International Journal of Nursing Sciences 11 (2024) 405–413

HOSTED BY

Contents lists available at ScienceDirect

International Journal of Nursing Sciences

journal homepage: http://www.elsevier.com/journals/international-journal-of-nursing-sciences/2352-0132

Research Paper

Effectiveness of a theory-based tailored mHealth physical activity intervention for women undergoing chemotherapy for breast cancer: A quasi-experimental study

Zhaohui Geng [a], Jingting Wang [b], Weibo Lyu [a], Xinyu Li [a], Wenjia Ye [a], Wei Zheng [c], Juan Yang [d], Li Ning [e], Lingzhi Cai [f], Ying Liu [g], Yingting Zhang [b], Fulei Wu [h], Changrong Yuan [h,*]

[a] School of Nursing, Shanghai University of Traditional Chinese Medicine, Shanghai, China
[b] School of Nursing, Navy Medical University, Shanghai, China
[c] Department of Breast Surgery, Longhua Hospital, Shanghai University of Traditional Chinese Medicine, Shanghai, China
[d] Department of Breast Surgery, Yueyang Hospital of Integrated Traditional Chinese and Western Medicine, Shanghai University of Traditional Chinese Medicine, Shanghai, China
[e] Department of Nursing, Hangzhou First People's Hospital, Hangzhou, China
[f] Department of Breast Surgery, Hangzhou First People's Hospital, Hangzhou, China
[g] Department of Nursing, Shanghai First Maternity and Infant Hospital, Tongji University School of Medicine, Shanghai, China
[h] School of Nursing, Fudan University, Shanghai, China

ARTICLE INFO

Article history:
Received 24 February 2024
Received in revised form
2 June 2024
Accepted 8 August 2024
Available online 10 August 2024

Keywords:
Anxiety
Breast cancer
Chemotherapy
Depression
Patients
Physical activity
Telemedicine

ABSTRACT

Objectives: This study aimed to explore the effectiveness of the theory-based tailored mHealth physical activity (PA) intervention among patients with breast cancer undergoing chemotherapy.
Methods: A quasi-experimental study design was adopted. A total of 60 breast cancer patients were selected from two tertiary hospitals in Shanghai and Hangzhou City from September 2019 to August 2021. According to the admission order, 30 patients were first included in the control group, followed by 30 patients in the intervention group. A smartphone application (app) named "Breast Care" was developed based on social cognitive theory, self-efficacy theory, and the theory of planned behavior. The app integrated various functions, including information browsing, PA monitoring and feedback, symptom reporting, and social interaction. Patients in the intervention group received three months of personalized online PA guidance in addition to routine care. The control group received routine care. Baseline and post-intervention investigations after three months were conducted in two groups using the Short Form of International Physical Activity Questionnaire, the Hospital Anxiety and Depression Scale, and the Functional Assessment of Cancer Therapy—Breast cancer.
Results: After three months of intervention, compared to the control group, breast cancer patients in the intervention group showed significant improvements in walking, moderate PA, and overall PA ($P < 0.05$). Compared to the baseline data, breast cancer patients in the intervention group had significant improvements in walking and overall PA after three months ($P < 0.05$), whereas the control group experienced significant declines in walking, moderate PA, and overall PA after three months ($P < 0.05$). There were statistically differences between the two groups in scores for anxiety, overall quality of life, and its dimensions, such as physical well-being, emotional well-being, and additional breast cancer well-being ($P < 0.05$).
Conclusions: The theory-based tailored mHealth PA intervention has demonstrated a positive impact on promoting PA behavior change and emotional management among breast cancer patients. The 'Breast Care' app integrated various practical behavior change strategies, offering valuable guidance for personalized remote rehabilitation support for cancer patients.

* Corresponding author.
E-mail address: yuancr@fudan.edu.cn (C. Yuan).
Peer review under responsibility of Chinese Nursing Association.

https://doi.org/10.1016/j.ijnss.2024.08.006

What is known?

- Physical activity (PA) plays an important role in sustaining the physical and psychosocial health of patients with breast cancer during chemotherapy, while cognitive deficiencies and treatment-related side effects restrict patients from engaging in regular exercise.
- Mobile health interventions have advantages in knowledge sharing, PA behavior tracking, implementing individualized guidance, and social connection.
- The social cognitive theory (SCT), self-efficacy theory (SET), and theory of planned behavior (TPB) provide a theoretical basis for designing a new tailored remote PA intervention.

What is new?

- Behavioral intervention strategies derived from SCT, SET, and TPB strengthened the efficacy of the smartphone application, with short message services serving as a valuable adjunct for disseminating personalized PA support information.
- The theory-driven tailored mHealth PA intervention showed favorable prospects in enhancing PA behavior, managing emotions, and improving quality of life in breast cancer patients during chemotherapy.

1. Introduction

Breast cancer is the most common invasive cancer threatening the lives of women. As GLOBOCAN 2020 claimed [1], the prevalence of breast cancer reached 2.3 million cases, surpassing lung cancer, which is one of the five leading causes of cancer-related deaths worldwide. More than 90% of breast cancer cases can be attributed to environmental, reproductive, and lifestyle factors, while less than 5% are genetically inherited [2]. With the popularity of early screening, innovation in gene diagnosis, and advanced targeted therapy, the prognosis of breast cancer is relatively positive. Unfortunately, with adjuvant combination chemotherapy, patients report unpleasant symptoms such as fatigue, weight gain, insomnia, and depression [3–6]. Reduced aerobic fitness and muscle function deterioration have also been identified in patients with sedentary lifestyles [7]. More effective strategies should be developed to maintain a high quality of life (QoL) and reduce survival deficits in women with breast cancer.

Physical activity (PA), a modifiable protective factor, provides an approach to sustaining the physical and psychosocial health of patients with breast cancer, both during and after treatment. The potential benefits of PA for a range of health outcomes have been verified in numerous studies. These include reducing cancer-related fatigue [8], decreasing the occurrence of fractures, joint pain, and lymphedema, managing sleep disorders and anxiety [9], and improving muscle strength, flexibility, cardiorespiratory fitness, bone density, and self-esteem [10]. Moreover, a large body of evidence has shown that regular PA can reduce the risk of cancer mortality and recurrence in the long run [11–13]. However, owing to a lack of awareness about PA, suffering from the side effects (e.g., fatigue, renal toxicity, the consciousness of one's vulnerability) of chemotherapy [14], or the influence of traditional customs of rest after illness, most patients with breast cancer remain inactive during chemotherapy [15,16].

Several mobile phone applications (apps) have been marketed to promote PA. This simple, accessible, and convenient method breaks the boundaries of time and space and demonstrates advantages in knowledge sharing and social connection. Especially for PA, mobile health (mHealth) technologies such as smartphone apps or wearable devices make behavior tracking easier, more accurate, and cost-efficient [17]. Moreover, real-time monitoring provides detailed information on healthcare workers' implementation of tailored interventions. However, few apps bring about practical transformation regarding PA behavior change because of the focus on health knowledge education and the lack of a theoretical basis to guide the development process of apps. Moreover, the advantages of short message sending (SMS) are not well reflected in current app-driven interventions. Defects in the mechanism restrict these mobile apps from producing sustainable benefits for cancer survivors.

The classical behavioral changing theories such as the social cognitive theory (SCT) [18,19], self-efficacy theory (SET) [20,21], and theory of planned behavior (TPB) [22] have been considered to perform well in promoting PA behavior in traditional intervention settings. The core concept of SCT posits that an individual's activities result from the interaction of personal factors (cognitive, emotional, and biological), environmental factors (social and physical environment), and behavior. Intervention strategies based on SCT emphasize the individual's ability to control their behavior and changes produced by the individual or the environment. Fundamental components of SCT include self-management skills, outcome expectancy, self-efficacy, and cue to action, which could be viewed as targeted skills to implement PA intervention for obtaining higher compliance and actual behavior change. Self-efficacy, a key construct of SCT, is a task-driven concept that indicates an individual's confidence in completing concrete assignments. Four ways extracted from the SET, including direct experience, indirect experience, verbal persuasion, and improvement of physical, psychological, and emotional states, can shape patients' self-efficacy and thus influence self-management behavior. TPB posits that behavior cannot be solely explained or predicted by attitudes. Instead, it is influenced by behavioral intentions and perceived behavioral control. The antecedents of behavioral intentions encompass attitudes, subjective norms, and perceived behavioral control. Concepts of subjective norms in the TPB can help predict and interpret individual PA behaviors. All the theories mentioned above have multidimensional implications for the practical intervention level of PA.

In this context, we conducted a tailored mHealth intervention approach based on specific psychosocial and behavioral theories, using smartphone apps and SMS to support PA management in patients with breast cancer. Considering not applying blinding in using the app and receiving SMS for participants, we chose a quasi-experimental design with participants having a similar cycle of chemotherapy to strengthen the results. Through conducting the intelligent remote intervention, we aimed to examine the effects of the theory-based tailored mHealth PA intervention program and to determine whether this mobile lifestyle rehabilitation model would improve PA behavior in patients with breast cancer during their chemotherapy, thus adding evidence to the field of mHealth interventions in cancer patients.

2. Methods

2.1. Study design and participants

This study employed a non-synchronized quasi-experimental design. A total of 60 participants were recruited from tertiary hospitals in Hangzhou and Shanghai, China, with 30 participants each in the control and intervention groups. Enrolment was conducted between September 2019 and August 2021. The inclusion criteria were: 1) diagnosis of breast cancer; 2) over 18 years old; 3) receiving chemotherapy for the first time with 21-day course; 4)

having no serious side effects to restrict PA and 5) owning an Android smartphone system. The sample size was calculated using the formula $n1 = n2 = 2*[(\mu^{\alpha}+\mu^{\beta})/(\delta/\sigma)]^2$ [23] by setting $\alpha = 0.05$, $\beta = 0.20$, $\mu^{\alpha} = 1.96$ and $\mu^{\beta} = 0.84$. According to the pilot study by our research team [24], the mean score of change of the short form of the International Physical Activity Questionnaire for patients with breast cancer was 945.7 (SD = 693.0) after the intervention. The recommended sample size was 30 for each group. As the participants in our study could interact with each other when undergoing chemotherapy at the Department of Breast Surgery at the hospital, random assignment and blinding patients in the two groups were not feasible. We recruited the control group first in two hospitals, with 15 patients in each, and after three months, the intervention group was recruited in each hospital with 15 patients, respectively.

2.2. Interventions

Given that the chemotherapy cycle is 21 days long, so the tailored mHealth PA intervention was implemented in hospital and home. On the first day of the chemotherapy cycle, recruited participants were investigated using the self-designed PA capability assessments at the hospital. After that, patients went back home and started the online supported journey in the remaining 20 days until the next appointment, upon which they returned to the hospital for the second round of chemotherapy, thus repeating the cycle. During the 3-month intervention, patients in the intervention group received app-based PA support throughout the entire process, supplemented by SMS twice a week. The other nursing interventions during the chemotherapy period were the same in the intervention and control groups delivered by the same group of medical staff.

2.2.1. Intervention group

2.2.1.1. Establishment of the research team. To effectively implement this mHealth PA intervention project, it is crucial to establish a research team comprising researchers and clinical nursing professionals. The research team comprised a lead nursing researcher, two research assistants, and two clinical nurses. The principal nursing researcher specializing in oncology nursing was responsible for the whole process, including baseline investigation, online PA behavior monitoring, and targeted short message delivery. Two postgraduate nursing students as the research assistants were trained to implement individualized patient management and undertake the app's client-side management and portal-side administration, including recording automatically identified weekly PA performance and unpleasant symptoms reported by participants, and they were also in charge of sending tailored short messages and updating the knowledge base at the portal. Two clinical nurses in the department of breast surgery helped answer the queries raised by the patients on the portal every week and provided health education and symptom guidance when patients visited the hospital. The app and backstage management system were developed by the software engineers, who were also responsible for ensuring smooth operation during the process of intervention.

2.2.1.2. Development of the theory-based tailored mHealth PA intervention application. A new version of a smartphone app named 'Breast Care' was developed under the guidance of behavioral changing theories, including SCT, SET, and TPB. The prototype of this app is called the 'Information Assistant' [25], which our research team has developed to meet patients' information needs in different phases. The key model constructs selected from the three behavioral theories were adopted to optimize the app's content and functionality. Specifically, intervention strategies including setting PA goals, PA self-monitoring, overcoming barriers, social interaction, internal triggers/external triggers extracted from SCT, reflecting on past successes, negative examples, and verbal persuasion extracted from SET, looking for role models, health education, and grouping extracted from TPB were integrated to organize the app front-stage and the portal site. The relational logic among the model constructs, intervention strategies, app layout, and function are presented in Table 1. The final 'Breast Care' included five main pages: 'Homepage,' 'Exercise,' 'Calendar,' 'Chats,' and 'My Profile.' Meanwhile, it covered functions including information browsing, PA monitoring and behavioral feedback, symptom reporting, and social interaction. Guided by the agile development model, an app system based on the Android platform was developed after testing the beta version of the user interface, icons, and functions. Screenshots of the client side and portal sites are shown in Appendix A. A usability test has been conducted to ensure the app is acceptable and feasible [24].

2.2.1.3. The implementation of the joint app-based and SMS-based tailored PA intervention. After the first baseline investigation at the hospital, participants were labeled as sedentary or active lifestyle persons according to the initial evaluation results of the International Physical Activity Questionnaire (IPAQ) [24]. The recommended daily step goal for active group participants was 6,000 steps supported by guidelines for PA for Chinese people [26] if the baseline IPAQ was over 540 metabolic equivalent task-min/week (MET-min/week). For sedentary group participants, the recommended daily step goal was 3,000 steps if the baseline IPAQ was less than 540 MET-min/week, and we set a relatively low target in case their enthusiasm is undermined; the whole principle for them is "Being active is beneficial, more activity is better, exercise in moderation, persistence is key." When participants completed the targeted steps in the previous course of chemotherapy, 1,000 more steps were recommended. The goal of daily steps could be increased to 10,000 steps over three months. Also, on the day of the first cycle of chemotherapy, short messages with tailored PA recommendations were sent notifying the time, intensity, and frequency of PA interventions. Suggestions were also made to remind the participants to read the information on the app, covering the benefits of PA, dietary precautions, and rest.

From the 2nd to the 21th day of each chemotherapy cycle, participants were recommended to use the 'Breast Care' at home. They could get the following professional support: 1) browsing health-related information, including treatment information, PA-related principles and recommendations, nutrition and diet, self-image maintenance et al.; 2) monitoring their own PA performance throughout the health recording at the 'Exercise' module; 3) reporting their disturbing symptoms with access to 'self-evaluation' at 'Homepage' when necessary and 4) online communicating with the peers at module of 'Chats'. The above various flexible intervention strategies were consistent with the theoretical framework, including health education, improving self-efficacy, PA behavior monitoring and feedback, and providing social support. Notably, a push notification about an individual's daily total steps (identified through the gyroscope function inside the smartphone) and a gap with goals were sent to their smartphone at 9:00 p.m. each day to help monitor PA behaviors. Meanwhile, daily step ranking, monthly and weekly mean steps, and the accumulative distance of history were also displayed in the app to stimulate enthusiasm for PA.

Except for PA self-management through the app in each cycle of chemotherapy, tailored short messages were sent twice a week to enhance compliance and strengthen the participants' focus. Based on users' labels (sedentary or active) and the indication of user behavior analysis on the portal site, tailored short messages were

Table 1
Overview of matching model constructs, intervention techniques, 'Breast Care' function and portal management section.

Model constructs/ theory	Intervention techniques	'Breast Care' function	Main interfaces and portal management section
Self-management skills/SCT	Setting PA goals; PA self-monitoring	Setting daily step goals; Alarm clock reminder; Demonstrating daily step completion rate; Weather monitoring	Exercise; Calendar
Self-efficacy/SCT	Overcoming barriers; Social interacting	Information support; Chats (post, comment and share personal ideas)	Homepage; Chats
Outcome expectancy/ SCT; Cue to action/SCT; Direct experience/SET	Internal triggers through identifying behavior change; Reflecting on past successes	Messages feedback through portal; Short message sending	Portal management
Cue to action/SCT; Indirect experience/ SET; Norms/TPB	External triggers through encouragement; Negative examples; Looking for role models	Daily steps ranking; Case sharing	Exercise
Verbal persuasion/SET	Verbal persuasion	Messages feedback through portal; Short message sending	Chats & portal management
Attitudes/TPB	Health education	Tailored information delivering and searching	Homepage
Norms/TPB	Grouping	Tailored information supporting and portal sending messages	Portal management

Note: SCT = social cognitive theory. PA = physical activity. SET = self-efficacy theory. TPB = theory of planned behavior.

delivered extracted from the following aspects during the three months: 1) continuous information exposure about the recommended frequency, intensity, and type of PA; 2) principles of nutrition, sleeping and other possible disturbing symptom guidance, and the above were also recommended to locate at the specific article at the 'Knowledge base' in 'Breast Care' and 3) summary of one's past PA performance with encouraging words. For SMS, intervention strategies were attached to the theoretical model, including overcoming barriers, reflecting on personal PA experiences, and encouraging.

2.2.2. Control group

During the three months, breast cancer patients in the control group received relevant fliers or booklets from local hospitals and got standard care containing face-to-face health education when they visited the hospital for chemotherapy every three weeks. On the day of each cycle of chemotherapy back to the hospital, patients were asked if they were experiencing any symptoms, and the oncology nurse gave specific recommendations. Furthermore, healthy lifestyle advice, including the benefits of regular PA behavior, principles of PA, and suggestions about managing treatment-related side effects and emotional issues, were also delivered by the clinical nurses. Patients were encouraged to consult the nurses for the rest of the days back home.

2.3. Instruments

The primary outcome was PA, the secondary outcomes were mood status and QoL. The measurements of these variables are listed below.

2.3.1. The International Physical Activity Questionnaire-short form (IPAQ-SF)

PA was measured using the short form (seven items) of the IPAQ [27]. Test-retest reliability was acceptable, with 75% data showing intraclass correlation coefficients above 0.65, and the comparison results of the walking distance and pedometer measurements showed good criterion validity for the original IPAQ-SF [27]. The Chinese version of IPAQ-SF, translated by Qu et al. (2004) [28], indicates a good test-retest reliability and validity with a correlation coefficients 0.779, and the concordance rate between IPAQ-SF and objective measurements of PA levels meeting the criteria reached 71.8%. The intensities of PA were classified as walking, moderate and vigorous intensity activities. According to the description of different categorization in PA intensity at the introduction part of the questionnaire, participants were guided to recall whether and how long they engage in vigorous PA (like heavy lifting, digging, aerobics, or fast bicycling), moderate PA (like carrying light loads, bicycling at a regular pace, or doubles tennis) or walking during the last 7 days. The final data of the IPAQ-SF are displayed in the form of metabolic equivalent task-min/week (MET-min/week) for each intensity (except for sedentary time).

2.3.2. Hospital Anxiety and Depression Scale (HADS)

The mood status of the participants was measured using the HADS developed by Zigmond et al. in 1983 [29]. The HADS has two subscales: anxiety and depression. Each subscale has seven Likert-type items ranging from 0 to 3 points. Sun et al. (2017) [30] tested the reliability and validity of the HADS in the Chinese population. The Cronbach's α coefficient for the anxiety and depression subscales were 0.806 and 0.806, respectively. The intraclass correlation coefficients (ICC) for test-retest reliability were 0.921 and 0.932. The subscores of HADS exhibit a high correlation with the Self-Rating Anxiety Scale (SAS) and the Self-Rating Depression Scale (SDS), with correlation coefficients all above 0.55, indicating good convergent validity. Exploratory factor analysis demonstrates good structural validity of HADS. A global sum of 7 or less indicates no psychological symptom tendency, 8–10 indicates suspected anxiety or depression, and 11–21 indicates definite anxiety or depression. Higher scores indicate more severe psychological symptoms.

2.3.3. The Functional Assessment of Cancer Therapy-B (FACT-B)

The FACT-B is a 37-item forced-choice self-report instrument that measures QoL [31]. The Chinese version of the FACT-B, translated by Wan et al. (2003) [32] is available for assessing the QoL of patients with breast cancer in a specific Chinese population. The scale can be divided into the general FACT and the breast cancer subscales. The four domains of the general FACT scale are physical, social, emotional, and functional well-being. Nine additional items specific to the breast cancer module were also embedded. Each item is rated on a 5-point Likert scale from 0 (not at all) to 4 (very much). The total FACT-B score ranges from 0 to 144. Higher scores indicate better QoL. The scale has good construct validity, with high correlations between the scores of each domain and the overall

quality of life scale (r values mostly above 0.65). Internal consistency α for physical, psychological, emotional, and functional well-being subscales, additional breast cancer subscale, and total FACT-B scale are 0.84, 0.84, 0.79, 0.83, and 0.61, respectively. Test-retest reliability for the above five subscales and total scale is 0.82, 0.85, 0.85, 0.85, 0.86, and 0.89, respectively [32].

2.4. Data collection

Participants in the intervention and control groups were introduced to the study purpose and were explained by the research team to complete the questionnaire at baseline and end of the study (pre- and post-intervention). Data collection in two hospitals were responsible by Z. Geng (Shanghai and Hangzhou), L. Cai (Hangzhou) and X. Li (Shanghai). All surveys were distributed and retrieved when patients came to the hospital for chemotherapy. The questionnaire could be finished in 10 min. To ensure the completeness of the questionnaire, the research assistants helped to address the doubts patients asked and double-check the completeness of every response. Due to the COVID-19 pandemic, individuals who were not convenient finishing face-to-face investigations were surveyed by telephone instead.

2.5. Data analysis

This study used SPSS 21.0 (IBM Corporation, Armonk, NY, USA) for data analysis. The Kolmogorov-Smirnov test was used to assess the normality of the data distribution. Continuous variables normally distributed were expressed as mean and standard deviation, while those not normally distributed were presented as medians. Categorical variables were presented as the frequency and percentage. Data comparison about the patients' characteristics, primary outcome, and secondary outcomes between the control group and intervention group was performed using the independent sample t-test for normally distributed data, the Mann-Whitney U test for non-normally distributed data, and the Fisher's exact test and chi-square test for categorical variables. Differences in variables before and after intervention were examined using paired t-test for normally distributed data and the Wilcoxon signed-rank test for non-normally distributed data. $P < 0.05$ was considered to indicate statistical significance.

2.6. Ethics considerations

This project was approved by the Medical Ethics Committee of Fudan University Shanghai cancer center (No.1810192–22). All participants gave informed consent before participantion.

3. Results

3.1. Participant characteristics

The 60 patients included in the study comprised 30 in the control group and 30 in the intervention group. The demographic data and disease information of participants in each group are shown in Table 2. The characteristics between the two groups were not statistically different ($P > 0.05$), which indicated that the two groups were comparable.

3.2. Primary outcome: physical activity

No significant differences existed between the intervention and control group in every dimension or overall PA at baseline ($P > 0.05$). After three months, the intensity of walking and moderate PA showed the improvement in the intervention group compared with the control group ($P \leq 0.001$). Accordingly, the overall PA demonstrated the same positive change in the intervention group ($P < 0.001$), with walking being the most common ($P < 0.001$). In the control group, after three months, the amount of MET-min/week during walking, moderate PA, and total PA declined ($P < 0.001$, $P = 0.003$ and $P < 0.001$, respectively). In the intervention group, the number of MET-min/week during walking and total PA increased ($P = 0.011$ and $P = 0.002$). (Table 3).

3.3. Secondary outcomes: mood status and quality of life

Notably, no statistically significant difference was observed between the two groups at baseline ($P > 0.05$). Anxiety, physical well-being, emotional well-being, breast-specific well-being, and the total QoL score were differed between the two groups after the intervention ($P < 0.05$). In addition, depression worsened after three months in the control group ($P = 0.001$). Physical well-being, social well-being, emotional well-being, functional well-being, breast-specific well-being, and total QoL score all showed negative trends in the control group ($P < 0.05$). A positive trend in the physical well-being of the QoL was observed in the intervention group ($P = 0.039$), though social well-being decreased in the intervention group ($P = 0.012$). (Table 4).

4. Discussion

The results of this study indicated that the theory-based tailored mHealth PA intervention could enhance PA behavior, relieve anxiety, and improve QoL during chemotherapy. After three months, as illustrated by the PA comparison between the two groups, the overall PA was mainly reflected in walking, and moderate PA demonstrated a significant increase. Meanwhile, we found a decreasing MET-min/week of PA in the control group, which is understandable when patients in the chemotherapy course cannot participate in work normally or are not allowed to engage in high-intensity PA for safety considerations by their doctors or family members. The present study's findings are similar to previous studies conducted in South Korea [33] and the USA [34], where weekly PA behaviors were confirmed to increase significantly after mHealth interventions. Specifically, the 12-week home-based program of aerobic and resistance exercises delivered by smart app and pedometer showed that the mean total PA of patients with breast cancer significantly increased from 2,050.6 to 3,026.9 MET-min/w [33]. Data from the USA also indicated a noteworthy improvement, with a mean change of 545 MET-min/week in moderate PA [34]. Overall, the results of these two studies demonstrated a higher increase in PA behavior than in the present study. However, it revealed a positive influence on participants' cognition and behavior. Although PA might have numerous beneficial effects during the intervention period, a reduction in long-term PA effects is natural. As reported in one study, the percentage of patients meeting PA guideline recommendations was 34.0%, 39.5%, and 21.4% after 1-year, 5-year, and 10-year follow-ups, respectively [35]. More challenges exist in sustaining behavioral change beyond six months or more, which is usually the selection of intervention duration. Overall, mHealth interventions that rely on mobile and remote devices are an excellent choice for prolonging the effects of PA and reaching larger populations.

The effectiveness of intervention strategies derived from the integrated theoretical framework was verified in this mobile PA intervention, which has previously been proposed in many non-cancer studies [36,37]. The current study extends the promise of the theoretical base in promoting health behavior change in mHealth settings. This leads to considering multiple determinants and strategies to improve the effectiveness and adherence to

Table 2
Comparison of the baseline characteristics between the two groups.

Characteristic	Intervention group ($n = 30$)	Control group ($n = 30$)	$Z/t/\chi 2$	P
Age (years)	52.50 (45.75, 59.00)	57.50 (44.50, 62.25)	−1.155 [a]	0.248
BMI (kg/m^2)	23.65 ± 3.64	22.79 ± 2.61	1.052 [b]	0.297
Marital status				
Married	28 (93.3)	25 (83.3)	–	0.424 [c]
Divorced/unmarried	2 (6.7)	5 (16.7)		
Job status				
Employed	21 (70.0)	16 (53.3)	1.763 [d]	0.184
Retied/unemployed	9 (30.0)	14 (46.7)		
Education level			2.593 [c]	0.501
Primary school	2 (6.7)	3 (10.0)		
Middle school	11 (36.7)	6 (20.0)		
High school	10 (33.3)	10 (33.3)		
College or above	7 (23.3)	11 (36.7)		
Family monthly income (RMB)			1.365 [c]	0.529
1,000–3,000	4 (13.4)	2 (6.7)		
3,001–5,000	13 (43.3)	11 (36.7)		
>5,000	13 (43.3)	17 (56.6)		
Disease stage			–	0.671 [c]
Stage I-III	26 (86.7)	28 (93.3)		
Stage IV	4 (13.3)	2 (6.7)		
Surgery			0.073 [d]	0.787
Yes	20 (66.7)	19 (63.3)		
No	10 (33.3)	11 (36.7)		
Chronic disease			–	1.000 [c]
Yes	2 (6.7)	3 (10.0)		
No	28 (93.3)	27 (90.0)		

Note: Data are *Median* (P_{25}, P_{75}), *n* (%) and *Mean* ± *SD*. [a] Mann-Whitney *U* test; [b] Independent sample *t*-test; [c] Fisher's exact test; [d] Chi-square test.

Table 3
Physical activity behavior change pre- and post-intervention in two groups (MET-min/w).

Variables	Baseline	Post-intervention	Z	P
Walking				
Intervention group ($n = 30$)	643.50 (255.75, 1,423.13)	1815.00 (773.25, 2697.75)	−2.540	0.011
Control group ($n = 30$)	544.50 (284.63, 853.88)	222.75 (148.50, 346.50)	−3.519	<0.001
Z	−0.556	−5.648		
P	0.578	<0.001		
Moderate PA				
Intervention group ($n = 30$)	0.00 (0.00, 0.00)	0.00 (0.00, 165.00)	−1.154	0.249
Control group ($n = 30$)	0.00 (0.00, 360.00)	0.00 (0.00, 0.00)	−2.938	0.003
Z	−1.655	−3.416		
P	0.098	0.001		
Vigorous PA				
Intervention group ($n = 30$)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	−0.447	0.655
Control group ($n = 30$)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	−1.000	0.317
Z	−0.024	−1.000		
P	0.981	0.317		
Overall PA				
Intervention group ($n = 30$)	841.50 (280.50, 1,590.38)	1994.00 (795.75, 2,817.00)	−3.051	0.002
Control group ($n = 30$)	685.50 (445.50, 1,386.00)	222.75 (148.50, 346.50)	−4.290	<0.001
Z	−0.044	−5.654		
P	0.965	<0.001		

Note: Data are *Median* (P_{25}, P_{75}). PA = physical activity. The comparison between two groups were examined by Mann-Whitney *U* test and changes within each group were examined by Wilcoxon signed-rank test.

mHealth interventions. The convergence of three theoretically diverse intervention strategies has proven instrumental in fostering behavior change by enhancing participants' awareness, thereby exerting a critical influence on their actions. The constructs derived from the theories interpret the point-by-point linking of behavioral intervention techniques to mobile smartphone functions. This new delivery model provides flexible interventions by setting goals, self-monitoring, behavior feedback, improving self-efficacy, overcoming barriers, etc. SMS feedbacks based on portal monitoring and daily step-gap reminders were vital in directly motivating users' PA actions. It met participants' preferences in receiving digital health intervention, as Phillips et al. (2019) [38] and Nielsen (2020) [39] reported that progress feedback, motivation, and reminder messages ranked as the first three interests of breast cancer survivors. Similarly, a recent systematic review [40] pointed out that personalization or tailoring the content of mHealth apps to the individual needs of users is a key factor in cancer self-management projects. Our findings provide clear clues for developing new apps to promote health behaviors or optimize current apps in the market for high acceptability and efficiency.

For secondary outcomes, emotional benefits were identified through the mHealth intervention by published articles that indicated the effects of relieving anxiety [41]. One possible reason that online interaction and personalized support work well, especially in clarifying uncertainty about the disease, providing a way to express emotions, and enhancing confidence in overcoming

Table 4
Depression, anxiety, and quality of life change from baseline to post-intervention of patients in two groups.

Variables	Baseline	Post-intervention	*Z*/*t*	*P*
Depression				
Intervention group ($n = 30$)	4.50 (1.00, 8.00)	6.00 (4.00, 8.00)	−1.846	0.065
Control group ($n = 30$)	1.00 (0.00, 6.25)	8.00 (2.75, 9.25)	−3.207	0.001
Z	−1.694	−0.884		
P	0.090	0.377		
Anxiety				
Intervention group ($n = 30$)	5.50 (4.75, 8.00)	5.50 (4.00, 7.25)	−0.278	0.781
Control group ($n = 30$)	5.00 (2.00, 9.00)	8.50 (5.75, 10.00)	−1.954	0.051
Z	−0.989	−2.102		
P	0.323	0.036		
Physical well-being of QoL				
Intervention group ($n = 30$)	20.00 (19.00, 21.00)	23.00 (19.75, 25.00)	−2.059	0.039
Control group ($n = 30$)	21.00 (19.00, 23.25)	15.00 (11.00, 21.00)	−4.424	<0.001
Z	−1.210	−3.973		
P	0.226	<0.001		
Social well-being of QoL				
Intervention group ($n = 30$)	21.50 (18.00, 23.25)	18.00 (14.75, 22.00)	−2.520	0.012
Control group ($n = 30$)	23.00 (18.75, 24.00)	19.00 (17.00, 22.00)	−2.467	0.014
Z	−1.354	−1.301		
P	0.176	0.193		
Emotional well-being of QoL				
Intervention group ($n = 30$)	18.00 (15.00, 20.00)	18.00 (16.00, 20.00)	−0.704	0.481
Control group ($n = 30$)	18.00 (12.75, 20.00)	12.00 (10.00, 16.00)	−3.280	0.001
Z	−0.826	−4.652		
P	0.409	<0.001		
Functional well-being of QoL				
Intervention group ($n = 30$)	14.00 (9.00, 19.00)	13.50 (8.50, 18.50)	−0.660	0.509
Control group ($n = 30$)	16.50 (15.00, 18.00)	12.50 (12.00, 16.25)	−3.023	0.003
Z	−1.759	−0.134		
P	0.079	0.894		
Breast specific well-being of QoL				
Intervention group ($n = 30$)	25.50 (22.00, 27.25)	24.00 (20.00, 26.00)	−1.775	0.076
Control group ($n = 30$)	24.50 (20.00, 26.25)	20.50 (13.00, 24.25)	−2.682	0.007
Z	−0.943	−2.121		
P	0.346	0.034		
Total score of QoL				
Intervention group ($n = 30$)	96.90 ± 13.24	93.20 ± 16.82	1.203	0.239
Control group ($n = 30$)	99.47 ± 10.82	81.03 ± 15.35	−6.087	<0.001
t	−0.822	2.927		
P	0.414	0.005		

Note: Data are *Median* (P_{25}, P_{75}) or *Mean* ± *SD*. QoL = quality of life.

difficulties and pushing oneself to be active, connecting with people, feeling control in their daily life, and having access to talk about their experiences with peers and patients' achievements despite being sick empowered users to pursue hope and happiness. Concerning QoL, our findings verified the positive influence of the mHealth intervention on the physical, emotional, and breast-specific well-being of QoL, which researchers expected. However, we did not find active changes in the social and functional well-being of QoL between the two groups, although we emphasized the establishment of an interaction platform with theoretical considerations. As most studies have reported, the social function in mobile apps is deemed a motivational strategy, having great value in shaping the sense of membership and belonging to a group [42]. In the present study, a limited user group in the online community seems to have not yet cultivated such influence.

Further research should be conducted to determine how to fuse chats in professional applications with existing social communication paths to improve social well-being. The negative findings on the functional well-being of QoL after intervention may be attributed to the inevitable impact of treatment-related symptoms; more targeted measures should be considered to help control the disturbing symptoms and improve functional capability and independence. Overall, evidence of PA's benefits on QoL was optimistic, supported by considerable evidence [43]. However, it is important to note that points of contention must also be addressed. Some studies have failed to find a statistically significant influence of the conventional intervention approach [43]. A previous study measuring the effectiveness of an exercise intervention during adjuvant chemotherapy implied that QoL returned to baseline levels at the 6-month endpoint [44]. Thus, more evidence is needed in the mHealth field to test whether delivering new PA care plans improves long-term QoL.

5. Limitations

Our study has some limitations that must be considered. First, affected by the COVID-19 pandemic, recruitment lasted longer than expected, and the sample size was not sufficiently large, which might limit some pronounced findings on PA behavior. Second, PA measurement lacked a more objective gauging method. Although most smartphones support recording participants' daily steps if they authorize access to our 'Breast Care' app, the accuracy of embedded steps tracking is still questionable [45]. Diverse brands of mobile phones vary in their health behavior recording algorithms. Therefore, data collection methods based on accelerometers, pedometers, or other wearable devices should be considered to reinforce the accuracy and reliability of step tracking [46]. In addition, we failed to randomly assign the participants, which may undermine the credibility of the outcomes, and the post-test of the intervention was conducted only once, so the long-term effects of

the mHealth PA intervention have not been verified. Third, the participation of users in 'Chats' and the utilization of the self-assessment module of the 'Breast Care' app were less than expected. One reason might be that participants prefer sharing personal feelings on other mature social media platforms (such as WeChat or Weibo) and are not accustomed to answering online questionnaires because of privacy considerations. In the future, these two app functions should be thoroughly evaluated and updated to increase participation and recognition.

6. Conclusion

This study established a theory-based tailored mHealth intervention to help women with breast cancer cope with cancer, depending on a personalized and professional information platform. The empirical results proved the potential benefits of enhancing PA behavior, relieving anxiety, and improving QoL. The results could inform other studies adopting the mHealth intervention model to appropriately utilize the theoretical framework and add to the literature on health behavior change based on mHealth interventions.

CRediT authorship contribution statement

Zhaohui Geng: Conceptualization, Methodology, Investigation, Writing – original draft, Funding acquisition. **Jingting Wang:** Methodology, Writing – review & editing. **Weibo Lyu:** Project administration, Writing – review & editing. **Xinyu Li:** Investigation. **Wenjia Ye:** Intervention. **Wei Zheng:** Resources. **Juan Yang:** Resources. **Li Ning:** Resources. **Lingzhi Cai:** Resources, Investigation. **Ying Liu:** Writing – original draft. **Yingting Zhang:** Writing – original draft. **Fulei Wu:** Writing – original draft. **Changrong Yuan:** Conceptualization, Methodology, Writing – review & editing.

Funding

This work was supported by the National Natural Science Foundation of China (72104145), the Humanities and Social Science Research Project of the Ministry of Education (21YJCZH032), and the Shanghai Science and Technology Innovation Action Plan Sailing Project (21YF1447700). The funders had no role in the study design; collection, analysis and interpretation of data; writing of the report; or the decision to submit the article for publication.

Data availability statement

The datasets generated during and/or analyzed during the current study are not publicly available due to they contain information that can compromise the privacy of the research participants but are available from the corresponding author upon reasonable request.

Declaration of competing interest

The authors declare that they have no competing interests.

Acknowledgments

We thank all the patients who participated in this study and the health professionals who supported our program during app development and intervention implementation.

Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnss.2024.08.006.

References

[1] Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global cancer statistics 2020:GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. Ca - Cancer J Clin 2021;71(3):209–49. https://doi.org/10.3322/caac.21660.
[2] Rojas K, Stuckey A. Breast cancer epidemiology and risk factors. Clin Obstet Gynecol 2016;59(4):651–72. https://doi.org/10.1097/GRF.0000000000000239.
[3] Ruiz-Casado A, Álvarez-Bustos A, de Pedro CG, Méndez-Otero M, Romero-Elías M. Cancer-related fatigue in breast cancer survivors: a review. Clin Breast Cancer 2021;21(1):10–25. https://doi.org/10.1016/j.clbc.2020.07.011.
[4] Nyrop KA, Deal AM, Shachar SS, Park J, Choi SK, Lee JT, et al. Weight trajectories in women receiving systemic adjuvant therapy for breast cancer. Breast Cancer Res Treat 2020;179(3):709–20. https://doi.org/10.1007/s10549-019-05501-8.
[5] Kwak A, Jacobs J, Haggett D, Jimenez R, Peppercorn J. Evaluation and management of insomnia in women with breast cancer. Breast Cancer Res Treat 2020;181(2):269–77. https://doi.org/10.1007/s10549-020-05635-0.
[6] Pilevarzadeh M, Amirshahi M, Afsargharehbagh R, Rafiemanesh H, Hashemi SM, Balouchi A. Global prevalence of depression among breast cancer patients: a systematic review and meta-analysis. Breast Cancer Res Treat 2019;176(3):519–33. https://doi.org/10.1007/s10549-019-05271-3.
[7] Ficarra S, Thomas E, Bianco A, Gentile A, Thaller P, Grassadonio F, et al. Impact of exercise interventions on physical fitness in breast cancer patients and survivors: a systematic review. Breast Cancer 2022;29(3):402–18. https://doi.org/10.1007/s12282-022-01347-z.
[8] Medeiros Torres D, Jorge Koifman R, da Silva Santos S. Impact on fatigue of different types of physical exercise during adjuvant chemotherapy and radiotherapy in breast cancer: systematic review and meta-analysis. Support Care Cancer 2022;30(6):4651–62. https://doi.org/10.1007/s00520-022-06809-w.
[9] Cuesta-Vargas AI, Buchan J, Arroyo-Morales M. A multimodal physiotherapy program plus deep water running for improving cancer-related fatigue and quality of life in breast cancer survivors. Eur J Cancer Care 2014;23(1):15–21. https://doi.org/10.1111/ecc.12114.
[10] Courneya KS, Segal RJ, MacKey JR, Gelmon K, Reid RD, Friedenreich CM, et al. Effects of aerobic and resistance exercise in breast cancer patients receiving adjuvant chemotherapy: a multicenter randomized controlled trial. J Clin Oncol 2007;25(28):4396–404. https://doi.org/10.1200/JCO.2006.08.2024.
[11] Cannioto RA, Hutson A, Dighe S, McCann W, McCann SE, Zirpoli GR, et al. Physical activity before, during, and after chemotherapy for high-risk breast cancer: relationships with survival. J Natl Cancer Inst 2021;113(1):54–63. https://doi.org/10.1093/jnci/djaa046.
[12] Islami F, Goding Sauer A, Miller KD, Siegel RL, Fedewa SA, Jacobs EJ, et al. Proportion and number of cancer cases and deaths attributable to potentially modifiable risk factors in the United States. Ca - Cancer J Clin 2018;68(1):31–54. https://doi.org/10.3322/caac.21440.
[13] Spei ME, Samoli E, Bravi F, Vecchia CL, Bamia C, Benetou V. Physical activity in breast cancer survivors: a systematic review and meta-analysis on overall and breast cancer survival. Breast 2019;44:144–52. https://doi.org/10.1016/j.breast.2019.02.001.
[14] Beaver K, Williamson S, Briggs J. Exploring patient experiences of neo-adjuvant chemotherapy for breast cancer. Eur J Oncol Nurs 2016;20:77–86. https://doi.org/10.1016/j.ejon.2015.06.001.
[15] Johnsson A, Johnsson A, Johansson K. Physical activity during and after adjuvant chemotherapy in patients with breast cancer. Physiotherapy 2013;99(3):221–7. https://doi.org/10.1016/j.physio.2012.05.012.
[16] Lynch BM, Dunstan DW, Healy GN, Winkler E, Eakin E, Owen N. Objectively measured physical activity and sedentary time of breast cancer survivors, and associations with adiposity: findings from NHANES (2003-2006). Can Cau Cont. 2010;21(2):283–8. https://doi.org/10.1007/s10552-009-9460-6.
[17] Rathbone AL, Prescott J. The use of mobile apps and SMS messaging as physical and mental health interventions: systematic review. J Med Internet Res 2017;19(8):e295. https://doi.org/10.2196/jmir.7740.
[18] Bandura A. Health promotion by social cognitive means. Health Educ Behav 2004;31(2):143–64. https://doi.org/10.1177/1090198104263660.
[19] Stacey FG, James EL, Chapman K, Courneya KS, Lubans DR. A systematic review and meta-analysis of social cognitive theory-based physical activity and nutrition behavior change interventions for cancer survivors. J Cancer Surviv. 2015;9(2):305–38. https://doi.org/10.1007/s11764-014-0413-z.
[20] Bandura A. Self-efficacy: toward a unifying theory of behavioral change. Psychol Rev 1977;84(2):191–215. https://doi.org/10.1037//0033-295x.84.2.191.
[21] Nahm ES, Resnick B, Covington B. Development of theory-based, online health learning modules for older adults: lessons learned. Comput Inform Nurs. 2006;24(5):261–8. https://doi.org/10.1097/00024665-200609000-00007.
[22] Ajzen I. The theory of planned behaviour: reactions and reflections. Psychol Health 2011;26(9):1113–27. https://doi.org/10.1080/08870446.2011.613995.
[23] Bolarinwa OA. Sample size estimation for health and social science researchers: the principles and considerations for different study designs. Niger Postgrad Med J 2020;27(2):67–75. https://doi.org/10.4103/npmj.npmj_19_

20.
[24] Geng ZH, Yuan CR. Usability test of a mobile physical activity program for breast cancer patients during chemotherapy: a pilot study. Stud Health Technol Inform. 2021;284:336–8. https://doi.org/10.3233/SHTI210738.
[25] Liu Y, Geng ZH, Wu FL, Yuan CR. Developing "information assistant": a smartphone application to meet the personalized information needs of women with breast cancer. Stud Health Technol Inform. 2017;245:156–60. https://doi.org/10.3233/978-1-61499-830-3-156.
[26] Chinese Center for Disease Control and Prevention, Ministry of Health of the People's Republic of China. Physical activity guidelines for Chinese adults. Beijing: People's Medical Publishing House; 2011 [in Chinese].
[27] Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003;35(8):1381–95. https://doi.org/10.1249/01.MSS.0000078924.61453.FB.
[28] Qu NN, Li KJ. Reliability and validity study of the Chinese version of the international physical activity questionnaire. Chin J Epidemiol 2004;25(3):265–8 [in Chinese].
[29] Zigmond AS, Snaith RP. The hospital anxiety and depression scale. Acta Psychiatr Scand 1983;67(6):361–70. https://doi.org/10.1111/j.1600-0447.1983.tb09716.x.
[30] Sun ZX, Liu HX, Jiao LY, Zhou T, Yang LN, Fan JY. Reliability and validity of hospital anxiety and depression scale. Chin J Clin Electron Ed. 2017;11(2):198–201. https://doi.org/10.3877/cma.j.issn.1674-0785.2017.02.005 [in Chinese].
[31] Brady MJ, Cella DF, Mo F, Bonomi AE, Tulsky DS, Lloyd SR, et al. Reliability and validity of the functional assessment of cancer therapy-breast quality-of-life instrument. J Clin Oncol 1997;15(3):974–86. https://doi.org/10.1200/JCO.1997.15.3.974.
[32] Wan CH, Zhang DM, Tang XL, Zhang WL, Li WH, Ren HX, et al. Revision of the Chinese version of the FACT-B in patients with breast cancer. Chin Ment Health J 2003;17(5):298–300. https://www.cnki.com.cn/Article/CJFDTOTAL-ZXWS200305002.htm [in Chinese].
[33] Uhm KE, Yoo JS, Chung SH, Lee JD, Lee I, Kim JI, et al. Effects of exercise intervention in breast cancer patients: is mobile health (mHealth) with pedometer more effective than conventional program using brochure? Breast Cancer Res Treat 2017;161(3):443–52. https://doi.org/10.1007/s10549-016-4065-8.
[34] Quintiliani LM, Mann DM, Puputti M, Quinn E, Bowen DJ. Pilot and feasibility test of a mobile health-supported behavioral counseling intervention for weight management among breast cancer survivors. JMIR Canc. 2016;2(1):e4. https://doi.org/10.2196/cancer.5305.
[35] Mason C, Alfano CM, Smith AW, Wang CY, Neuhouser ML, Duggan C, et al. Long-term physical activity trends in breast cancer survivors. Cancer Epidemiol Biomarkers Prev 2013;22(6):1153–61. https://doi.org/10.1158/1055-9965.EPI-13-0141.
[36] Kim BH, Glanz K. Text messaging to motivate walking in older African Americans: a randomized controlled trial. Am J Prev Med 2013;44(1):71–5. https://doi.org/10.1016/j.amepre.2012.09.050.
[37] Murawski B, Plotnikoff RC, Rayward AT, Vandelanotte C, Brown WJ, Duncan MJ. Randomised controlled trial using a theory-based m-health intervention to improve physical activity and sleep health in adults: the Synergy Study protocol. BMJ Open 2018;8(2):e018997. https://doi.org/10.1136/bmjopen-2017-018997.
[38] Phillips SM, Courneya KS, Welch WA, Gavin KL, Cottrell A, Nielsen A, et al. Breast cancer survivors' preferences for mHealth physical activity interventions: findings from a mixed methods study. J Cancer Surviv. 2019;13(2):292–305. https://doi.org/10.1007/s11764-019-00751-3.
[39] Nielsen AM, Welch WA, Gavin KL, Cottrell AM, Solk P, Torre EA, et al. Preferences for mHealth physical activity interventions during chemotherapy for breast cancer: a qualitative evaluation. Support Care Cancer 2020;28(4):1919–28. https://doi.org/10.1007/s00520-019-05002-w.
[40] Jakob R, Harperink S, Rudolf AM, Fleisch E, Haug S, Mair JL, et al. Factors influencing adherence to mHealth apps for prevention or management of noncommunicable diseases: systematic review. J Med Internet Res 2022;24(5):e35371. https://doi.org/10.2196/35371.
[41] Luo X, Chen YZ, Chen J, Zhang Y, Li MF, Xiong CX, et al. Effectiveness of mobile health-based self-management interventions in breast cancer patients: a meta-analysis. Support Care Cancer 2022;30(3):2853–76. https://doi.org/10.1007/s00520-021-06568-0.
[42] Al Ayubi SU, Parmanto B, Branch R, Ding D. A persuasive and social mHealth application for physical activity: a usability and feasibility study. JMIR Mhealth Uhealth 2014;2(2):e25. https://doi.org/10.2196/mhealth.2902.
[43] Travier N, Velthuis MJ, Steins Bisschop CN, van den Buijs B, Monninkhof EM, Backx F, et al. Effects of an 18-week exercise programme started early during breast cancer treatment: a randomised controlled trial. BMC Med 2015;13:121. https://doi.org/10.1186/s12916-015-0362-z.
[44] van Waart H, Stuiver MM, van Harten WH, Geleijn E, Kieffer JM, Buffart LM, et al. Effect of low-intensity physical activity and moderate- to high-intensity physical exercise during adjuvant chemotherapy on physical fitness, fatigue, and chemotherapy completion rates: results of the PACES randomized clinical trial. J Clin Oncol 2015;33(17):1918–27. https://doi.org/10.1200/JCO.2014.59.1081.
[45] Bort-Roig J, Gilson ND, Puig-Ribera A, Contreras RS, Trost SG. Measuring and influencing physical activity with smartphone technology: a systematic review. Sports Med 2014;44(5):671–86. https://doi.org/10.1007/s40279-014-0142-5.
[46] Oppezzo M, Tremmel J, Desai M, Baiocchi M, Ramo D, Cullen M, et al. Twitter-based social support added to Fitbit self-monitoring for decreasing sedentary behavior: protocol for a randomized controlled pilot trial with female patients from a women's heart clinic. JMIR Res Protoc 2020;9(12):e20926. https://doi.org/10.2196/20926.