Breast Cancer (2020) 27:25–46
https://doi.org/10.1007/s12282-019-00982-3

REVIEW ARTICLE

A Systematic Review of Electronic Health (eHealth) interventions to improve physical activity in patients with breast cancer

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Received: 2 February 2019 / Accepted: 27 May 2019 / Published online: 12 June 2019

Abstract

Background Electronic Health (eHealth) may have a positive effect on healthcare, such as patient education and decreasing the costs of healthcare services. Evidence suggests that such interventions can also improve physical activity (PA) of patients. This systematic review aimed to investigate the effects of PA interventions provided through eHealth on breast cancer patients.

Methods This study was conducted through a search in electronic databases up to July 2018. PubMed, EMBASE, Cochrane Central Register of Controlled Trials, Web of Science, Scopus, Science Direct, and Google Scholar databases were searched without time limitation.

Results In total, 2187 articles were retrieved and finally 16 articles remained. Five were pre/post and 11 were randomized trial studies. Different platforms were used in these studies including web-based, mobile-based, both web-and-mobile-based and email. In total, these articles comprise 2304 breast cancer patients with the mean age of 51 years and 50% were conducted in the USA. Four studies measured PA using wearable devices such as accelerometers and pedometers. All studies reported an increase in PA level at least in one of moderate or vigorous PA, although not all these results were significant.

Conclusion The results show that eHealth interventions can improve the level of PA in breast cancer patients. Although there are numerous eHealth interventions focusing on PA in cancer patients, there is still an essential need for eHealth interventions to be tailored for breast cancer patients specifically. Clinical trials with appropriate methodology, enough intervention time and follow-up are needed to make evidence-based results more generalizable.

Trial Registration PROSPERO CRD42018092422; https://www.crd.york.ac.uk/PROSPERO/.

Keywords eHealth · mHealth · Physical activity · Systematic review · Breast cancer

Introduction

The number of new cases of cancer diagnosed annually in the world is quickly increasing from 14.1 million in 2012 to an estimated value of over 20 million by 2030 [1]. From among these, breast cancer (BC) is one of the most prevalent cancers in women worldwide [2]. Despite a good prognosis and advanced treatments, BC survivors suffer from many negative consequences following the initial treatment of cancer, including mental, physical, and family and financial problems [3]. Shoulder morbidity is one of the most important consequences of treatment which may be accompanied by pain, reduced shoulder range of motion (ROM), and lymphedema [4]. These shoulder morbidities, especially the reduced ROM of the shoulder and arms in the long term, can significantly reduce the quality of life (QOL) [5–7], decrease upper limb function, and reduce the patients' return to workability [4]. Thus, these issues must be diagnosed and

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s12282-019-00982-3) contains supplementary material, which is available to authorized users.

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treated on time. Various types of physical therapies can treat these functional problems [4, 8–10]. Following the surgery, exercise therapy must be combined with daily care so that patients at risk of increased shoulder problems would face fewer complications [6, 11]. The majority of these complementary therapies are neglected due to limited resources, especially in low- and moderate-income countries [6]. The important point is that these interventions can not only play a role in the physical aspects of the overall QOL of patients with BC but also create a positive trend in the improvement of cancer site-specific QOL domains (in this case, breast and arms) [12].

The standard level of PA determined by the American College of Sports Medicine (ACSM) is a moderate-intensity exercise for more than a minimum of 150 min per week [13]. Unfortunately, the level of PA is low among BC patients [14]. On the other hand, BC survivors are at risk of overweight due to decreased PA [15]. Moreover, overweight is associated with a high risk of mortality. Therefore, PA can play a significant role in decreasing the risk of mortality following the diagnosis of BC [16].

Electronic Health (eHealth) is a new field between medical informatics, public health, and business, delivering information and health services via the Internet and related technologies [17]. Currently, eHealth can play a significant role in the improvement of self-care, communication between patient and healthcare team, and access to health information [18]. An increasing volume of evidence has proven the positive effects of eHealth in supporting patient-centered care [19–22].

Moreover, mobile Health (mHealth) is considered as an important part of eHealth [23]. mHealth is a wide term for describing the use of mobile technologies for the health care delivery [24]. mHealth has the potential for improving access to and enhancing the quality of healthcare [25], decreasing healthcare costs [26], supporting self-management for chronic diseases, reducing patients' visit to healthcare centers, and enhancing the capability of providing individual, regional, and on-demand services [27, 28].

The analysis of BC apps showed that patient education is the first topic covered by mobile apps, followed by behavioral change and mental supports [29]. It has been shown that patients with BC and healthcare professionals have a positive attitude towards the use of mobile apps [30, 31]. mHealth tools can provide information with regard to BC education, self-examination, patient follow-up, lifestyle change, and PA [32–38]. Low level of PA has motivated the treatment team to discover new ways for optimizing the level of PA in patients. Today, with the popularity of information and communications technology (ICT), the use of electronic health (eHealth) approaches seems feasible for enhancing PA [39].

eHealth interventions may be an effective strategy for improving PA and provide a better QOL for patients with BC. The present systematic review aimed to find and evaluate studies related to PA designed for BC patients implemented through eHealth.

Materials and methods

Protocol

This systematic review was conducted based on PRISMA [40] guideline, which is described below. The present study is registered on PROSPERO (https://www.crd.york.ac.uk/PROSPERO/; ID: CRD42018092422).

Inclusion criteria

Participants in these studies were women aging above 18 who had received treatment, including surgery, radiotherapy, or chemotherapy for BC. Women of any race, ethnicity, employment status, occupational status, and role were included.

eHealth interventions had to be primarily focused on PA in BC patients. Interventions had to be designed with the aim of improving health-related behaviors (e.g., Increasing PA) or changing the lifestyle (e.g., weight loss activities through PA). More specifically, the primary outcomes in this systematic review had to directly or indirectly measure PA, whether through a change in the level of PA or physical functions, the time lapsed during PA, compliance with PA recommendations, and the consumed energy.

The employed technologies included mobile tools which were capable of establishing cellular and wireless communication. The following portable tools were acceptable in this study: mobile phones (including smartphones, Android, or IOS phones), personal digital assistants, tablets, and portable light laptops. The main focus was on smartphone apps, but other formats such as web-based interventions were also acceptable. Studies from any continent, country, or healthcare center, regardless of geographical borders, were acceptable. This method allowed us to collect comprehensive data from various sources in different countries.

Exclusion criteria

Exclusion criteria were as follows: studies which were merely a description of various phases of software development, with no specified outcome for the participants; studies which solely evaluated software usability; all studies on women at a high risk of BC, not patients with BC; studies published after June 2018; letters to the editor, review studies, and protocols; studies whose method was not clearly

described; studies in languages other than English; and duplicate studies in which the same research was conducted using the same method with similar results.

Information sources and search strategy

This study was conducted through a search in electronic databases in July 2018. PubMed, EMBASE, Cochrane Central Register of Controlled Trials, IEEE, Web of Science, Scopus, Science Direct, and Google Scholar databases were searched without time limitation.

Search strategy consists of three main categories including (1) the condition "breast cancer", (2) technology "eHealth", and (3) "physical activity" and their synonym keywords in each category.

The search was conducted in English. The search strategy was modified and revised for all databases by a Health Information Management and Medical Informatics specialist. A manual search was also performed for retrieving grey literature and the bibliographies of relevant articles.

The full text of articles was extracted and evaluated. This study included randomized controlled trials (RCTs) and non-randomized studies. Non-randomized studies included case–control, cohort, cross-sectional and pre/post studies in which eHealth was the primary intervention used for BC patients.

Data extraction and quality assessment

Two authors (SD, FA) independently reviewed the full text and extracted all critical data from included studies including author, country of study, study design, sample size, retention rate, population studied, the age of participants, study duration, intervention type, intervention content, inclusion/exclusion criteria and outcomes measured. Any discrepancies were resolved through discussion with a third author.

Risk of bias in each study

The Cochrane Collaboration's tool for assessing risk of bias was used to evaluate methodological quality of included studies [41]. Non-randomized studies were assessed for risk of bias using the RoBANS tool [42]. The RoBANS tool contains six domains including the selection of participants, confounding variables, measurement of intervention (exposure), blinding of outcome assessment, incomplete outcome data and selective outcome reporting.

Results

Upon searching electronic databases, 2187 citations were retrieved. Using manual search and finding the references of articles, 15 articles were added. After removing duplicates, 1390 articles remained which were evaluated based on the title and then abstract. Then, 151 records were selected for full-text evaluation. All evaluations were performed by two Medical Informatics Specialists. In case of disagreements, the opinions of a third specialist were used. Finally, 16 articles remained for final evaluation, all having an acceptable level of quality. The PRISMA flowchart is depicted in Fig. 1.

Finally, 16 articles were included [43–58]. In total, these articles comprise 2304 patients with the mean age of 51 years (sample size and mean age are presented in Table 1). All studies were conducted on patients with BC, of which six studies also included participants with other types of cancer [43, 45, 46, 48, 53, 55]. General characteristics of these studies are presented in Table 1.

Clinical characteristics

Eight studies were RCTs [43, 45–48, 50, 55, 57], three were randomized trial without control group [44, 56, 58], and five were pre/post studies [49, 51–54]. The characteristics of these studies are presented in Table 2.

In terms of journals, 63% (12 articles) belonged to Q1 journals (i.e., the top 25% in their specialized domain), 6% (1 article) belonged to a Q2 journal (i.e., Top 50%), and this factor was not calculated for the rest yet.

All the studies were written from 2012 to 2018, with the majority being published in 2016 (5 articles).

PA [43, 45, 47, 49, 51–53, 55, 56, 58] and related variables, including high- and moderate-intensity PA [44, 46, 48, 54, 57], physical strength and its related factors [57], and PA pattern [46] were considered in the articles. Other study variables (indirect outcomes) were QOL [45, 49, 51, 53, 58], health-related QOL [44, 50], fatigue [43, 45, 50, 53–55], consumption of vegetables [43, 48, 50, 51, 54], diet quality [50, 57], weight loss [52, 54], anxiety [50, 53], depression [43, 50, 53], insomnia [43, 53], mood [55], promotion of exercise [50], motivational readiness [50], self-efficacy [54, 56], acceptability [46, 54, 56], cardiovascular fitness [52, 57], physical activity readiness [47], psychosocial construct [52], and patient activation [49, 54].

Physical activity measurement

The included studies had assessed PA using various questionnaires, e.g., [49, 54, 58] using the International Physical Activity Questionnaire (IPAQ) which assesses the frequency (day per week) and duration (minute) of PA over the past

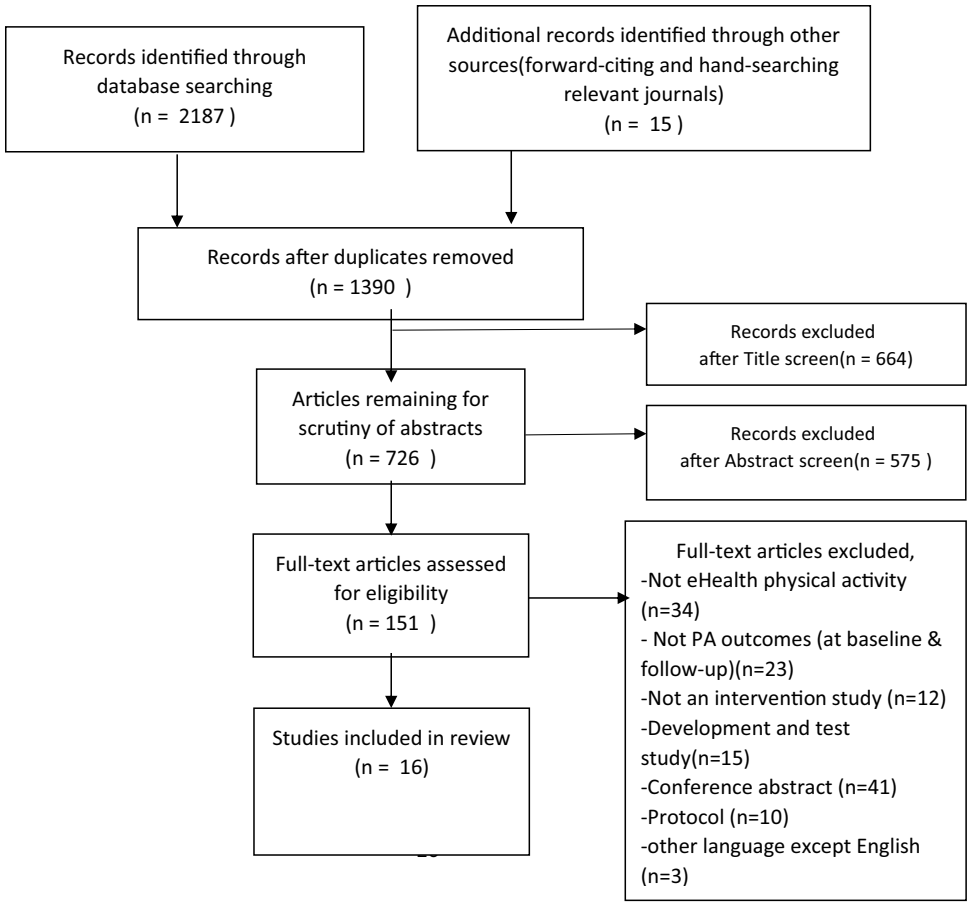

Fig. 1 PRISMA flowchart of the selection process

7 days in the following domains: job-related physical activity, transportation physical activity, housework, and recreation and leisure–time physical activity [59]. This tool provides an international measure for PA which has undergone numerous reliability and validity examinations. IPAQ covers all domains of moderate and vigorous PA in daily life as well as work-related PA items [54].

Some studies had only measured the duration of PA, e.g., [51]. In this study, the data of PA were collected using the log data of the Lose It! mobile app. Participants were encouraged to reach the level of the standard guideline of PA proposed by American College of Sports (ACM) [60] which included moderate-intensity cardiorespiratory exercises (150 min per week) and vigorous activity (over 40 min per week) in addition to resistance exercises for each set of major muscle groups.

Moreover, Lee et al. [50] measured the changes in the level of exercise over a 12-week intervention using data (type, duration, and intensity of exercise) entered by patients in a web-based app over the intervention time.

Some studies utilized the Physical Activity Readiness Questionnaire as the inclusion criteria for patient recruitment [47, 52].

In References [47, 55], the 7-day physical activity recall (PAR) [61] was administered. Participants reported hours spent in sleep, moderate activity, hard activity, and very hard activity. PAR was used in previous studies on cancer survivors [62, 63] and validated on multiple populations, including cancer-free youth [64].

Godin Leisure–Time Exercise Questionnaire (GLTEQ) [65, 66] has been used by Short [56]. The adapted version of GLETQ includes six items measuring the participants' mild, moderate, or strenuous PA in a typical week in the past month, as well as three items on resistance-training which ask the participant to report the frequency (times per week) and volume (number of completed exercises in each session and the number of completed repeats for each exercise) of resistance exercises in the past month. This questionnaire was completed online by the participants. Forbes [45], Chapman [44], Puszkiewicz [53], and Bantum [43] used an old version of this questionnaire in addition to another one which served their purpose [53].

Sturgeon [57] utilized the Modifiable Activity Questionnaire. This questionnaire evaluates current physical activity at work and leisure time, as well as maximum levels of inactivity due to disability. This questionnaire is designed

Table 1 General characteristics of included studies ($n = 16$)

Study	Publication year	Country	Participant number	Type of Intervention	Mean age
Bantum [43]	2014	USA	352	Web-based intervention	51
Chapman [44]	2018	Australia	101	Online volitional help sheet (Web-based)	59
Forbes [45]	2015	Canada	95	Web-based	65.1
Hartman [46]	2018	USA	87	Fitbit + accelerometer Web and mobile-Based	58
Hatchett [47]	2012	USA	74	Email	Not reported
Kanera [48]	2017	Netherland	462	Web-based Early cancer survivor	55
Kuijpers [49]	2016	Netherland	92	MijnAVL Portal (Web-based)	49
Lee [50]	2014	South Korea	59	Web-based WSEDI (Web-based self-management exercise and diet intervention program	42
McCarroll [51]	2015	USA	50	LoseIt Web and Mobile-Based	58
Pope [52]	2018	USA	10	Map My Fitness + Actigraph GT3X + accelerometers	45
Puszkiewicz [53]	2016	UK	11	GAINFitness App	45
Quintiliani [54]	2016	USA	10	Fitbit App Wristband pedometer	59
Rabin [55]	2012	USA	18	Web-based	32
Short [56]	2016	Australia	492	Web-based	55
Sturgeon [57]	2017	USA	35	Web-based	46
Uhm [58]	2016	South Korea	356	Smart After Care App + Pedometer	50

to be easily modified so that it can provide the maximum capability of evaluating PA in different populations [67].

The noted studies have used self-report questionnaires for determining changes in PA. However, some other studies measured the level of PA using wearable devices such as uniaxial accelerometers and pedometers as well as multisensor systems [46, 52, 54, 58]. Pope [52] recorded the level of PA using a mobile app with the help of auxiliary tools such as an accelerometer and Actigraph GT3X, thus minimizing the rate of self-report.

Level of physical activity

From a clinical viewpoint, all studies reported an increase in PA at least in one of the domains of moderate or vigorous PA. The majority of studies (10/16) reported positive effects on PA ($p < 0.05$). Results are presented in Table 3.

Although these differences were not significant in some studies. For instance, the study by McCarroll found no significant change in the PA pattern using the Lose It! app, although positive changes were observed in the other variables of this study, including weight loss and waist circumference [51]. Another example is a 12-week aerobic and resistance exercise program through Smart After-Care app reporting a significant improvement in the physical function, PA, and QOL of both groups compared to the baseline, while no significant between-group difference was observed [58]. Similarly, Forbes reports that, although total minutes of PA increased in the intervention group, these changes were not significant [45]. Moreover, Rabin achieved a moderate effect size for PA using a web-based 12-week intervention. Of course, this study was not specified to BC patients [55]. Some studies also used descriptive statistics and did not examine statistical significance [52, 54].

Eliminated studies included qualitative studies, feasibility studies, usability studies and case studies with a small sample size. Numerous studies were eliminated at the beginning of the process because new studies were limited to the provision of protocols and the preliminary steps of app development. Many of these studies, e.g., the one by Harder, described the steps of designing and developing a system using patient-centered approaches [68], whereas many others were qualitative and only sought the opinion of patients and the treatment team. Of the studies which were candidates for inclusion, those which failed to measure PA [69–73], did not specify the type of cancer [74], or measured functional activity and capacity [75], isometric and muscular strength [76] were removed from this study (Appendix 1).

Table 2 Characteristics of included studies

Author	Design/sample size (*n*)/retention rate (%)	Inclusion/exclusion criteria	Experimental group		Control group	Outcomes measured
			Intervention duration/time for measures	Contents	Contents	
Bantum [43]	RCT/Total: 352 IG (*n* = 176–156), CG (*n* = 176–147)/86%	Aged > 18 years Completion of primary treatment at least four weeks prior Not more than 5 years before joining the study Diagnosis with only one cancer No recurrence Access to the internet Ability to read English	6-week/baseline, 6-month	6-week online workshop	No information or materials	Fatigue Insomnia Exercise Fruit and vegetable intake Depression
Chapman [44]	Pilot randomized trial/ Online volitional help sheet (*n* = 50–44–36) Implementation intention (*n* = 51–45–42)/77%	Survivors ≥ 18 years Completed active treatment, 2 or more years ago Had no contraindications to exercise were eligible to participate	3-month/baseline, 1,3-month	Online volitional help sheet Implementation intention	Not mentioned	Moderate–strenuous leisure–time physical activity Health-related quality of life and mood
Forbes [45]	RCT/Total: 95 IG (*n* = 48–41), UC (*n* = 47–43)/88%	Being able to speak and read English Having access to the Internet Being able and interested in an Internet-delivered program designed to increase weekly PA levels Exclusion criteria: not mentioned	9-weeks Baseline, 9-week	9-week workshop to deliver content (e.g., dispelling PA myths, exercising safely, planning/making SMART goals). A website used to log/monitor PA and email feedback	No intervention	PA QoL (cancer-specific) QoL (generic)
Hartman [46]	RCT/Total: 87 IG (*n* = 43–42), CG (*n* = 44–43)/97.7%	21 < survivors < 85 years, Diagnosed < 5 years before study enrollment Had completed chemotherapy or radiation treatment Less than 60 min of MVPA in 10 min bouts per week) Had access to the Internet and a Fitbit-compatible computer, tablet, or phone Exclusion criteria Included any medical condition Other primary or recurrent invasive cancer within the last 10 years Unable to commit to a 12-week intervention	12-weeks/baseline,12weeks	The Fitbit one was worn daily throughout the 12-week intervention. ActiGraph GT3X + accelerometer was worn for 7 days at baseline and end of intervention (week 12)	Not mentioned	Patterns of physical activity Adherence to wearing the Fitbit Moderate to vigorous physical activity

Table 2 (continued)

Author	Design/sample size (*n*)/ retention rate (%)	Inclusion/exclusion criteria	Experimental group		Control group	Outcomes measured
			Intervention duration/ time for measures	Contents	Contents	
Hatchett [47]	RCT/Total: 85 IG (*n* = 43–38), CG (*n* = 42-–6)/87%	Aged ≥ 18 years Female breast cancer survivors Completion of cancer treatment Ability to access and navigate the Internet Ability to communicate through email Ability to complete online questionnaires Not engaged in moderate or vigorous physical activity at the outset of the intervention Ability to engage safely in physical activity Exclusion criteria: none specified	12-week/ baseline, 6-weeks, 12-weeks	IG: the Email-based intervention designed to influence PA Supplemented by PA e-counseling	CG: did not receive email messages and did not have access to PA e-counseling	Physical activity readiness Level of physical activity
Kanera [48]	RCT/Total: 462 IG (*n* = 231–188–169), CG (*n* = 231–221–212)/82%	Adult (≥ 18 years of age) Dutch-speaking cancer survivors Diagnosed with various types of cancer Completed primary cancer treatment at least 4 weeks, and up to 56 weeks prior to initial participation Exclude Individuals with signs of cancer recurrence or severe medical, psychiatric, or cognitive disorders	12-month/baseline, 6-month, 12-month	Web-based self-management program focused on physical activity and Vegetable consumption for 6 month	Usual care waiting list control condition Received access after 12-months	Moderate physical activity Vegetable consumption
Kuijpers [49]	Pretest–posttest/*n* = 92	Currently receiving curative or had received such treatment 3–12 months ago Having a computer and Internet, Mastery of the Dutch language Exclusion criteria Women with cognitive disorders or emotional instability	4-month/baseline, 4-month	Interactive portal (MijnAVL) including patient education, an overview of appointments, access to the electronic medical records (EMR), patient-reported outcomes, plus feedback and physical activity support	NA	Patient activation (PAM) Quality of life (SF-36) Physical activity (IPAQ)

Table 2 (continued)

Author	Design/sample size (*n*)/ retention rate (%)	Inclusion/exclusion criteria	Experimental group		Control group	Outcomes measured
			Intervention duration/ time for measures	Contents	Contents	
Lee [50]	RCT/Total: 59 EG (*n*= 30–29), CG (*n* = 29–28)/96%	Undergone curative surgery and completed primary cancer treatment within the 12 months prior to the study Diagnosed with stage 0–III cancers within the 2 years prior to the study Age of 20 years or older Serum hemoglobin 10 g/dl Had not met: exercise for at least 150 min per week OR consuming five servings of fruits and vegetables (F&V) per day Ability to use the computer Home internet access Mobile phone user Excluded if Currently receiving any cancer treatment A serious psychological disorder An infectious condition Visual or motor dysfunction	12-weeks/baseline,12-weeks	Web-based self-management exercise and diet intervention program incorporating. The Transtheoretical Model(TTM)-based strategies	50-page educational booklet on exercise and diet	Promotion of exercise Consumption of five servings of F&V per day Dietary quality HRQOL Anxiety Depression Fatigue Motivational readiness Self-efficacy
McCarroll [51]	Pre-post/*n* = 35	Aged 18 to 75 years Stage I or II endometrial or breast cancer Within the previous three years and no evidence of recurrent disease Smartphone or Internet with unlimited data or Internet connection (BMI) ≥ 25 kg/m^2 Medical clearance from the patient's oncologist A performance status of 0–2 Surgical treatment greater than 6 months prior to starting the study An endorsed desire to lose weight Exclusion criteria Non-English speaking Inability to read the consent form Lack of smartphone or Internet connection Inability to use the Lose It! app Patients with severe depression Physical or cognitive deficits, pregnancy, plan to become pregnant, breastfeeding, surgical treatment less than 6 months prior to starting the study Women who participated in a structured weight-loss program in the last 6 months	1-month/baseline, 4 time point within 1 month	Lifestyle intervention focusing on weight-loss via a popular mHealth app (LoseIt!) which offers both a website and mobile versions for users	NA	Quality of life (FACT-G) Self-efficacy Feasibility outcomes Anthropometrics Daily food intake Physical activity

Table 2 (continued)

Author	Design/sample size (*n*)/ retention rate (%)	Inclusion/exclusion criteria	Experimental group		Control group	Outcomes measured
			Intervention duration/ time for measures	Contents	Contents	
Pope [52]	Pre-post/$n = 10$	Aged ≥ 21 years With stage 0–III breast cancer Completed breast cancer treatment between 3 months and 5 years earlier with no recurrence Android or Apple smartphone owner Willing to complete the Physical Activity Readiness Questionnaire Exclusion criteria Currently undergoing breast cancer treatment Having any contraindications to physical activity engagement	10-week/baseline, midpoint, post-intervention	MapMyFitness (Social Cognitive Theory-based, Facebook- delivered health education intervention)	NA	Physical activity Weight or body composition Cardiovascular fitness Psychosocial constructs Quality of life
Puszkiewicz [53]	Pre-post/$n = 11$	Adults aged ≥ 18 years Finished primary curative treatment Having iPhone device	6-weeks	Tailored PA programme (GAINFitness) Identify exercise goal, location, duration, and muscle group Accessible exercise equipment Including video demonstration and trainer tips Instructions on how to perform each exercise		PA QoL (cancer-specific and generic) Fatigue BMI Anxiety Depression Sleep quality
Quintiliani [54]	Pre-post/$n = 10$	18 < years old Able to speak and read English Female 2 years or more since breast cancer diagnosis 6 months or more since the end of cancer treatment Self-reported overweight or obese (BMI > 25 kg/m^2) Have smartphone and WiFi at home Exclusion criteria Contraindications for physical activity, pregnancy, the presence of a pacemaker or other internal medical device, and medical conditions (dementia, active cancer, anorexia) or other	10-week/every week	mHealth components (self-monitoring of selected diet behaviors via daily text messages, wireless devices to automatically track weight and steps) and 4 motivational interviewing–based technology-assisted phone sessions with a nonprofessionally trained counselor	NA	Weight lost Physical activity Vegetable daily servings Engagement Acceptability Fatigue

Table 2 (continued)

Author	Design/sample size (*n*)/ retention rate (%)	Inclusion/exclusion criteria	Experimental group		Control group	Outcomes measured
			Intervention duration/ time for measures	Contents	Contents	
Rabin [55]	RCT/Total:19 IG ($n = 8$), CG ($n = 10$)/94%	Aged 18–39 years Diagnosed with cancer in the past 10 years Completed treatment Spoke and wrote fluently in English Could access the internet regularly Reported having a sedentary lifestyle Excluded if pregnant or had any medical condition or severe psychiatric illness	12-weeks/baseline, 12-weeks	12 weeks of website access Individually tailored The website had customization	Other websites with useful resources, including online peer support, but not PA information	7-day Physical Activity Recall (PAR) Psychosocial outcomes (mood, fatigue)
Short [56]	Randomized trial Three experimental arms/total: 492 3 X monthly module group ($n = 167$–48-16)/10% 3 X Weekly Module Group ($n = 168$–46-21)/13% Single Module Group ($n = 157$–61-16)/10%	English proficient breast cancer survivors 18 < years of age Had finished active cancer treatment Had no contraindications to exercise Had not participated in previous research conducted by the research team Were not already meeting national physical activity guidelines	12-weeks/3-month follow-up	Three-module intervention delivered monthly, a three-module intervention delivered weekly or a single module intervention		Website acceptability Physical activity behavior
Sturgeon [57]	RCT/Total: 35 IG ($n = 19$–16), CG ($n = 16$–16)/91%	Aged 18–55 years BRCA1/2 + breast cancer survivors Underwent prophylactic oophorectomy two or more years prior to study initiation Aged ≤ 45 at the date of oophorectomy, Completed breast cancer treatment at least 4 months prior to study initiation Did not use hormone replacement therapy for 2 years prior to study initiation Received physician clearance to participate in the weight loss and exercise programme Weight stable over the past year (e.g., no changes greater than 10% in the past 12 months) Had a BMI ≥ 23 kg/m when recruited Access to the Internet and a computer Access to basic fitness equipment (dumbbells, resistance bands) or willingness to join a fitness facility	12-months	Web-based lifestyle modification	Control group participants were not prohibited from exercise or eating a healthy diet	Cardiovascular fitness Dietary intake Leisure–time activity Body composition Bone mineral density Bone structure Muscle strength

Table 2 (continued)

Author	Design/sample size (*n*)/retention rate (%)	Inclusion/exclusion criteria	Experimental group		Control group	Outcomes measured
			Intervention duration/time for measures	Contents	Contents	
Uhm [58]	Prospective, quasi-randomized multicenter trial/total: 356 IG (n = 179–167), CG (n = 177–172)/95%	20–70 years old breast cancer Completion of primary cancer informed consent Exclusion criteria History of treatment for accompanying severe disease within one month; severe cardiovascular, pulmonary, or renal diseases that required exercise restriction; bone metastasis that caused severe pain during movement or exacerbated the risk for pathologic fracture; ECOG performance status C3; or inability to perform a 2-min walk test (2MWT)	12-week/baseline, 6-weeks, 12-weeks	Smart After Care app to provide information and monitor the prescribed exercises with pedometer	Exercise brochure	Self-reported physical activity QOL

IG intervention group, *UC* usual care, *CG* control group, *MVPA* moderate to vigorous physical activity

Technological characteristics

The technology used in included studies comprised web-based [43–45, 48–50, 55–57], mobile-based (apps) [46, 52–54, 58], web-and-mobile-based apps [46, 51]as well as email [47]. The mobile apps used were Lose it! [51], Smart After Care [58], GAINFitness [53], MapMyFitness [52], and Fitbit [46, 54].

The main features of these apps were exercise and diet recording [51]; exercise with a pedometer [58]; diet and training plans [52]; individualized exercise [53]; daily recording of the number of steps, distance passed, and minutes of exercise; and sleep pattern [46]. None of these apps were developed specifically for BC patients. Of these apps, four failed to provide a strong positive evidence supporting the improvement of PA using mobile phones [51, 52, 54, 58]. In web-based technology, however, this value was 2 vs. 9 articles [45, 55].

Patient satisfaction

In the case of the noted apps, only one study had evaluated user satisfaction. Mean Likert scale of total user satisfaction was 4.27 out of 5 (85%) [58]. In the case of websites, three studies had assessed user satisfaction [45, 49, 55]. Kuijpers [49] reported a user satisfaction of 76% (3.8 out of 5), Rabin [55] 71%, and Forbes [45] 73%.

Risk of bias within studies

The Cochrane Collaboration's tool [41] was used for assessing risk of bias in RCTs. The overall risk of bias in RCTs was assessed as low except in Hatchett et al. [47] and Rabin et al. [55] studies that rated as 'unclear risk of bias' (Table 4). Five non-randomized studies were assessed for risk of bias using the RoBANS tool [42]. The overall risk of bias in the studies by Kuijpers et al. [49], McCarroll et al. [51] and Pope et al. [52] was assessed as low, while the studies by Puszkiewicz et al. [53], Quintiliani et al. [54] were rated as high (Table 5). There was proper randomization sequence generation in the majority of the studies, while allocation concealment was unclear and performance bias was high.

Most of the studies had adequate sample sizes and only four studies had a small sample size < 20 [52–55]. However, having big sample size did not prevent study from other bias like retention bias as shown in the Short et al.'s [56] study. Self-reporting PA against direct measuring is another source of bias in most articles. In the five pre–post studies, the risk of bias increased due to the lack of control group.

Table 3 Results of PA interventions in included studies

Author (year)	Intervention Main/specific strategies	Baseline and end-intervention PA results: mean (SD) unless otherwise stated	Researchers evaluation of studies
Bantum 2014 [43]	6-week Web-based multiple health behavior change program	Baseline CG: mild aerobic exercise, 58.9 (51.5–66.2) Moderate aerobic exercise 37.0 (30.9–43.2) Strenuous aerobic exercise 29.0 (22.5–35.5) IG: (1) 56.1 (48.9–63.3) (2) 49.0 (42.2–55.7) (3) 32.0 (25.5–38.5)* 6-months CG: (1) 65.0 (56.5–73.6) (2) 45.3 (37.5–53.0) (3) 28.9 (21.8–36.0) IG: (1) 74.1 (64.2–84.1) (2) 54.1 (46.5–61.7) (3) 50.8 (40.7–60.9)* *The significant difference between intervention* and control groups in increased strenuous exercise (32–51 min/week, $p = .01$)	Not specific for breast cancer Self-reported data
Chapman 2018 [44]	Online volitional help sheet (VHS) ($n = 50$) Implementation Intention (IMP) ($n = 51$) Intervention Pilot randomized trial conducted online over 3 months	**Leisure score index moderate–strenuous physical activity** VHS: Baseline: 20.74 (2.68) 1 month: 29.08 (2.77) 3 months:28.62 (2.91)* IMP: Baseline: 20.11 (2.65) 1 month: 26.73 (2.74) 3 months:22.04 (2.79) *The between-group differences in moderate–strenuous physical activity after 3 months were statistically significant. ($p = 0.004$) *Leisure score index mild activity* VHS: Baseline: 8.64 (1.26) 1 month: 10.96(1.31) 3 months:9.82(1.41) IMP: Baseline: 8.94 (1.25) 1 month: 10.04(1.30) 3 months:9.50(1.33)	Not enough description about online intervention The current pilot trial did not include a no-treatment control group Participants were highly motivated to exercise The volitional help sheet may be more effective for facilitating lasting change and emotional well-being

Table 3 (continued)

Author (year)	Intervention Main/specific strategies	Baseline and end-intervention PA results: mean (SD) unless otherwise stated	Researchers evaluation of studies
Forbes 2015 [45]	9-week workshop Website used to log/monitor PA and email feedback	*Moderate aerobic minutes* UC: Baseline: 117 (140), Post study: 128 (110) IG: Baseline:112 (132), Post study: 140 (132) *Vigorous aerobic minutes* UC: Baseline: 39 (66), Post study: 47 (71) IG: Baseline: 48 (91), Post study: 59 (109) Results were more pronounced, though still non-significant, among those not meeting guidelines at the baseline where IG increased PA by 52 min compared to a decrease of 15 min in UC (adjusted between-group difference = 75, 95% CI −95 to 244; = .38, d = 0.27)	Self-reported data Selection bias toward those more motivated and Internet Website issues Not specific for breast cancer
Hartman 2018 [46]	**Intervention group (n = 43)** Focused on Fitbit's "Active Minutes," which consists of MVPA	Minutes of MVPA per week significantly differed over the 12 weeks ($F_{11/392} = 1.91$, $p = 0.04$)	Low power study Not clear intervention and exercise Not specific for breast cancer

Table 3 (continued)

Author (year)	Intervention Main/specific strategies	Baseline and end-intervention PA results: mean (SD) unless otherwise stated	Researchers evaluation of studies
Hatchett 2013 [47]	Emails designed to increase PA E-counsellor offered tailored PA advice and encouraged participant engagement with intervention	Baseline CG: 0 (0.00), IG: 0 (0.00) 6 weeks CG: 1.39 (1.58), IG: 1.42 (1.67)* *Significant between-group differences at 6 weeks ($p=.002$) 12 weeks CG: 1.42 (1.67), IG: 3.47 (2.19)* *Significant between-group differences at 12 weeks ($p=.001$) Moderate Intensity Baseline CG: 0.00 (0.00), IG: 0.00 (0.00) 6 weeks CG: 0.32 (0.62), IG: 0.50 (1.06) 12 weeks CG: 0.39 (0.75), IG: 1.08 (1.05)* *Significant differences in moderate intensity between-groups at 12 weeks ($p=0.002$) Vigorous intensity Baseline: CG: 0.00 (0.00), IG: 0.00 (0.00) 6-weeks CG: 1.08 (1.17), IG: 2.31 (1.82)* 12-weeks CG: 1.03 (1.15), IG: 2.39 (1.76)* Significant differences in vigorous intensity PA between-groups at 6 weeks ($p=0.001$)and 12 weeks ($p<0.001$)	Performance bias Reliance on self-reported data
Kanera 2017 [48]	**Intervention Group ($n=231$)** The web-based intervention KNW (Kanker Nazorg Wijzer) **Control Group: ($n=231$)**	IG: Baseline: 595.9 (620.5) 6 months: 746.6 (676.3) 12 months: 688.1 (570.6)* CG: Baseline: 526.5 (546.5) 6 months: 598.9 (510.7) 12 months: 512.2 (452.1)* *The between-group differences in moderate PA after 12 months were statistically significant. ($p=0.010$)	Effective among early cancer survivors younger than 57 years Long-term follow-up Not specific for breast cancer

Table 3 (continued)

Author (year)	Intervention Main/specific strategies	Baseline and end-intervention PA results: mean (SD) unless otherwise stated	Researchers evaluation of studies
Kuijpers 2016 [49]	The system includes personalized educational material (e.g., about their disease, their treatment, and possible side effects) and an overview of past and upcoming appointments. Users can also access parts of their electronic medical record (EMR) including radiology, pathology and lab results, conclusions from multidisciplinary meetings, and a medication overview	**PA (metabolic equivalent of task-min/week)** *Moderate activity* Baseline: 1420 (0–13,220) Post-intervention: 1560 (0–11,220) *Vigorous activity* Baseline: 0 (0–9600) Post-intervention: 360 (0–8160)* *Different from baseline; $p < 0.05$	Limited generalizability Overestimate the feasibility and accessibility of the program because of more experienced Internet-users
Lee 2014 [50]	**Intervention group ($n = 29$)** 12-week tailored exercise and dietary Web-based material for exercise and diet **Control Group ($n = 28$)** 50-page educational booklet on exercise and die	Baseline CG: 10 (34.5), IG: 10 (33.3) 12-weeks CG: 10 (35.7), IG: 19 (65.5)* *Significant post-intervention between-group differences, adjusted for baseline values ($p < 0.0001$)	Further research with a larger sample size is required Selection bias (elderly people)
McCarroll 2015 [51]	A 1-month lifestyle intervention delivered via a web- and mobile-based weight-loss application (app) (LoseIt!) using a healthcare-provider interface	Baseline: 22.7 (44.0) Week 1: 182.3 (196.6)* Week 2:200.2 (216.1) Week 3:181.2 (244.0) Week 4: 127.0 (185.3) *A significant increase ($p = 0.001$) in PA was noted from baseline to week1 Finally, no significant differences were noted in PA patterns	Short-term reductions in weight Not specific for breast cancer Generalization issues
Pope 2018 [52]	10-week single-group pilot study Social Cognitive Theory-based Facebook-delivered health education intervention	*Average daily moderate-to-vigorous physical activity duration (min)* Baseline: 26.8 ± 13.8 Post-intervention: 29.4 ± 22.5 **Average daily Light physical activity (min)** Baseline: 94.9 ± 44.8 Post-intervention: 86.7 ± 64.7 *Average daily sedentary behavior duration (min)* Baseline: 493.7 ± 176.0 Post-intervention: 381.0 ± 265.3	The study did not include a control group Inadequate sample size Lack of analytical statistics

Table 3 (continued)

Author (year)	Intervention Main/specific strategies	Baseline and end-intervention PA results: mean (SD) unless otherwise stated	Researchers evaluation of studies
Puszkiewicz 2016 [53]	Mobile app (GAINFitness)	*Strenuous physical activity* T0: median = 40 (IQR = 105) T1: median = 120.0 (IQR = 150.0)* *There was a significant increase in participants 'strenuous PA between T0 and T1 ($z = -2.80$, $p = .002$) *Moderate physical activity* 180.0 (150.0), T1:180.0(330.0) *Mild physical activity* T0: median = 150 (IQR = 90), T1: median = 80 (IQR = 120)* *There was a signification reduction in participants' mild PA between T0 (median = 150, IQR = 90) and T1 (median = 80, IQR = 120) ($z = -2.21$, $p = .031$)	Not specific for breast cancer Recruitment strategies Just iOS operating system
Quintiliani 2016 [54]	Self-monitoring of selected diet behaviors via daily text messages, wireless devices to automatically track weight and steps) four motivational interviewing	*Low physical activity* Baseline: 1967 (3189) 10-week follow-up: 3076 (2685) *Moderate physical activity* Baseline: 2792 (4475) 10-week follow-up: 3336 (4422) *Vigorous physical activity* Baseline: 1776 (4103) 10-week follow-up: 2568 (3751) Self-reported moderate physical activity increased (2791–3336, mean change 545 [SD 1694])	Lack of statistical analysis Lack of a control group and a small sample size
Rabin 2012 [55]	**Intervention Group ($n = 8$)** 12 weeks website access to promote PA among sedentary adults **Control Group ($n = 10$)** Other websites with useful resources	*Moderate to vigorous intensity physical activity* Baseline: IG: 58.75 (44.54) CG: 39.00 (35.65) 12 weeks: IG:161.25 (221.79) CG: 55.50 (77.48) Regression models did not suggest a significant between-group difference in minutes of at least moderate-intensity PA at follow-up [when controlling for baseline value and marital status, b (regression coefficient) = 48.78, SE (standard error) = 69.55, $p = 0.48$, effect-size (Cohen's $f^2 = 0.04$)	A larger trial is needed to draw conclusions about intervention efficacy Inadequate sample size Not specific for breast cancer

Table 3 (continued)

Author (year)	Intervention Main/specific strategies	Baseline and end-intervention PA results: mean (SD) unless otherwise stated	Researchers evaluation of studies
Short 2017 [56]	Three intervention group with the same material but different schedule Monthly three-module intervention Weekly three-module intervention Single module group	Aerobic exercise data for study completers IG1: Baseline: 96.15 (119.63) 3 months: 186.05 (172.56) IG2: Baseline: 97.17 (124.10) 3 months: 186.08 (157.89) IG3: Baseline: 90.08 (106.63) 3 months: 216.99 (219.99) Resistance exercise data for study completers IG1: Baseline: 2.79 (6.45) 3 months: 8.95 (16.24)* IG2: Baseline: 3.17 (7.07) 3 months: 6.52 (9.86) IG3: Baseline: 2.69 (7.27) 3 months: 4.5 (6.83)* *Incidence of resistance-training among participants allocated to the monthly module group was 1.88 times higher than participants allocated to the single module intervention group ($p=0.01$)	High dropout Systematic evaluation The most favorable outcomes observed in the monthly delivery group
Sturgeon 2017 [57]	IG: (Precision Nutrition) Web-based lifestyle modification intervention to improve physical activity and exercise CG: Participants randomized to the control group were waitlisted and enrolled in the programme following study activities	IG: Baseline: 483.7 (292.2) 12 months: 740.6 (330.2)* CG: Baseline: 559.6 (656.6) 12 months: 425.2 (325.6)* *There was a significant between-group difference for daily caloric expenditure with the intervention group increasing physical activity more by the end of the intervention ($p<0.05$)	Unclear effect of every component in this package
Uhm 2016 [58]	12-week home-based program of aerobic and resistance exercises Patients were quasi-randomly assigned to the mHealth with pedometer or brochure	IG: Baseline: 2050.6 (2182.2) 12 weeks: 3026.9 (2489.5)* CG: Baseline: 2091.5 (1811.2) 12 weeks: 2560.4 (2354.9)* *Weekly physical activity was significantly increased in both groups ($p<0.05$), with the increment being greater in the mHealth group, but not significantly so	Lack of assessment of adherence to each intervention Lack of post-intervention follow-up Further studies will be needed to identify long-term outcome

IG intervention group, *CG* control group

Table 4 Risk of bias in included RCTs

	Random sequences generation	Allocation concealment	Incomplete outcome data addressed adequately	Blinding of participants to allocation	Blinding of outcome	Selective outcome reporting	Other bias	Final evaluation
Chapman	+	?	+	−	?	+	−	+
Forbes	+	?	+	−	?	+	−	+
Hartman	+	−	+	−	?	+	−	+
Hatchett	?	?	+	−	?	?	−	?
Kanera	+	+	+	−	+	+	−	+
Lee, M	+	?	+	+	+	+	−	+
Bantum	+	+	+	−	?	+	−	+
Rabin	?	?	+	−	?	+	−	?
Short	+	+	+	−	+	+	−	+
Sturgeon	+	+	+	+	?	+	−	+
Uhm	?	+	+	+	?	+	−	+

Table 5 Risk of bias in non-randomized studies

	Selection of participants	Confounding variables	Measurement of intervention (exposure)	Blinding of outcome assessment	Incomplete outcome data	Selective outcome reporting	Final evaluation
Kujiperse	h	l	l	h	un	l	l
Quantini	h	h	l	h	l	un	h
Puszkiewicz	h	un	l	h	h	l	h
Mccaroll	l	un	l	h	h	l	l
Pop	h	un	l	h	l	l	l

+ Low risk

− High risk

? Unclear risk of bias

Discussion

Overview

This systematic review provided a comprehensive evaluation of the effects of eHealth interventions on PA in women with BC. Results revealed that all the mentioned interventions can increase the level of PA, and the majority of studies (10/16) reported statistically significant positive effects on PA level.

In this study, the most commonly used technology was web-based interventions (nine articles), followed by mobile-based (five articles), and web- and mobile-based technology (two articles). Email was also used as an older form of technology in one article. Two studies provided apps with both mobile- and web-based versions [46, 51]. Apps which can be used on more than one device, e.g., Lose It! [51] and Fitbit [46], can provide more flexibility for patients.

All included studies reported an increase in PA, indicating the effectiveness of interventions for patients with BC, although significant differences were not observed in some studies [45, 51, 52, 54, 55, 58]. Some studies reported within-group differences compared to the baseline [58] which may be due to selection bias because those who had a PA less than the average range may reflect more effects in clinical results [45]. Moreover, those who have a more tendency for participation in these studies probably had more PA prior to these interventions.

Another important point is that the duration of intervention may have affected the stabilization of the results. For instance, the shortest period of intervention was 1 month which reported positive results only for weight loss. If the interventions had been longer with more follow-ups, the results of PA could have become significant [51]. In the present study, the longest duration of intervention was 12 months [48, 57]. The fact that interventions were not specified for patients with BC may be another important point affecting the significance of results. For instance, the study by Rabin obtained a moderate effect size for PA [55]. Studies which prescribe PA in a general manner may be

inappropriate for patients with BC because the special condition of these patients and their requirements after treatment differ from those of other cancers.

Many e-Health studies evaluated the mental aspects of QOL in BC patients. The presence of a large number of studies on this topic demonstrates that studies on mental aspects have overtaken those on physical aspects. In addition, numerous studies investigated mental factors in addition to physical ones, depicting the mutual effect of mental and physical factors.

The use of novel devices and wearable technologies for recording PA is one way to directly and reliably measure PA. The most common devices for this purpose include uniaxial accelerometers and pedometers and multi-sensor systems which can transfer the received information to other devices, such as mobile phones or websites [77]. In this study, 25% of articles had employed this method for measuring PA [46, 52, 54, 58]. It is recommended that, in future, researchers use this method of measurement and minimize patient self-report methods.

The weak points of these studies were non-specificity of PA for patients with BC, small sample size, lacking a strong design (RCTs), and lack of a theoretical framework.

Breast cancer mobile apps

PA apps are now highly popular among users; from every five users, one has installed at least one PA app on his/her mobile phone [78]. Despite a large number of PA apps available for download, few apps specifically focus on the improvement of PA in cancer patients [79]. Despite the increase in the use of mobile apps for health purposes [80] and the possible potential for monitoring the QOL of cancer patients, providing treatment strategies, and improving patients' conditions [81], the present study indicated that four out of five mobile apps failed to prove statistically the effectiveness of interventions for BC patients.

Designing eHealth interventions based on breast cancer patients need

BC treatment may lead to upper-limb dysfunction (ULD). Symptoms of ULD include pain, numbness, reduced shoulder ROM, reduced strength, joint limitations, axillary web syndrome, and lymphedema due to injury to the axillary lymphatic system [82–86]. To solve and manage these issues, tailored exercises and rehabilitation programs for these patients are required. Although no app specialized for BC patients was found in the present study, the use of self-management theories, frameworks, and models for designing apps specialized for patients with cancer can significantly help with this matter. The main challenge is ensuring that these apps effectively focus on cancer, during design, test, and use [87, 88]. There are protocols from RCTs which indicate that strong studies on this topic are being conducted and, in the near future, one can refer high-quality evidence-based results [38, 89–93].

Usability consideration

Cancer patients suffer from cognitive problems over the course of the disease. Therefore, issues related to usability and accessibility are points which must be taken into consideration in the design and development of systems, especially for the elderly [81]. Nowadays, a wide range of apps is available, determining which one is appropriate for BC patients and what is the best method of using them is difficult, and may confused patients in selecting the appropriate app [94]. A usability factor examined here was user satisfaction. In the present study, four articles provided information on the level of patient satisfaction. Overall, patient satisfaction with interventions ranged from 71 to 85%. These statistics show the relatively high satisfaction of participants with eHealth interventions, indicating that researchers care about patient preferences and design their products based on the principles of patient-centered design. The user interface designed for patients must be specialized to them and meet their needs. Many studies had considered this point and designed apps based on the guidelines provided by the National Cancer Institute or other sources.

Limitations

A limitation of the present study is that PA measurement differed across studies and, therefore, it was not possible to calculate the final level of effect on PA. The language of the search was limited to English, so there may have been other articles which were not included.

Conclusion and recommendations

The reviewed articles can reflect the first scientific efforts for increasing PA in BC patients. Results showed that the use of eHealth tools is effective in promoting PA in BC patients and can be used as a supportive opportunity for these patients. Still, studies on this topic must expand and increase in number.

The present study indicated that there are some issues in this regard, including inappropriate methodology, short duration of intervention and follow-up, inhomogeneity in studies, and patients' self-report of their PA in some studies instead of directly measuring PA.

It is recommended that future studies perform clinical trials with appropriate methodology, enough intervention time

and follow-up. Furthermore, physical interventions specialized for BC patients must be designed and implemented in various stages of treatment. It is also suggested that the type of PA measurement be changed from patient self-report to direct measurement using new technologies.

Acknowledgements This study was part of a PhD project conducted at Shahid Beheshti University of Medical Sciences.

Funding None.

Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest.

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