Evaluation of a Theory-based Mobile Health Physical Activity Intervention for Breast Cancer Patients During Chemotherapy: Mixed Method Study

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Abstract

Purpose Mobile health (mHealth) application (app) targeted promoting physical activity (PA) demonstrates advantages in knowledge sharing, social connecting and tailored intervention for breast cancer (BC) patients. However, lacking of theoretical basis restricted sustainable benefits of these apps. We construct a theory-based mHealth PA intervention program and to determine whether this would improve PA behavior change during chemotherapy for BC patients.

Methods Social cognitive theory, self-efficacy theory and the theory of planned behavior were referred to construct mHealth intervention strategies. Guided by agile development model, "Breast care" smartphone app based on above integrated theories was developed. Then, a three-month pre-post mHealth PA intervention delivered by the app was implemented. A mixed method was utilized to test the effectiveness of this remotely intervening.

Results Twenty participants were recruited. Based on PA capability assessment and baseline PA evaluation, 12 patients were divided into active group, and 8 patients were grouped in sedentary lifestyle. Within three months, the average accumulated app usage time of each participant identified at portal site was 40 minutes a week. The total PA increased 945.70 metabolic equivalents (MET) -min/w with a significant improvement ($P=.04$) after 3 months. Walking displayed a significant improvement after intervention (904.20 MET-min/w) ($P=.03$). Qualitative results showed satisfaction and willingness of BC patients to use the app to manage PA and relevant health behaviors.

Conclusion The theory-based mHealth PA intervention has great potential to enhance BC patients' PA awareness and engagement, meanwhile to facilitate their PA behavior change.

Introduction

Breast cancer (BC) is becoming the most common invasive cancer threatening women's lives. As the World Health Organization claimed in 2018 [1], the prevalence of BC reached 2.09 million cases, standing one of five leading cause of cancer death worldwide. To date, with the popularity of early screening and advanced targeted therapy, prognosis of BC is relatively positive. Unfortunately, process of going through chemotherapy, patients reported symptom disturbing seriously affect their daily life [2–4]. Reduced aerobic fitness and deterioration of muscle function are also identified in BC patients along with tendency of sedentary lifestyle [5].

Physical activity (PA), known as a modifiable protective factor, provides an approach to sustain physical and psycho-social health for BC patients both during and after treatment. Potential benefits of PA for a range of health outcomes were verified in numerous researches, which include reducing cancer-related fatigue [6], decreasing occurrence of fractures and lymphedema, managing sleeping disorder and anxiety [7], improving muscle strength, cardiorespiratory fitness, bone density and self-esteem [8]. Besides, large body of evidence also showed regular PA could reduce risks of cancer mortality and recurrence in the long run [9, 10]. However, owing to lacking of cognition about PA or influencing by traditional customs of rest after illness, majority of BC patients act inactive during chemotherapy [11].

There emerge numbers of mobile phone application (app) marketed to assist PA promotion. This simple, accessible, convenient way breaks boundary of time and space, demonstrates advantages in knowledge sharing and social connecting. Especially for PA, mobile health (mHealth) technology, such as smartphone apps or wearable devices, makes behavior tracking easier, more accurate and cost efficient [12]. However, one limitation of app development regarding behavior changing is short of theoretical basis. Defect from mechanism aspect restricts these mobile apps produce sustainable benefits to cancer survivors.

In this context, we plan to conduct a mHealth intervention approach to smartphone app to support PA management of BC patients based on specific psychosocial and behavior changing theory. Prototype of this smartphone application is called "Information Assistant" [13], which is developed by our research team to meet patients' needs on demand in different phase. Drawn from above experience, we expanded function of the app on health behavior control and optimize the displaying structure, organizing the app into new version, named by "Breast Care Version 1.0". In present study, we aim to construct a theory-based mHealth PA intervention program based on the app, and to determine whether this mobile lifestyle rehabilitation model would improve PA behavior change of BC patients during chemotherapy, meanwhile to capture their perspectives and experiences on engagement with mHealth to add evidence in field of mHealth PA intervention.

Methods

Construction of the theory-based mHealth PA intervention program

Selection of theoretical framework

Theories of social cognitive theory (SCT) [14, 15], self-efficacy theory (SET) [16, 17] and the theory of planned behavior (TPB) [18] were integrated as their good performance in promoting PA behavior in traditional intervention settings. Fundamental components of SCT including self-management skills (such as self-monitoring and setting goals), outcome expectancy, self-efficacy and cue to action which could be viewed as targeted skills to implement PA intervention for obtaining higher compliance and behavior change. Four ways extracted from SET containing shaping patients' self-efficacy, reflecting on direct/indirect experience, verbal persuasion, improvement of physical, psychological and emotional state add multi-dimension implications on PA practical intervening level. Additionally, concepts of intention and norms in TPB contribute to help predicting and interpreting individual PA behaviors [19–21]. Given thought of various attributes of three theories on PA promotion, contents and functions of the app based on above integrated conceptual framework were designed accordingly. Corresponding intervention techniques and model constructs, content, front-stage and portal management function of the app were exhibited in Table 1.

Table 1
Overview of “Breast Care V1.0” Content and Model Constructs

Intervention techniques	“Breast Care V1.0” Content	Application Section and portal management function	Model Constructs
Setting PA goals	Setting daily step goals; Alarm clock reminding	Exercise	Setting goals
PA self-monitoring	Demonstrating daily step completion rate; weather monitoring	Exercise& Calendar	Self-monitoring
Improving self-efficacy	Information support	Homepage	Self-efficacy
Health education	Tailored information delivering and searching	Homepage	Attitudes
Behavior feedback	Messages feedback through portal; Short message sending	Portal management function	Outcome expectancy
Overcoming barriers	Information support	Homepage	Self-efficacy
Social interacting	Chats (post, comment and share personal ideas)	Chats	Self-efficacy
Encouragement and rewarding	Daily steps ranking	Exercise	Norms; Cue to action
Identifying behavioral change	Messages feedback through portal; Short message sending	Portal management	Outcome expectancy
Verbal persuasion	Messages feedback through portal; Short message sending	Chats &portal management	Self-efficacy
Negative examples	Case sharing	Exercise	Norms
Looking for role models	Case sharing	Exercise	Norms; Self-efficacy
Looking back on past successes	Portal sending messages	Portal management	Norms; Self-efficacy
Grouping	Tailored information supporting and portal sending messages	Portal management	Norms; Intension

“Breast Care V1.0” application interface and portal site

Based on our previous work [13, 22] and theoretical consideration, additional health behavior recording and other related modules were added in the app, named by “Breast Care Version 1.0”, which included five main pages (homepage, calendar, chat, exercising, personal center) covering six functions, containing information delivering, disease tracking, events reminding based on calendar, online interaction, health behavior recording and self-reported assessment. Guided by agile development model, after testing of beta version, two versions of app system based on Android and iOS platform were launched to the application store. Screenshots of client-side and portal site were shown in Supplementary Fig. 1–6.

Evaluation of the theory-based mHealth PA intervention program

A mixed method was utilized to test the effectiveness of mHealth PA intervention program. Quantitative results from app-side and self-reported questionnaires were collected after a 3-month intervention. Qualitative feedback was also recorded to explore patients’ using experiences.

Participants

Twenty participants were recruited in this study from a tertiary hospital in Hangzhou city. Patients were eligible if they were diagnosed with BC, over 18 years old, receiving chemotherapy for the first time with 21 days a course, having no serious side effects to restrict PA, owning an iOS or Android system smartphone. Enrollment was conducted from November 2017 to January 2018. All of them signed informed consent to receive the intervention and self-reported investigation. Privacy protection was guaranteed by researchers no matter data of survey or data tracking online.

Intervention

Firstly, recruited participants who did the first course of chemotherapy were directed to download “Breast Care V1.0”; then, based on self-made PA capability assessment and results of long version of international physical activity questionnaire (IPAQ-L), users were divided into two groups and instructed to set daily step goal and input individual health data. One group was called sedentary group with a start goal of daily 3,000 steps (score of IPAQ-L < 540 MET-min/w [12]), and the other group was called active group with a start goal of daily 6,000 steps (score of IPAQ-L > 540 MET-min/w). Guided by the theoretical framework,

various flexible intervention strategies were included relied on both app and SMS, including PA behavior monitoring and feedback, improving self-efficacy, health education, overcoming the PA barriers, providing social support and looking back of personal PA experiences, etc.

The concrete intervention included: (1) One was based on the app, as initially step goals, participants were recommended to walk 3000/6000 steps a day. At 9 pm of each day, a reminding about individuals' daily total steps and gap with goals would be send to their smartphone (see Supplementary Fig. 7). For other time, they could browse the information in the app and participate in the online peer interaction. Every week, back-stage administrated researchers would renewal headline recommendation information displayed in homepage from the knowledge base. (2) The other intervention way was based on SMS. Through the third platform "Jiguang", tailored SMS with time, intense, frequency of PA intervention, nutrition, sleeping and mental health support were delivered twice weekly. For each week, summary report of patients' PA was texted to them with encouraging words. When participants completed the aimed steps in the former course of chemotherapy, 1,000 more steps would be recommended in the following course until maximal 10,000 steps after 3 months.

Data collection

Usage tracking through application

Using behavior of participants was monitored through backstage portal site. Census of cumulative views, comments, favorites of information were collected. Login times and cumulative using time of app was also collected under specific algorithm.

Measurement tools

Primary outcome of this present intervention study was PA. Secondary outcomes included PA self-efficacy, cancer-related fatigue, sleeping quality, mood status and QoL. Measurement for above variables were listed, respectively.

IPAQ-L

Measurement of PA is long version (31 items) of international physical activity questionnaire (IPAQ-L). It collects PA relevant data with domains of household and yard work activities, occupational activity, self-powered transport, and leisure-time PA as well as sedentary activity. Intensities of PA could be counted as walking, moderate and vigorous intensity. Test-retest reliability performed well with intraclass correlation coefficients of 0.67 for total PA in mainland China [23]. Final data of IPAQ-L is displayed with form of metabolic equivalent task-min/week (MET-min/week) for each dimension or intensity (except sedentary time). Furthermore, three levels of PA are concluded according to the recommended categorical score [24, 25], including low or totally sedentary, moderate and high.

ESES

Exercise self-efficacy scale (ESES) is selected to measure PA self-efficacy [26]. Individual marked their confidence participating recommended dose of activity at least 3 days a week. The scale rates from 0 (cannot do at all) through 50 (moderately certainly can do) to 100 (certainly can do) with 10-unit intervals. Average of all 18 items is calculated to indicate overall ESES. Three clusters are identified including situational factors, competitive factors and interpersonal factors. Test-retest reliability across two weeks is 0.77. Internal consistency of ESES is 0.96.

CRFS -CV

Instrument gauging cancer-related fatigue is cancer-related fatigue scale-Chinese version (CRFS-CV) which developed previously by our research team [27]. It distributes 3 dimensions consisted of 17 items, covering physical fatigue, mental fatigue and emotional state. The internal consistency reliability of the scale is 0.925. The reliability of the retest is good, and the calibration validity is 0.584. This 5 points Likert scale range from 17 to 85 points.

PSQI

Sleep quality is evaluated by Pittsburgh sleep quality index (PSQI). This scale was established by Buysse who was a psychiatrist in University of Pittsburgh in 1989 [28]. It contains 18 items, covering domains of subjective sleep quality, sleep latency, habitual sleep efficiency, sleep duration, use of sleeping medication, daytime dysfunction and sleep disturbances. Scores of each factor range from 0 to 3. Total score of PSQI range from 0 to 21. Higher score indicates worse the sleep quality is. Points more than 7 implies having sleep disorders. Scholar of Chen XL in China imported PSQI in 1996 and verified its good performance in psychometrics [29].

HADS

Mood status of participants is measured by hospital anxiety depression scale (HADS) which developed by Zigmond in 1983 [30]. HADS has two sub-scales, anxiety and depression. Each sub-scale has 7 Likert-type items ranging from 0 to 3 point. Cronbach's α of two sub-scales is 0.762 and 0.787, respectively. A global sum of 7 or less indicates none psychological symptom tendency, 8 to 10 indicating suspicious anxious or depressive, 11 to 21 indicating definite anxious or depressive. High points indicate severe psychological symptom.

FACT-B

Functional assessment of cancer therapy-B (FACT-B) is a 36-item self-reported instrument measuring QoL. Chinese version of FACT-B is available [31]. The whole scale can be divided into two parts, general FACT and BC sub-scale. Four domains of general FACT scale include physical well-being, social well-being, emotional well-being and functional well-being. Besides, 9 additional items specific to BC module are also embedded. Each item is a 5-Likert scoring with 0 (not at all) to 4 (very much). Total score of FACT-B is around 0 to 144. Higher score indicates better QoL.

Qualitative evaluation

All recruited users were contacted to be asked for whether agreeing to join a telephone interviewing. Conversations focusing on perceptions of mHealth intervention, cognitions towards benefits of PA, opinions about function and interface of app were conducted. On basis of acquiring participants' authorization, content of interviewing would be recorded.

Statistical analysis

Quantitative analysis: PA behavior and other secondary outcomes were analyzed using SPSS (version 21, IBM Corporation®). Mean scores and standard deviation were reported. Paired t test and wilcoxon signed-rank test were utilized to examine PA's and secondary outcomes' differences before and after intervention. P value of < .05 was considered statistically significant.

Qualitative analysis: after interviewing, anonymous transcription was conducted by separate researcher within 24 hours. Content analysis was adopted on basis of deeply immersing in text. Finally, qualitative data were coded and categorized into subthemes and the main theme.

Results

Characteristics of Participants

Twenty participants were recruited. Mean age was 44.85 ± 10.05 years. Demographic material and disease information of participants were demonstrated in Table 2.

Table 2
Characteristics of enrolled BC patients

Characteristic	Participants
Age, n (%)	
18–44	12 (60)
45–54	5 (25)
55–64	1 (5)
65–74	2 (10)
BMI, mean (SD)	23.44 (3.72)
Marital status, n (%)	
married	20 (100)
Job, n (%)	
employed	16 (80)
unemployed	4 (20)
Education level, n (%)	
Primary school	2 (10)
Middle school	5 (25)
High school	7 (35)
College or above	6 (30)
Monthly income, n (%)	
<1000	1 (5)
1000 ~ 3000	5 (25)
3000 ~ 5000	9 (45)
> 5000	5 (25)
Disease stage, n (%)	
Stage Ⅰ	4 (20)
Stage Ⅱ	5 (25)
Stage Ⅲ	8 (40)
Stage Ⅳ	3 (15)
Surgery, n (%)	
Yes	8 (40)
Not	12 (60)
Catheter placement, n (%)	
PICC	10 (50)
PORT	7 (35)
Others	3 (15)
Preferences type of PA, n (%)	
Walking	12 (60)
Yoga	2 (10)
Swimming	1 (5)
None	5 (25)

Usage of “Breast Care” of phone users

Participants' usage behavior identified at portal site indicated the accumulated app usage time was 40 minutes a week. Most of the time spent on knowledge browsing, in which headline information were read most. On contrast, clients' active retrieval behavior was less. Average login time of each participant was three times a week.

Quantitative Results

Baseline PA assessment

Based on PA capability assessment and baseline IPAQ-L investigation, 12 patients were divided into active group and 8 patients were in sedentary group.

Primary Outcome: Change of PA

For primary outcome, the total PA increased 945.70 MET-min/w with a significant improvement ($P = .04$) after 3-month, details shown in Table 3. Except dimension of occupational PA had a decreased trend (-177.25 MET-min/w), the other three domains of PA showed an increasing tendency. Post-pre leisure-time PA improved the largest with a mean of 592.35 MET-min/w, followed by self-powered transport PA and household and yard work PA. Sedentary mean time declined 112 mins/w, while it didn't show statistically significant ($P = .49$). From the point of domains of PA, self-powered transport PA and leisure-time PA demonstrated a significant increasing changing ($P = 0.046$ & $P = .01$). Whilst for levels of PA with different intensities aspect, walking displayed a statistically significant improvement after intervention ($P = .03$).

Table 3

PA behavior changing after intervention of BC patients (MET-min/w)									
Variables		Pre-intervention		Post-intervention		Post-intervention - pre-intervention		Z ^b	P Value
		Mean	SD	Mean	SD	Mean	SD		
Dimension of PA	Occupational PA ^c	258.10	586.58	80.85	212.92	-177.25	588.80	1.153	.25
	Self-powered Transport PA ^d	453.98	583.35	864.08	742.75	410.10	884.56	-1.994	.046 ^a
	Household and yard work PA ^d	96.25	286.64	216.75	491.63	120.50	602.82	-0.968	.33
	Leisure-time PA ^d	478.50	715.82	1070.85	790.73	592.35	1010.56	-2.541	.01 ^a
Level of PA	Walking ^d	1098.08	1119.76	2002.28	1141.07	904.20	1632.34	-2.173	.03 ^a
	Moderate PA ^d	140.75	372.57	230.25	487.31	89.50	659.18	-0.785	.43
	Vigorous PA ^c	48.00	214.66	0.00	0.00	-48.00	214.66	-1.000	.32
Sedentary time (mins/week)		901.50	309.96	1013.25	449.46	-111.75	623.99	-0.685	.49
Total PA ^d		1286.83	1289.01	2232.53	1457.76	945.70	2059.04	-2.053	.04 ^a
a $P < 0.05$									
b Wilcoxon signed rank test									
c is based on negative rank									
d is based on positive rank									

As shown in classification of different PA levels in Table 4, percentage of participants with sedentary lifestyle decreased from 40–10%, and percentage of participants with moderate PA/active lifestyle increased from 60–90%. An apparent rise was observed in regard with numbers of patients who met guideline PA recommendation.

Table 4

Classification of different PA levels after mHealth intervention		
Classification of PA levels	Pre-intervention n (%)	Post-intervention n (%)
Sedentary	8 (40%)	2 (10%)
Moderate	10 (50%)	14 (70%)
Active	2 (10%)	4 (20%)
Meeting guideline recommendation (above 540 MET-min/w)	12 (60%)	19 (95%)

Second Outcome: Change of exercise self-efficacy, cancer-related fatigue, sleep quality, mood status and QoL

For secondary outcomes, the results presented that there was a significant difference in situational factors of exercise self-efficacy ($P = .02$) and depression ($P = .02$) between baseline and after intervention. Notably, mean level of depression of the participants after the intervention showed a higher score than baseline, while still in normal level (mean score = 4.05 VS mean score = 6.30, $P = .02$). In addition, increasing trend of exercise self-efficacy was found in every domain and the total score. Details were shown in Table 5.

Table 5
Exercise self-efficacy, cancer-related fatigue, sleep quality, depression, anxiety, QoL change from baseline to post-intervention of BC patients

Variables	Pre-intervention		Post-intervention		Post-intervention- pre-intervention		t/Z	PValue
	Mean	SD	Mean	SD	Mean	SD		
Exercise self-efficacy								
Total score ^d	46.78	21.92	53.82	13.59	7.04	21.62	-1.207 ^b	.23
Situational factors	41.00	23.85	56.08	14.34	15.08	25.31	2.665 ^c	.02 ^a
Competitive factors ^d	57.30	24.24	58.70	15.22	1.40	21.56	-0.022 ^b	.98
Interpersonal factors	44.21	24.83	48.40	18.35	4.19	28.69	0.652 ^c	.52
Cancer-related fatigue								
Total score ^d	1.88	0.64	1.92	0.51	0.04	0.75	-0.411 ^b	.68
Physical fatigue	2.13	0.72	2.18	0.65	0.05	0.90	0.248 ^c	.81
Emotional fatigue ^e	1.81	0.82	1.73	0.59	-0.08	0.81	-0.141 ^b	.89
Mental state ^d	1.66	0.71	1.84	0.49	0.18	0.86	-1.097 ^b	.27
Sleep quality								
Total score	7.70	2.94	9.15	4.13	1.45	3.97	1.635 ^c	.12
Subjective sleep quality ^d	1.10	0.72	1.15	0.99	0.05	1.00	-0.159 ^b	.87
Sleep latency ^d	1.50	0.89	1.80	0.83	0.30	0.98	-1.396 ^b	.16
Sleep duration ^f	2.00	0.00	2.00	0.00	0.00	0.00	0.000 ^b	\
Habitual sleep efficiency ^d	0.85	1.04	1.30	1.21	0.45	1.36	-1.468 ^b	.14
Sleep disturbance ^d	1.15	0.37	1.40	0.68	0.25	0.64	-1.667 ^b	.10
Use of sleeping medication ^d	0.10	0.31	0.25	0.72	0.15	0.81	-0.707 ^b	.48
Daytime dysfunction ^d	1.00	0.86	1.25	0.97	0.25	1.12	-0.929 ^b	.35
Mood Status								
Depression	4.05	3.56	6.30	2.81	2.25	3.89	2.586 ^c	.02 ^a
Anxiety	6.15	3.01	6.25	2.88	0.10	3.89	0.115 ^c	.91
QoL								
Total score	94.45	19.48	91.60	18.01	-2.85	20.84	-0.611 ^c	.55
Physical well-being ^e	20.40	5.33	20.70	5.29	0.30	5.15	-0.119 ^b	.91
Social well-being	18.70	4.86	17.35	5.25	-1.35	7.56	-0.799 ^c	.43
Emotional well-being	17.20	3.50	17.00	3.20	-0.20	3.11	-0.288 ^c	.78
Functional well-being	13.85	7.39	14.05	6.69	0.20	7.97	0.112 ^c	.91
Breast specific well-being ^e	24.30	5.69	22.50	3.87	-1.80	4.56	-1.797 ^b	.07
a <i>P</i> < 0.05								
b Wilcoxon signed rank test								
c Paired t test								
d is based on positive rank								
e is based on negative rank								
f The sum of negative ranks is equal to the sum of positive ranks.								

Qualitative Results

After 3-month intervention, five of twenty participants agreed to receive the interviewing. Basic information of users was displayed in Table 6. Four themes were categorized by content analysis.

Table 6
Basic information of patients participated qualitative interview

Case Number	Age	Education level	Job status	Smartphones system
U1	40	Middle school	At work	iOS
U2	41	Middle school	At work	Android
U3	40	High school	At work	Android
U4	30	Associate college	At work	iOS
U5	59	Middle school	Retired	Android

Improvement on cognition of PA

Positive feedback was received from five participants about improvement on PA cognition. Gained knowledge on PA especially on benefits of PA increased their confidence on PA engagement.

"I feel puzzled in the beginning of chemotherapy. Through the app and weekly SMS reminders, now I know except the two days doing chemo, other days during course of chemo, I could do some exercise." (U1)

"I need to go back to work when I finish chemotherapy. I am following your instruction to walk 6,000 steps per day, the intensity is acceptable, and I will insist on walking and feel motivated for long-term physical health. (U4)

"My family didn't allow me to exercise and do housework, they hold opinions of rest for better recovery. While I have nothing to do, information on the app give me confidence to do something I am qualified." (U5)

Satisfaction with user interface and mobile timely feedback of the App

Of five users, two participants explicitly stated satisfaction of user interface of "Breast Care". Besides, timely feedback of the app was emphasized by users. They admired the feedback information bringing about a sense of caring and self-controlling.

"The brochures you sent are very clear. Step by step, the application is easy to use and the interface is friendly" (U2)

"Color and collocation of the app's whole interface looks very comfortable" (U4)

"Once receiving short message, I will log on to browse your recommended videos or essay. In addition, your weekly message encourages me to do better next week." (U2)

"Information pushed to my mobile phone at 9 pm everyday will remind me the gap between actual steps and step goals, with those tips I would intend to walk more the next day." (U3)

"I had a good exercise habit before, your weekly SMS told me I rank first, I feel so happy and have a great sense of accomplishment." (U4)

Perceived benefits of mobile PA intervention

Participants expressed benefits in aspect of getting knowledge and self-management skills through the app.

"Content in the app is good and comprehensive. When I have some questions about treatment, I will log in and look for stuff I am interested in, such as chemotherapy precautions. After all, they are managed by professionals and are relatively trusted." (U1)

"Headline information in homepage I read the most. I could see it updated frequently. I also use the Calendar to mark dates of chemotherapy, it's convenient of the automatic calculation." (U1)

Future advice to application and intervention

Within three months using period, users also pointed out some advice about "Breast Care V1.0" including technique functions and using experiences, especially on desire of online communication with peers.

"To be honest, the usage time of app is not very much. What I should know is almost know already. If it provides continuing feedback for a long time, that will be nice." (U2)

"Sometimes it's not smooth when watching the video. The buffer is very long, but it's much better to watch it again." (U3)

"I want to share my feelings with somebody else, but I think the number of people post their feelings in this app is not much. When there are more discussions, I'm willing to use them often." (U4)

Discussion

This study indicated that the theory-based mHealth PA intervention could improve exercise self-efficacy, decrease sedentary time of BC patients and facilitate their PA behavior change during chemotherapy. In addition, rather salutary effects after PA intervention were explored in qualitative process, including improving participants' cognition and self-management skills.

As reported, total PA, level of walking and moderate PA, domains including self-powered transport PA, leisure-time PA and household work PA all showed obvious increasing trends. Findings in present study are similar with previous researches. For instance, one combining aerobic and resistance exercises program delivered by a smart app and pedometer showed, mean of total PA of BC patients significantly increased 976.3 MET-min/w [32]. The increasing spectrum in walking (from 1098.08 to 2002.28 MET-min/w) intensity in our study showed a similarity with the piece of research conducted in USA (from 1967 to 3076 MET-min/w) [33]. The above results also verify the effectiveness of intervention strategies derived from the integrated theoretical framework which proposed previously in many non-cancer studies [34, 35]. Constructs in the model interpret point by point linking behavior change techniques to smartphone functions, adding more possibility to behavior intervening in flexible ways.

For secondary outcomes, situational factor in exercise self-efficacy demonstrated a rising change indicating more confidence doing exercise participants gained. For cancer-related fatigue, none benefits were found in current study consistently with the research conducted in 2013 [36]. However, a published meta-analysis in 2016 reported opposite results that physical fatigue was sensitive to physical exercise [6]. For sleep quality, it was viewed as having a bidirectional relationship with PA [37], while limited resources were obtained to test the relationships between PA and sleep quality in RCTs [38]. With respect to QoL, one program conducted in 2019 supported potential benefits of PA on QoL even lasted for 1 year follow-up from chemotherapy [39], while some failed to find statistically significant influence with conventional intervention approach [40].

Compared with quantitative findings, more positive qualitative feedback from participants was concluded. The feeling of mastery their daily life as normal, having access to interact with peer patients, all empowered them to pursue hope and happiness. One prominent feature addressed by participants in qualitative interview is behavior live feedback, like Nielsen et al [41] claimed, personalized and highly tailored intervention was the key factor to enhance engagement in PA during chemotherapy for BC patients. What's more, in qualitative evaluation process, some participants acknowledged their hesitation to share personal feelings openly. There are previous studies in line with our findings about social interaction [42]. For some participants featured by coping strategies with avoiding, they prefer made progress by their own instead of actively anticipating competition. By contrast, for most of the studies, it is deemed a motivational strategy of social features in mobile app, having great value in shaping sense of membership and belonging in the group [43]. The relevant findings give a clear clue to develop new apps aiming promoting health behaviors for high acceptability and efficiency.

Some limitations should be noted in our study. First, it is a pre-post intervention design weakening the efficacy of intervention on relevant health outcomes. Second, small sample size might limit some pronounced findings on psychological indicators and restrict a thorough exploration of users' experience. Third, measurement of PA lacks more objective gauging method. Although most of smartphones support recording of participants' daily steps if they authorize the access of our "Breast Care V1.0" app, accuracy of embedded steps tracking is still questionable [44]. Forms of data collection based on accelerometer, pedometer or other wearable devices should be considered to reinforce the accuracy and reliability of step tracking in future.

Declarations

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Conflicts of interest/Competing interests

The authors have no conflicts of interest to disclose.

Availability of data and material

The data of this study are available on request from the corresponding author.

Code availability

The codes of the app are available on request from the corresponding author.

Authors' contributions

Zhaohui Geng made contributions to designing the whole study, developing the application, implementing the intervention and drafting the manuscript. Li Ning and Lingzhi Cai were involved in recruiting participants, clinical management and data collection. Ying Liu and Jingting Wang made contributions on developing and testing the application. Yingting Zhang and Fulei Wu were responsible for data collection and data analysis. Changrong Yuan contributed conception, designing and revising the manuscript.

Ethics approval

This project was approved by the ethics committee of second military medical university.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent for publication

The authors affirm that human research participants provided informed consent for publication of the data and relevant images.

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