education gave a higher score to total usability than others (Table 4).

## Discussion

In this study, the lymphedema self-management application including ten modules related to patient education, interaction with peers and nurse, self-management support and settings was designed. Then we evaluated its usability from the patients’ points of view. The findings showed that the mean usability scores of the application

in all dimensions and items of the questionnaire were in the “good” range.

Some sections of our application were educational and interactive modules. In this regard, a recent Iranian study revealed that the most important needs of the patients with lymphedema included training about special exercises to reduce edema, interaction with the therapist and lifestyle training [33]. Other applications that are designed to support these patients basically included educational contents on special exercises and lifestyle modification related to lymphedema [26], lymphedema measurement and self-care practices [15]. However, the current application is different with the previous applications. In the mentioned applications, the trainings were not based on CDT guidelines in the management of lymphedema. According to the statement of the international society of lymphology, CDT is the gold standard for lymphedema treatment [34]. It is worth noting that in our application, the important aspects of nursing care of these patients are also considered, while in designing the previous applications the nursing approach was not considered.

Our application allowed patients to interact with the nurse as a therapist and be in touch with their peers. In the “ask from the nurse” module of this application,

**Table 2** The educational contents of the application's videos

Module	The video Title	Contents of educational videos
Lymphedema reduction skills	Bandage	1-The purposes of using bandages 2-Introduction to different layers of the bandages 3-Compression garments 4-Demonstration of self-bandage 5-Dos and do nots of bandaging
	Massage	1-The importance of massage 2-The principles of effective massage 3-Demonstration of step-by-step lymphedema self-massage 4-Important considerations during massage
	Exercises	1-The purposes of the exercises 2-Demonstration of easy-to-learn exercises in activating lymphatic system, including: • Muscle-tightening-deep-breathing • Muscle-tightening pumping • Large muscle exercises
	Skin care	Based on four important skin care components: 1- Skin protection in BCRL* 2-Early identification of infection signs 3-Treatment of minor skin injuries 4-Nail care
Lymphedema information	Lymphatic system and lymphatic dysfunction	1-Introduction to lymphatic system 2-Pathophysiology of lymphedema 3-Stages of BCRL*
	Lymphedema manifestations	1- Common signs and symptoms of lymphedema 2-Skin changes during different stages of lymphedema
	Lymphedema risk management	1-Lymphedema risk factors 2- Strategies to reduce the risk of lymphedema
Arm circumference measurement	Manual circumferential measurement of the arms	1-Demonstration of self-measurement of arm circumference in five points with a tape 2-Interpretation of the measurement findings

\*Breast cancer related lymphedema (BCRL)

patients could ask their questions and receive self-management recommendations and nursing support. In this way, it provides patients with the possibility of free access to individualized medical care and overcomes the time and place limitations of access to the therapists. On the other hand, this application allows nurses to remotely monitor patient's lymphedema status and encourages them to adhere to treatments and communicate with their peers. One of the capabilities of the present application was the possibility of communicating and exchanging information with other patients in the "self-help online group" module. Zhu et al. stated that communication between patient and therapist using a mobile application, can increase the patients' motivation to continue the treatment and improve their perception of disease [35]. Moreover, Drewes et al. considered interaction between patients as one of the ways to increase compliance with treatments [36]. In our review of the available applications related to lymphedema, we noticed that in other applications it was not possible for patients to interact with each other and receive support from a nurse [37, 38].

In addition, using a health diary that included forms of self-management, goal setting, and self-reporting, helped patients to evaluate their daily performance in terms of

health improvement activities and by receiving feedback, their motivation to do self-management practices increased. In this module, patients can view the weekly arm circumference measurement table, as well as the chart of its changes. This feature could help them to be aware of the condition of their arm edema by regularly monitoring the process of lymphedema changes. In fact, monitoring the changes in the lymphedema is considered as one of the effective ways to evaluate edema changes overtime and improve self-management [39]. In addition, in our application, daily reminder messages according to the personal preferences of each user were sent to them at a specific time, to remind the patients and increase their adherence to the practices. Furthermore, the use of an online exam module allowed patients to self-evaluate and review the topics learned in the application.

The results related to evaluation of the application showed its favorable usability from the patients' points of view. The level of satisfaction with the "screen" dimension was higher than the other dimensions of the questionnaire. This dimension includes items related to the legibility of letters, easy performance of tasks, and organization of information and sequence of the application pages. The findings of the study showed that the patients assigned the lowest usability score to the "terminology

**Table 3** Mean scores of the questionnaire dimensions and items

Dimensions		Items		Rank order
Mean ± SD		Mean ± SD		
Overall reactions to the app	7.83 ± 1.04	General functionality of the application	8.41 ± 1.30	1
		The degree of difficulty of working with the application	7.95 ± 1.92	8
		Users' feelings about working with the application	8.20 ± 1.26	3
		General application design	8.28 ± 1.14	2
		Continuous work with the application	7.24 ± 1.43	17
Screen	8.06 ± 1.02	Possibility to change the application settings	6.90 ± 1.90	19
		Screen properties	8.28 ± 1.15	2
		The degree of legibility of letters on the screen	8.03 ± 1.33	6
		Organization of the application information	7.92 ± 1.58	10
Terminology and systems information	7.29 ± 1.62	Screen sequence	8.03 ± 1.40	6
		Terminologies used in the application	7.62 ± 2.03	13
		Use of terms related to the tasks	6.98 ± 2.03	18
		Location of the messages on the screen	7.48 ± 2.11	15
		Message to record necessary data	7.55 ± 1.74	14
Learning	7.96 ± 1.23	Informing the users about what the application is doing	7.40 ± 1.91	16
		Error messages in the application	6.74 ± 2.15	21
		Learning to work with the application	8.11 ± 1.48	4
		Discovering the application's features by trial and error	8.03 ± 1.80	6
		Remembering the names and using the capabilities	7.90 ± 1.87	11
		Quick and easy task completion	7.56 ± 1.82	13
		Help messages on the screen	8.04 ± 1.51	5
System capabilities	7.45 ± 1.32	Application guide	8.14 ± 1.61	3
		Application speed	6.70 ± 1.95	23
		Application reliability	8.02 ± 1.56	7
		Variety of the application features	7.93 ± 1.56	9
		Correcting users' mistakes	6.87 ± 1.86	22
		Designed to meet the needs of all users	7.72 ± 1.67	12

**Table 4** Comparison of the application usability and its dimensions according to the education level

Variable	Mean ± SD	Education level			P-value*	Eta squared
		Primary (Mean ± SD)	Secondary (Mean ± SD)	Academic (Mean ± SD)		
Overall reactions to the app	7.83 ± 1.04	7.57 ± 1.18	7.61 ± 1.10	8.31 ± 0.62	0.007	0.269
Screen	8.06 ± 1.02	7.66 ± 1.15	7.93 ± 0.96	8.57 ± 0.74	0.000	0.272
Terminology and systems information	7.29 ± 1.62	6.94 ± 1.80	7.07 ± 1.89	7.86 ± 0.87	0.098	0.235
Learning	7.96 ± 1.23	7.64 ± 1.31	7.81 ± 1.41	8.42 ± 0.77	0.024	0.290
System capabilities	7.45 ± 1.32	7.33 ± 1.11	7.16 ± 1.70	7.86 ± 0.90	0.086	0.216
Total	7.72 ± 1.08	7.43 ± 1.09	7.52 ± 1.25	8.20 ± 0.63	0.002	0.796

\*Kruskal-Wallis test

and systems information" dimension. In addition, the two items related to the error messages and use of terms related to the tasks in this dimension received lower scores than other items. The error messages could be related to the multi-step process of installing the application. Therefore, we suggest simplifying and facilitating the installation of the application in future studies. Moreover, evaluating and revising the terms and phrases used in the application may be effective in increasing users' satisfaction. Out of all the items in the questionnaire, general functionality of the application received the highest score and the system speed got the lowest score. The

latter could be the reason for the low speed of the internet in our country.

Similar to our findings, in Ahmadi et al.'s study, patients with lymphedema were most satisfied with the "screen" and "system capabilities" dimensions and the least satisfied with the "terminology and system information" dimension [26]. Similarly, in a study by Amiri et al. on Alzheimer's caregivers, "screen" got the highest mean score among all dimensions. Contrary to our findings, their participants assigned the least scores among all dimensions to the "learning" dimension [40]. Our study was different with the mentioned studies in that the

duration of participants' access to the application was three months in the current study, while this time was two weeks in the other studies [26, 40]. According to the Nielsen Norman Group report, three months is a more suitable time to access the application for usability evaluation purposes [41]. Moreover, the sample size of our study was more than the previous studies [26, 27]. An appropriate duration of participants' access to the application in addition to a larger sample size could strengthen the accuracy of the current findings.

Findings showed that patients with academic education and people living in the city assigned higher scores to this dimension than other patients. Although satisfaction scores of people with primary and secondary education and village residents with this dimension place in the good range. This shows that even though the educated people and city residents were more satisfied with the application screen, it was favorable for other participants as well. In general, evaluation of the role of demographic information in the usability of the application showed that it is useful for all women with BCRL who are over 18 years old, and have different educational levels.

### Strengths and limitations

Among the strengths of our study is designing an application to improve the patients' contribution in their self-management and facilitate individualized care. This application provides the nurse support for patients with BCRL that can reinforce the community-oriented roles of nurses. The use of such technologies can promote access to lymphedema management services for patients, especially who do not have access to specialized lymphedema clinics due to financial issues or distance [5]. Unlike other studies, the present application was designed for both Android and IOS operating systems. Application usability was evaluated in a larger sample size of patients and a longer follow-up period compared to the previous studies. One of the other strengths of this study was the assignment of a personal username and password for each patient to protect her privacy. However, our study had some limitations. One of the limitations is that the usability evaluation in our study was questionnaire-based, so we suggest using objective evaluation methods such as assessing task completion time or error rates in future studies. The use of convenience sampling method was another limitation of the study.

### Conclusion

In this study, a lymphedema self-management application was designed and evaluated for breast cancer surgery survivors with lymphedema. By using this application, people can get to know the causes, symptoms and skills to reduce lymphedema and manage their edema in a favorable way. They can also use this application to

monitor their condition, communicate with their peers, and ask the nurse questions. In this application, patients were taught to measure the circumference of the arm at five points using a tape and record it in a special table, and the changes in their lymphedema overtime were shown to them on the chart.

Findings showed that the usability of the application was in the optimal range, which indicates the usefulness of the application for all age groups of 30 years and above and with different educational levels. The highest usability score was obtained in the "screen" dimension and the lowest score was obtained in the "terminology and systems information" dimension. Therefore, we recommend using this application to manage the lymphedema of these patients. Moreover, we suggest revising terms used in application and simplifying the installation process in the next versions of the application. In addition, designing the offline version of the application will help to overcome the errors related to low speed of the internet. Furthermore, we suggest conducting qualitative studies to provide enrich data about users' experiences of application usability, and conducting clinical trials to investigate the effectiveness of the application in the improving the patients' outcomes.

### Abbreviations

BCRL	Breast Cancer Related Lymphedema
CDT	Complex Decongestive Therapy
SPSS	Statistical Package for the Social Sciences
QUIS 5.5	Questionnaire for User Interaction Satisfaction version 5.5

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### Author contributions

MH, ZKh and MR made substantial contributions to the conception and design of the study. Data was collected by MH. Data analysis and interpretation were done by ZKh and MH. MH conducted the intervention. ZKh and MH participated in drafting the manuscript. ZKh, MH and MR revised the manuscript critically for important intellectual content and final approval of the manuscript.

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### Data availability

Data resource and statistical analysis outputs can be provided by the first author (Mehrvash Hemati) on reasonable request.

## Declarations

### Ethics approval and consent to participate

Ethics approval was obtained from the Ethics Committee of Shiraz University of Medical Sciences (code: IR.SUMS.NUMIMG.REC.1401.084). Moreover, the authorities of the lymph clinic approved the study. Participation in the study was voluntary and the subjects could withdraw at any time. Patients signed informed consent forms. Moreover, the application was free to use for the participants during the study. Data collected from patients with lymphedema were confidential. Furthermore, the study carried out in accordance with Declaration of Helsinki and relevant guidelines and regulations.

### Competing interests

The authors declare no competing interests.

### Consent for publication

Not applicable.

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## References

- Torgbenu E, Luckett T, Buhagiar MA, Chang S, Phillips JL. Prevalence and incidence of cancer related lymphedema in low and middle-income countries: a systematic review and meta-analysis. *BMC Cancer*. 2020;20(1):1–20.
- Tomčić S, Malenković G, Mujičić E, Šljivo A, Tomić SD. Impact of risk factors, early rehabilitation and management of lymphedema associated with breast cancer: a retrospective study of breast cancer survivors over 5 years. *BMC Womens Health*. 2024;24(1):226.
- Wong HC, Wallen MP, Chan AW, Dick N, Bonomo P, Bareham M, et al. Multinational association of supportive care in cancer (MASCC) clinical practice guideline for the prevention of breast cancer-related arm lymphoedema (BCRAL): international delphi consensus-based recommendations. *EClinicalMedicine*. 2024;68:102441.
- Ramirez-Parada K, Gonzalez-Santos A, Riady-Aleuy L, Pinto MP, Ibañez C, Merino T, et al. Upper-limb disability and the severity of lymphedema reduce the quality of life of patients with breast cancer-related lymphedema. *Curr Oncol*. 2023;30(9):8068–77.
- Omidzi Z, Kheirkhah M, Abolghasemi J, Haghightat S. Effect of lymphedema self-management group-based education compared with social network-based education on quality of life and fear of cancer recurrence in women with breast cancer: a randomized controlled clinical trial. *Qual Life Res*. 2020;29(7):1789–800.
- Beck AC, Lizarraga IM. Long-term burden of breast cancer-related lymphedema. *Curr Breast Cancer Rep*. 2024;16(2):251–9.
- Jeffs E, Ream E, Shewbridge A, Cowan-Dickie S, Crawshaw D, Huit M, Wiseman T. Exploring patient perception of success and benefit in self-management of breast cancer-related arm lymphoedema. *Eur J Oncol Nursing: Official J Eur Oncol Nurs Soc*. 2016;20:173–83.
- Cansız G, Dönmez AA, Kapucu S, Borman P. The effect of a self-management lymphedema education program on lymphedema, lymphedema-related symptoms, patient compliance, daily living activities and patient activation in patients with breast cancer-related lymphedema: a quasi-experimental study. *Eur J Oncol Nurs*. 2022;56:102081.
- Brown JC, Cheville AL, Tchou JC, Harris SR, Schmitz KH. Prescription and adherence to lymphedema self-care modalities among women with breast cancer-related lymphedema. *Support Care Cancer*. 2014;22(1):135–43.
- Sun Y, Fu MR, Jiang Y, Little AS. Initiating and maintaining complete decongestive therapy self-management of lymphedema among breast cancer survivors: descriptive qualitative study. *Integr Cancer Ther*. 2024;23:15347354241226625.
- Wang Y, Wei T, Li M, Wu P, Qiang W, Wang X, Shen A. Factors influencing the self-management of breast cancer-related lymphedema: a meta-synthesis of qualitative studies. *Cancer Nurs*. 2024.
- Temur K, Kapucu S. The effectiveness of lymphedema self-management in the prevention of breast cancer-related lymphedema and quality of life: a randomized controlled trial. *Eur J Oncol Nurs*. 2019;40:22–35.
- Cal A, Bahar Z, Gorken I. Effects of health belief model based nursing interventions offered at home visits on lymphedema prevention in women with breast cancer: a randomised controlled trial. *J Clin Nurs*. 2020;29(13–14):2521–34.
- Cruz FOAM, Vilela RA, Ferreira EB, Melo NS, Dos Reis PED. Evidence on the use of mobile apps during the treatment of breast cancer: systematic review. *JMIR mHealth uHealth*. 2019;7(8):e13245.
- Fu MR, Axelrod D, Guth AA, Scagliola J, Rampertaap K, El-Shammaa N, et al. A web and mobile-based intervention for women treated for breast cancer to manage chronic pain and symptoms related to lymphedema: results of a randomized clinical trial. *JMIR Cancer*. 2022;8(1):e29485.
- Tieu L, Sarkar U, Schillinger D, Ralston JD, Ratanawongsa N, Pasick R, Lyles CR. Barriers and facilitators to online portal use among patients and caregivers in a safety net health care system: a qualitative study. *J Med Internet Res*. 2015;17(12):e275.
- Liang X, You M, Wen C, Hou F, Kang J, Lv Z, Tian J. Self-administration of complex decongestive therapy facilitated by the mobile application WeChat improves lymphedema and quality of life in breast cancer survivors: an observational study. *Annals Translational Med*. 2022;10(3):146.
- Harrison R, Flood D, Duce D. Usability of mobile applications: literature review and rationale for a new usability model. *J Interact Sci*. 2013;1(1):1.
- Jordan PW. An introduction to usability. 1st ed. CRC Press; 2020. <https://doi.org/10.1201/9781003062769>
- Krebs P, Duncan DT. Health app use among US mobile phone owners: a national survey. *JMIR mHealth uHealth*. 2015;3(4):e4924.
- Zhou L, Bao J, Setiawan IMA, Saptono A, Parmanto B. The mhealth app usability questionnaire (MAUQ): development and validation study. *JMIR mHealth uHealth*. 2019;7(4):e11500.
- Aydin A, Gürsoy A, Karal H. Mobile care app development process: using the ADDIE model to manage symptoms after breast cancer surgery (step 1). *Discover Oncol*. 2023;14(1):63.
- Harder H, Holroyd P, Burkinshaw L, Watten P, Zammit C, Harris PR, et al. A user-centred approach to developing Bwell, a mobile app for arm and shoulder exercises after breast cancer treatment. *J Cancer Surviv*. 2017;11:732–42.
- Aydin A, Gürsoy A, Karal H. Mobile care app development process: using the ADDIE model to manage symptoms after breast cancer surgery (step 1). *Discover Oncol*. 2023;14(1):1–10.
- Fu MR, Axelrod D, Guth A, Scagliola J, Rampertaap K, El-Shammaa N, et al. A web and mobile-based intervention for women treated for breast cancer to manage chronic pain and symptoms related to lymphedema: randomized clinical trial rationale and protocol. *JMIR Res Protocols*. 2016;5(1):e7.
- Ahmadi M, Shahrokhi SN, Khavaninzadeh M, Alipour J. Development of a mobile-based self-care application for patients with breast cancer-related lymphedema in Iran. *Appl Clin Inf*. 2022;13(05):935–48.
- Fu MR, Axelrod D, Guth AA, Wang Y, Scagliola J, Hiottis K, et al. Usability and feasibility of health IT interventions to enhance self-care for lymphedema symptom management in breast cancer survivors. *Internet Interv*. 2016;5:56–64.
- Chin JP, Diehl VA, Norman KL. Development of an instrument measuring user satisfaction of the human-computer interface. In: Proceedings of the SIGCHI conference on Human factors in computing systems: 1988;1988:213–218.
- Zare Z, Hajizadeh E, Mahmoodi M, Nazari R, Shahmoradi L, Rezayi S. Smart-phone-based application to control and prevent overweight and obesity in children: design and evaluation. *BMC Med Inf Decis Mak*. 2023;23(1):201.
- Moulaei K, Sheikhtaheri A, Ghafaripour Z, Bahaadinbeigy K. The development and usability assessment of an mhealth application to encourage self-care in pregnant women against COVID-19. *Journal of healthcare engineering 2021*, 2021.
- Mishra P, Pandey CM, Singh U, Gupta A, Sahu C, Keshri A. Descriptive statistics and normality tests for statistical data. *Ann Card Anaesth*. 2019;22(1):67–72.
- University N. Partial eta squared. 2024. <https://resources.nu.edu/stats-resources>. Accessed 5 Dec 2023.
- Dorri S, Olfatbakhsh A, Asadi F. Informational needs in patients with breast cancer with lymphedema: is it important? *Breast Cancer: Basic Clin Res*. 2020;14:1178223420911033.
- International Society of Lymphology. The diagnosis and treatment of peripheral lymphedema. Consensus document of the international society of lymphology. *Lymphology*. 2020;53(1):3–19.
- Zhu J, Ebert L, Liu X, Wei D, Chan SW. Mobile breast cancer e-support program for chinese women with breast cancer undergoing chemotherapy (part 2): multicenter randomized controlled trial. *JMIR mHealth uHealth*. 2018;6(4):e104.

36. Drewes C, Kirkovits T, Schiltz D, Schinkoethe T, Haidinger R, Goldmann-Posch U, et al. Ehealth acceptance and new media preferences for therapy assistance among breast cancer patients. *JMIR Cancer*. 2016;2(2):e5711.
37. Saevarsdottir SR, Gudmundsdottir SL. Mobile apps and quality of life in patients with breast cancer and survivors: systematic literature review. *J Med Internet Res*. 2023;25:e42852.
38. Sohrabei S, Atashi A. The impact of mobile health on breast cancer patient's life and treatment: a systematic review. *Front Health Inf*. 2021;10(1):88.
39. Mayrovitz HN. Measuring breast cancer-related lymphedema. *Exon Publications*. 2022:63–82.
40. Amiri P, Gholipour M, Hajesmaeel-Gohari S, Bahaadinbeigy K. A mobile application to assist alzheimer's caregivers during COVID-19 pandemic: development and evaluation. *J Caring Sci*. 2023;12(2):129.
41. Budiu R. Usability testing for mobile is easy. 2014. <https://www.nngroup.com/articles/mobile-usability-testing/>. Accessed 15 Dec 2023.

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