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How do different delivery schedules of tailored web-based physical activity advice for breast cancer survivors influence intervention use and efficacy?

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Abstract
Purpose The purpose of the study is to investigate the impact of differing delivery schedules of computer-tailored physical activity modules on engagement and physical activity behaviour change in a web-based intervention targeting breast cancer survivors.
Methods Insufficiently active breast cancer survivors (n = 492) were randomly assigned to receive one of the following intervention schedules over 12 weeks: a three-module intervention delivered monthly, a three-module intervention delivered weekly or a single module intervention. Engagement with the website (number of logins, time on site, modules viewed, action plans completed) was measured using tracking software. Other outcomes (website acceptability, physical activity behaviour) were assessed using online surveys. Physical activity outcomes were analysed using regression models for both study completers and when applying intention-to-treat (using multiple imputation).
Results Completers allocated to the monthly module group rated the intervention higher (b = 2.2 95 % CI = 0.02–4.53) on acceptability and had higher levels of resistance-training (IRR = 1.88, 95 % CI = 1.16–3.04) than those in the single module group. When accounting for missing data, these differences were no longer significant. The completion of at least two action plans was higher among those allocated to the monthly module group compared to those in the weekly module group (53 vs 40 %, p = 0.02); though the completion of at least two modules was higher in the weekly module group compared to the monthly module group (60 vs 46 %; p = 0.01). There were no other significant between group differences observed.
Conclusion This study provides preliminary evidence that web-based computer-tailored interventions can be used to increase physical activity among breast cancer survivors. Further, there were some outcome differences based on how the tailored modules were delivered, with the most favourable outcomes observed in the monthly delivery group.
Implications for Cancer Survivors This study will be useful for informing the design of future web-based interventions targeting breast cancer survivors.

Keywords Physical activity · eHealth · Cancer · Behaviour change

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Breast cancer survivors experience greater levels of burden and disability and have a lower life expectancy compared to their age matched counterparts [1–3]. Previous clinical trials have demonstrated that participation in regular aerobic and resistance-based physical activity can significantly improve these health outcomes [4], and as such participation in both types of activity are recommended to assist with recovery and improve quality of life among cancer survivors [5–7]. Unfortunately, despite this evidence, the majority (50–70 %) of breast cancer survivors are not sufficiently active to obtain health benefits [8, 9].

To facilitate physical activity participation among breast cancer survivors, there is a need to develop evidence-based physical activity support services that can be delivered in a cost-effective and sustainable way. Such interventions must have sufficient reach, adoption, and maintenance in order to have a real public health impact [10, 11]. Given that the number of breast cancer survivors is steadily increasing each year in Australia (by about 3 % annually), and that at least a third of those diagnosed in Australia live outside of major service areas [12], this represents a major service delivery challenge. To overcome this challenge, there has been a call for the development of effective distance-based interventions as an alternative and/or adjunct to face-to-face approaches [10, 13].

Computer-tailored interventions delivered via the Internet have been put forth as a promising distance-based approach for use with breast cancer survivors [10, 14]. In these interventions, content delivered online is adjusted based on individual characteristics through an automated computer process. This leads to the delivery of more personally relevant information, and in turn leads to higher engagement with the intervention and greater intervention efficacy [15]. Recent reviews of web-based computer-tailored interventions suggest that these interventions are more effective than control interventions and non-tailored websites [16, 17]. However, substantial problems engaging participants in web-based interventions, including those that employ computer-tailoring are also evident, with low intervention use widely reported across studies [18, 19]. Given the positive relationship between intervention dose and intervention efficacy, this raises concerns regarding the public health potential of web-based approaches [19]. In recognition of this, research examining how to improve the design of web-based interventions to enhance user engagement and intervention effectiveness is needed [15, 18, 20].

One design component that requires greater examination is the delivery schedule of computer-tailored content. Tailored intervention content is often delivered in a modular setup, whereby content is delivered in sequential order and typically unlocked over time. This technique is known as ‘Tunneling’ [18, 21, 22], whereby the user is guided through the process of behaviour change by the system. This is in contrast to a ‘free’ setup, where all content of the intervention is available to the user from the start [18]. Tunneling has been put forth as a promising approach to control and optimise engagement in web-based lifestyle interventions [18], owing to the increased capacity of this design to foster a dialogue with users (by facilitating on-going interaction opportunities and providing on-going support) and control the amount of information conveyed at any one point in time [22]. However, very little research regarding optimal module delivery has been conducted. This limits our capacity to make evidence-based decisions regarding how many modules should be delivered and at what frequency they should be delivered to enhance engagement and intervention efficacy. There are many options for delivering intervention modules and, thus far, the impact of these decisions on behaviour change intervention efficacy has been untested. If we are to optimise intervention design, this issue requires further examination.

The current study aimed to investigate the impact of number of modules and intervention delivery schedule on breast cancer survivors’ engagement in a computer-tailored intervention, in terms of both perceptual (i.e., perceived acceptability and usability) and behavioural (i.e., intervention usage) engagement-related outcomes. Second, we aimed to explore the preliminary and relative efficacy of the developed interventions in comparison to each other for producing changes in aerobic and resistance-based physical activity behaviour.

Method

Study design

This trial was a randomised study, with three experimental arms. There was a 3-month treatment phase, with follow-up assessments conducted immediately post-treatment (3 months post-baseline) and 3 months post-treatment (6-months post-baseline). Participants were randomised into either (a) a computer-tailored three-module intervention delivered monthly; (b) a computer-tailored three-module intervention delivered weekly (over the first 3 weeks) or (c) a computer-tailored single module intervention. The delivery schedule of each intervention is depicted in the supplementary file fig. S1. The conducting and reporting of this study adheres to the Consolidating Standards of Reporting and Clinical trials (CONSORT) guidelines [23]. Ethics approval was obtained from the Central Queensland University’s Human Research Ethics Committee (EC00158). The trial is registered with the Australian and New Zealand Clinical Trials Registry (registration number: ACTRN12613001220752). Informed consent was obtained from all individual participants included in the study.

Setting and participants

The study was conducted at Central Queensland University in 2014. English proficient breast cancer survivors who were over 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 and were not already meeting national physical activity guidelines (i.e., participating in 150 min of moderate-vigorous aerobic activity across at least 5 days a week) [24] were eligible to participate in this study.

Recruitment was conducted entirely online between June and August in 2014. Members from two breast cancer-related review and survey groups (i.e., Breast Cancer Network Australia review and survey group and Register4), interested in breast cancer-related research, were emailed about the study on behalf of the research team by review and survey group managers. Facebook was also used to recruit potential participants using an *iMove More for Life* Facebook page, which enrolled participants could like and share. The landing page of the study website contained study information and a link to the eligibility questionnaire.

Random assignment

The study website was utilised to automatically randomise participants using a random number generator (from random.org). All project team members were blinded to this process. Prior to commencement, participants were notified of the general aim of the study (i.e., to investigate the usefulness of a website for promoting physical activity among breast cancer survivors) and advised that they would be allocated into either a group that received personalised feedback and advice about physical activity all at once or a group that received personalised advice and feedback over three separate sessions. Participants were not informed that there were two three-module conditions with a different delivery schedule.

Interventions

The principle objective of the interventions was to promote increases in moderate-vigorous aerobic physical activity and resistance-training activity by influencing key determinants of behaviour change (see Table S1, supplementary file), as described by Social Cognitive Theory [25]. A brief overview of the intervention modules is described below. A detailed overview of the theory and evidence-based development of intervention content (the print-version on which this is based) is described in detail elsewhere [26, 27].

Monthly three-module intervention Participants randomised to this group were granted access to three personally tailored modules, with one module being available to complete each month. The participants were required to complete a brief web-based survey prior to each module. The first survey assessed demographic, psycho-social, health and physical activity variables. The latter surveys assessed physical activity status and action planning only. The responses to these surveys determined the tailored content of the modules each participant received.

Module 1 comprised information on physical activity guidelines for cancer survivors (non-tailored), feedback on physical activity behaviour (tailored based on current aerobic and resistance-based physical activity) relative to the guidelines, information on the benefits of physical activity (tailored based on outcome expectations), advice on how to engage in activity safely (tailored based on health status), and an action-planning message, which explained the benefits and purpose of action planning and directed participants towards the action planning tool available on the website.

Module 2 included feedback on physical activity behaviour (aerobic and resistance) relative to module 1, advice from a behaviour change expert on how to use behaviour change techniques to increase motivation and prevent relapse (non-tailored), information on self-monitoring tools (non-tailored), advice on eliciting social support (tailored based on preferred exercise partner and social support status), advice on overcoming barriers (tailored based on main barrier identified by participant) and feedback on action planning (tailored based on whether the participant set goals after the last module).

Module 3 included tailored feedback on physical activity performance (aerobic and resistance) relative to module 1 and module 2, information on and tips to reduce prolonged inactivity (non-tailored), a testimonial illustrating success (tailored based on self-efficacy and weight status), information about available support services (tailored based on location) and encouragement to complete the action planning modules (tailored based on whether the participant had set any goals since the last session, and if so if they had met them).

Weekly three-module intervention Participants in this group received the same intervention as outlined above; however, instead of being delivered with a monthly interval, it was delivered with a weekly interval in the first 3 weeks of the intervention period (see Fig. S1 (supplementary file)).

Single module group The participants in this group received the same psycho-social module content as participants in the three-module groups; however, all content was delivered in a single module at week 1 (rather than being distributed to participants over three separate sessions like in the three-module groups). Feedback on physical activity behaviour was also provided, which was akin to what participants in the three module conditions received in module 1 (no iterative feedback on physical activity performance and action planning was provided over-time like in the other two conditions). To generate the tailored content the completion of only the first web-based survey was required.

Additional intervention features In addition to the module(s), all participants were provided with access to an action planning tool and were encouraged via the module(s) to log on to the website each week to set-up a new action plan (stating what, where, when and with who physical activity will be performed in the following week). Developing a detailed action plan has been identified as a key behaviour change technique for physical activity promotion [28, 29]. All participants also had access to a library page, which contained generic information on resistance-training exercises and stretches that could be done at home, strategies for fitting physical activity into daily routines, and suggestions on how to make physical activity fun. No new content was uploaded onto the library page during the course of the study (for screenshots see https://osf.io/2vb8n). Given these additional features, all participants were encouraged (via the modules) to utilise the website weekly to complete action plans and could log on as many times as they liked over the 3-month treatment period. Participants were sent up to two email reminders (3 days apart) each time they had a module due. Participants were also sent up to two reminders to complete action plans when they became available, however as action plans were programmed to 'unlock' 1 week after each one was completed, no additional reminders were sent if the open action plan remained uncompleted.

Measures

All assessments were conducted online. If participants failed to complete an assessment they were sent up to two email reminders (up to 3 days apart). A copy of the surveys used can be obtained from the iMove More for Life open science framework project page (https://osf.io/2vb8n/).

Engagement

Website acceptability Perceptions of website acceptability were assessed using nine items based on previous research [26] and theory of engagement in online interventions [15, 30]. Items assessed whether the website was considered interesting, credible, personally relevant, easy to understand, met expectations, changed attitudes, and was considered useful. Example items include 'the information provided to me on the website was interesting', 'the information provided on the website was relevant to me personally' and 'the action planning activity on the website was useful to me'. Response options ranged from 0 (strongly disagree) to 4 (strongly agree). Participants' scores for each item were added together (with negatively framed items reverse coded) to form an overall score, ranging from 0 to 36. Essential unidimensionality of the scale was confirmed through exploratory factor analysis [31] and internal consistency of the scale was found to be high (Omega coefficient = 0.92, 95 % CI 0.89–0.94) [32].

Website usability Website usability was assessed using the 10-item System Usability Scale [33], which is a reliable and widely used tool for assessing users' subjective ratings of a product's usability [34]. Example items include 'I think I would like to use this website frequently' and 'I found the website very cumbersome to use'. All items were assessed on a 5-point Likert scale, with response options ranging from strongly disagree to strongly agree. Participants' scores for each item were added together (with negatively framed items reverse coded) and then multiplied by 2.5 to convert the original scores of 0–40 to 0–100 for interpretability. Factor analysis (using the method outlined above) confirmed 'essential unidimensionality'. Internal consistency was high (omega coefficient = 0.91, 95 % CI [0.88–0.93]). Based on previous research, a SUS score above 68 indicates 'above average usability' [35].

Website usage For each participant, the number of times the website was visited and the total time spent on the website (in minutes) from baseline to the 3-month follow-up was assessed using Google Analytics. The number of intervention modules viewed and action plans completed was also passively collected using inbuilt website tracking tools. 'Intended usage' was defined in each group as the completion of all available modules and action plans.

Physical activity

Two physical activity outcomes, moderate-vigorous aerobic physical activity (mins/week) and resistance-based physical activity (resistance training score) were assessed at all time-points using an adapted version [36] of the validated Godin Leisure-Time Exercise Questionnaire (GLTEQ) [37, 38]. The adapted version of the GLTEQ contains six items assessing participants' average participation in mild, moderate and vigorous aerobic physical activity in a typical week over the past month and three resistance-training items that asks participants to report (on average) the frequency (times per week) and volume (number of exercises completed in each session reported and number of repetitions completed for each exercise reported) of resistance training activities performed over the past month. To determine moderate-vigorous aerobic physical activity minutes per week, vigorous aerobic activity was multiplied by two (to account for the additional benefits associated with vigorous physical activity) and then the individual scores for the moderate to vigorous aerobic activities were summed. To determine the resistance training score the average number of sessions were multiplied by the average number of exercises completed in each session.

Participant characteristics

Demographic characteristics assessed include age, marital status (5 categories collapsed into 'married/defacto', 'separated' or 'other'), highest level of education completed (5 categories collapsed into 'university degree' or 'no university degree'), gross family income (6 categories collapsed into '≤ $799 per week' or '> $799 per week', based on the national median household income; [39]), employment status (11 categories collapsed into full-time, part-time, retired, other) internet use in leisure time (0–2 h per week, 3–6 h per week, 7–10 h per week, 11 or more hours per week) and geographical location (3 categories collapsed into 'major city' or 'non-major city').

Health status characteristics assessed include stage of breast cancer (stage 0–stage 4), time since breast cancer treatment (years), height and weight (to calculate BMI), current menopausal status, fatigue (using the validated 13-item FACIT [40])—scores range from 0 to 52, with less than 30 indicating severe fatigue [41] and number of co-morbidities (including arthritis, osteoporosis, asthma, emphysema, angina, heart disease, heart attack, neurological disease, stroke, peripheral vascular disease, diabetes type 1 or 2, depression, anxiety or panic disorders, degenerative disk disease, obesity and lymphedema).

Statistical analysis

Analyses were conducted according to the intention to treat principle, as recommended by White et al. [42]. Namely, the primary analysis was conducted using all observed data, and sensitivity analyses (using multiple imputation with chained equations and five imputed data sets) [43] were conducted to explore the impact of missing data. The primary time-point of interest is the immediate post-intervention assessment. Other than for data relating to drop-out, study outcomes relating to the 6-month assessment are not reported (due to small sample sizes $n = 53$). Study completers are defined as those who completed the 3-month follow-up survey.

Descriptive statistics were computed for all study variables and statistical assumptions were checked prior to conducting analyses. For all regression analyses, the single module group was entered as the reference category in the first instance, and post hoc tests were conducted to examine differences between the two three-module groups. Multiple imputation with chained equations was conducted in *R* version 3.2.2 [43, 44]. All analyses were conducted in STATA 11 [45].

Statistical tests Difference in drop-out between groups was explored using chi-square analyses. Difference in drop-out based on participant characteristics were assessed using anova for continuous variables and chi-square tests for categorical variables. *Engagement—perceptual outcomes (Aim 1):* The effect of study group on website acceptability and usability scores were assessed using linear regression. *Engagement—behavioural outcomes (Aim 1):* Due to the over-dispersed nature of the data, negative binomial regression models were used to assess the effect of group on time on site (minutes) and number of site visits. Chi-square analyses were used to examine between group differences for number of modules completed (between the weekly module group and the monthly module group only) and completion of at least two action plans (based on median split). *Physical Activity outcomes (Aim 2):* The effect of group on moderate-vigorous aerobic physical activity among study completers was assessed using a linear regression analysis, with baseline and follow-up activity data square-root transformed (due to skew of the data) and extreme values truncated to be to 3.29 standard deviations from the mean (to reduce the impact of outliers). For the sensitivity analysis, a negative binomial regression model (with no transformation) was utilised as the data were over-dispersed. To examine the effect of group on resistance-training scores, zero-inflated negative binomial models were used, since the data was over-dispersed and zero-inflated (for both the primary and sensitivity analysis). For each of these analyses, baseline physical activity (of the same type) was also entered into the model.

Results

Flow of participants

The flow of participants through the trial is presented in Fig. 1. Overall, 724 individuals visited the study website and completed the eligibility questionnaire, 539 were deemed eligible and of those, 492 enrolled in the study and completed the baseline questionnaire. Retention was 32 % ($n = 156$) at the 3-month follow-up and 11 % ($n = 53$) at the 6-month follow-up. There was evidence of differential drop-out between groups at the 3-month follow-up ($p = 0.04$). Retention in the single module intervention group (39 %) was higher compared to the weekly three module intervention group (27 %; $p = 0.02$) and the monthly three module intervention group (29 %; $p = 0.04$). There was no other difference in drop-out between groups (all *p's* > 0.05).

Sample characteristics

Participant characteristics are presented in Table 1. Participants were generally middle-aged (*M* age = 55, SD = 9.72), married (74 %), overweight or obese (67 %) and users of the Internet in their leisure time. Most participants (71 %) were engaging in some moderate-vigorous aerobic

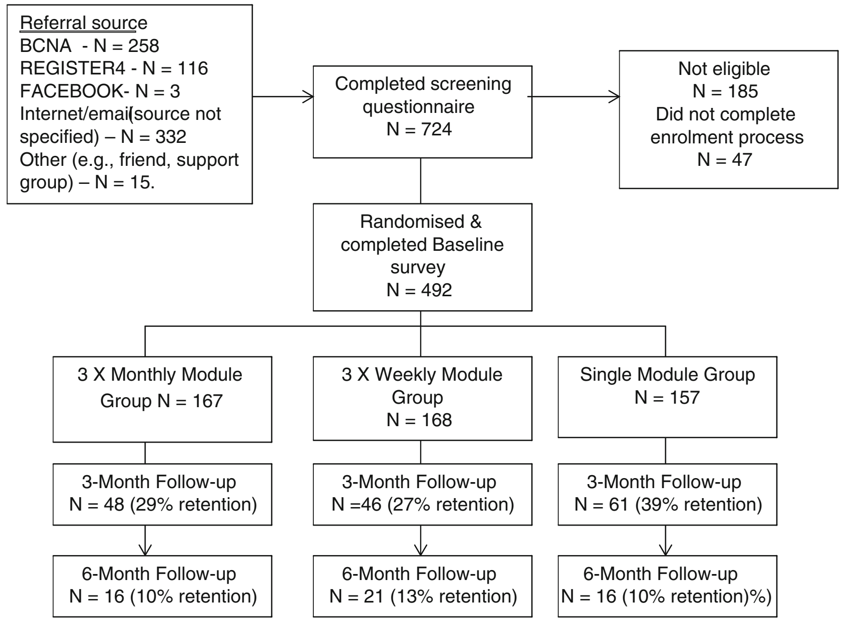


Fig. 1 Participant flow through the study

activity at baseline (*M* = 99 min/week; SD = 120; median = 60 min/week), but none where meeting the physical activity guidelines. Less than a quarter (24 %) reported engaging in any resistance training. Participants were found to be generally representative of the target population in terms of age, weight status, cancer stage, fatigue and physical activity participation [9, 46]. However, more participants in the current study had a university degree (48 %) and resided in rural/regional areas (43 %) than would be expected based on Australian population-based data for cancer survivors [2]. At both follow-up time-points, drop-out was higher among those with lower levels of resistance-training at baseline (3-month follow-up $p = 0.02$; 6-month follow-up $p = 0.03$). There were no other significant differences between those that were retained in the study and those that were lost to follow-up (all *p's* > 0.05).

User perception of the website: psychological outcomes related to engagement

Website acceptability score Overall, website acceptability among study completers was fair, with a mean score of 22.20 (SD = 5.98) out of a possible 36. Mean scores for each group are presented in Table 2. The linear regression analysis conveyed that participants allocated to the monthly module group rating the intervention 2.27 (95 % CI = 0.02 to 4.53) points higher on average than participants allocated to the single module intervention group ($p = 0.048$). There was no significant treatment effect of the weekly module group compared to the single module group ($b = 1.65$, 95 % CI = −0.62, 3.93) or the weekly module group compared to the monthly module group ($b = -0.61$, 95 % CI = −3.03, 1.80). For the sensitivity analysis (which accounts for missing data), website acceptability was less positive (*M* = 15.39, SD = 12.47), and no evidence of significant group effects were found (all *ps* > 0.05).

Usability score Overall, study completers rated the usability of the website as adequate, with the rating reflecting a score slightly 'above average' (*M* = 69.16, SD = 17.06). The range of scores was large (range = 5–100). There were no significant group effects (all *ps* > 0.05, see Table 2). A similar pattern of results were observed in the sensitivity analysis (*M* = 66.74, SD = 29.36; all ps > 0.05).

Website usage: behavioural outcomes relating to engagement

Time spent on the study website in minutes Study completers spent an average of 61.14 min (SD = 80.10, range 0–550 min) using the website, with no treatment effect of group observed (all ps = > 0.05). A similar pattern of results was observed when analyses were repeated with the whole study sample (*M* = 57.01, SD = 71.98, range = 0–556 min; all ps > 0.05).

Number of visits to the website On average, study completers logged on to the website 5.18 times (SD = 8.48, median = 3, range = 1–45) over the monitoring period. There was no evidence of between group differences (all *ps* > 0.05). As above, a similar pattern of results was observed when analyses were repeated with the whole study sample (*M* = 4.8, SD = 8.48, range 1–146; all *ps* > 0.05).

Modules viewed The number of modules viewed by study participants in each group is presented in Table 3. All participants viewed at least one module. Overall, modules views

Table 1 Participant characteristics for whole sample at baseline ($n = 492$) and those retained at the 3-month follow-up ($n = 156$)

	Randomised	Retained
Demographics		
Age		
M (SD)	55.09 (9.73)	55.34 (9.73)
Range	22–80	22–80
Marital status		
Married/defacto	75 %	74 %
Separated	13 %	12 %
Other	12 %	14 %
Education level		
University	48 %	44 %
No university	52 %	56 %
Gross family income/week		
≤$799	26 %	30 %
>$799	48 %	47 %
Prefer not to answer	26 %	23 %
Employment status		
Full-time	24 %	21 %
Part-time	24 %	22 %
Retired	23 %	25 %
Other	30 %	33 %
Location		
Major city	57 %	52 %
Non-major city	43 %	48 %
Internet use (leisure time) per week		
0–2 h	19 %	17 %
3–6 h	28 %	29 %
7–10 h	33 %	33 %
≥11 h	21 %	20 %
Health-related factors		
Breast cancer stage		
0	2 %	3 %
1	22 %	20 %
2	31 %	35 %
3	21 %	18 %
4	3 %	3 %
Do not know	21 %	21 %
Time since treatment (years)		
M (SD)	4.22 (4.02)	3.94 (4.46)
Range	0.5–21	0.5–21
Extent to which physical health limits physical activity		
Not at all	30 %	31 %
A little	42 %	42 %
Somewhat	22 %	21 %
Mostly	4 %	3 %
Completely	2 %	3 %
Comorbidity index		
M (SD)	1.75 (1.76)	1.71 (1.84)
Range	0–15	0–15
Cancer-related fatigue		
M (SD)	37.73 (10.24)	39.03 (9.63)
Range	6–52	6–52
BMI		
M (SD)	28.18 (SD 5.57)	27.67 (SD 6.05)
Underweight	<1 %	2 %
Normal weight	31 %	35 %
Overweight	35 %	34 %
Obese	34 %	29 %
Physical activity		
MVPA min/week		
M (SD)	99.14 (120)	95.45 (116.28)
Range	0–525	0–525
Resistance-training score (no. sessions × no. exercises)		
M (*SD*)	2.03 (5.34)	2.86 (6.93)
Range	0–45	0–45

MVPA moderate to vigorous aerobic activity

among study completers was high, with most participants in the weekly module group (85 %) and monthly module group (73 %) viewing all three available modules. There were no significant differences observed between these two groups ($p = 0.20$). Among the whole study sample (including those lost to follow-up), module views for the weekly and monthly module groups were somewhat lower compared to study completers (see Table 3). There were also significant differences between the weekly and monthly module groups, with significantly more participants in the weekly module group completing at least two of the three modules compared to participants in the monthly module group (60 % vs 46 %; $p = 0.01$).

Action plans completed The percentage of participants completing each available action plan by group is presented in Figs. 2 and 3. The majority of participants (75 %) completed at least one action plan. Among study completers, the average number of action plans completed was 4.37 (SD = 3.40), with approximately 40 % of all available action plans completed (i.e., 683 out of 1716). A between group difference was observed ($p = 0.04$), with post hoc tests showing significantly more participants allocated to the monthly module group completing at least two action plans (91.67 %), compared to participants allocated to the weekly module group (71.74 %, $p = 0.01$). There were no significant differences between the single and monthly module groups (83.87 vs 91.67 %, $p = 0.224$) or the single and weekly module groups (83.87 vs 71.74 %, $p = 0.13$). The same pattern of results was observed when

Table 2 Differences in participants' rating of website acceptability and usability by group ($n = 156$)

	Overall	Single module group	Weekly module group	Monthly module group	*p*
Acceptability					
M, SD	22.20 (5.98)	21.01 (6.13)	22.67 (5.80)	23.29 (5.79)	WMG vs SMG[a]
Range	0–35	6–34	5–36	0–36	MMG* vs SMG[b]
					WMG vs MMG[c]
Usability					
M, SD	69.16 (17.06)	67.42 (17.56)	67.44 (15.45)	73.07 (17.55)	WMG vs SMG[d]
Range	5–100	5–100	40–95	35–100	MMG vs SMG[e]
					WMG vs MMF[f]

*p value <0.05

[a] $b = 1.65$ (95 % CI = −0.62, 3.93)

[b] $b = 2.27$ (95 % CI = 0.02, 4.53; $p = 0.048$)

[c] $b = -0.61$ (95 % CI = −3.03, 1.80; $p = 0.61$)

[d] $b = 0.02$ (95 % CI = −6.49, 6.54; $p = 0.99$)

[e] $b = 5.65$ (95 % CI = −0.79, 12.10; $p = 0.09$)

[f] $b = -5.62$ (95 % CI = −12.54, 1.28; $p = 0.11$)

Table 3 Module views by study completers ($n = 156$) and the entire study sample (including those lost to follow-up, $n = 492$)

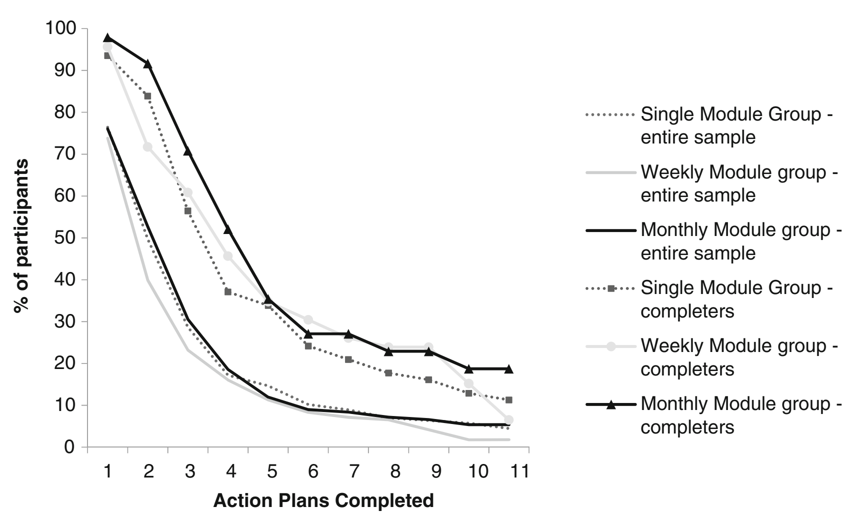
	Single module	Weekly modules	Monthly modules
Completers			
1 module	100 %	100 %	100 %
2 modules	–	91 %	92 %
3 modules	–	85 %	73 %
Entire sample			
1 module	100 %	100 %	100 %
2 module	–	60 %	46 %
3 module	–	36 %	30 %

analyses were rerun using data from the entire study sample (53 % monthly vs 40 % weekly, $p = 0.02$), though overall action plan completion rates were lower (see Fig. 3). For the whole sample, the average number of action plans completed was 2.18 (SD = 2.63), with approximately 20 % of all available action plans completed (i.e., 1094 out of 5412). Few participants ($n = 19$) completed all available action plans.

Physical activity behaviour change

Changes in physical activity behaviour for each study group are described in Table 4.

Fig. 2 Percentage of participants completing each action plan by group



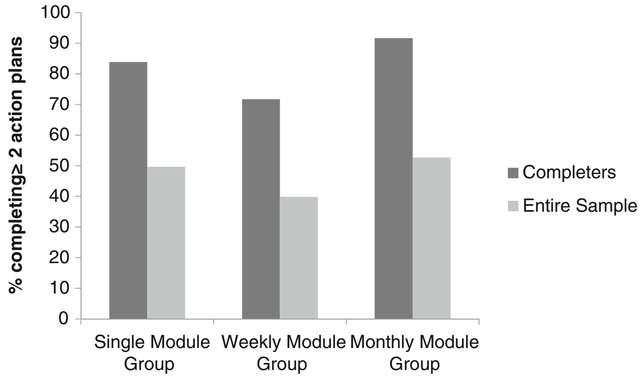


Fig. 3 Percentage of participants completing two or more action plans by group

Aerobic activity There was a significant increase in moderate-vigorous aerobic activity observed across all study groups (among completers and when accounting for missing data). However, there were no significant effects of group observed on moderate-vigorous aerobic activity in either analysis (all *ps* < 0.05).

Resistance-based activity As above, an increase in resistance-based activity across all study groups was observed. However, among study completers, there was a significant effect of group (see Table 5), with the incidence of resistance-training among participants allocated to the monthly three module intervention group 1.88 times higher than participants allocated to the single module intervention group ($p = 0.01$). There were no other significant between group effects observed among study completers (all ps > 0.05). When accounting for missing data, the significant treatment effect of the three module intervention group on increase in resistance-training was no longer observed ($b = 0.17$, IRR = 1.19, 95 % CI = 0.88–1.62, $p = 0.25$), and there were no other significant treatment effects (all *ps* > 0.05).

Discussion

Overall, our findings contribute to the growing body of research indicating that module delivery schedule may influence engagement and intervention outcomes in online health behaviour change interventions and should be considered when developing interventions [18, 22, 47, 48]. Effects on behaviour, and in particularly aerobic physical activity participation remain to be determined.

Principle findings

Impact of module delivery schedule on user engagement

The varying module delivery schedules examined in this study impacted psychological (i.e., user's perception of website) and behavioural (i.e., website usage) outcomes related to user engagement. While perceived usability was equivalent across the three groups, overall website acceptability was highest among participants in the three monthly module condition. As positive perceptions of the website are likely associated with greater persuasion potential [15] this is an important finding. Findings relating to website usage were more mixed. Among participants provided with three modules, the proportion of participants completing at least two modules in the weekly module group was higher than in the monthly module group; though completion of at least two action plans was higher in the monthly module group compared to the weekly module group. It appears that, in lieu of a module to complete after the first week, participants in the monthly module group logged on to complete an action plan; whereas with both a module and action plan to complete after the first week, participants in the weekly module group focused on completing the module and were less likely to also complete the action plan. This may suggest that the weekly module intervention overloaded some participants [49], and in contrast that participants in the monthly module group disengaged prior to having the opportunity to complete another module. Given that

Table 4 Changes in physical activity behaviour for each study group from baseline to immediate-post-intervention follow-up

	Study completers			Intention to treat sample		
	Baseline (*M*, SD)	Follow-up (*M*, SD)	Mean change (*M*, 95 % CI)	Baseline (*M*, SD)	Follow-up (*M*, SD)	Mean change (*M*, 95 % CI)
Moderate-vigorous aerobic activity (min)						
SMG	90.08 (106.63)	216.99 (219.99)	126.91 (84.29–169.52)	93.47 (111.23)	285.81 (337.69)	192.33 (139.88–244.79)
WMG	97.17 (124.10)	186.08 (157.89)	88.90 (34.52–143.9)	96.96 (125.67)	265.31 (327.12)	168.34 (116.80–219.89)
MMG	96.15 (119.63)	186.05 (172.56)	89.90 (42.96–136.83)	106.64 (124.32)	280.59 (332.38)	173.94 (119.04–228.84)
Resistance-training score						
SMG	2.69 (7.27)	4.5 (6.83)	1.80 (0.22–3.38)	2.10 (5.57)	9.54 (19.53)	7.43 (4.31–10.55)
WMG	3.17 (7.07)	6.52 (9.86)	3.34 (0.26–6.43)	1.72 (5.05)	12.75 (23.66)	11.04 (7.36–14.72)
MMG	2.79 (6.45)	8.95 (16.24)	6.16 (1.62–10.70)	2.28 (5.39)	12.59 (21.93)	10.31 (6.87–13.74)

SMG single module group, *WMG* weekly module group, *MMG* monthly module group reading the module and completing an action plan were both considered important for encouraging behaviour change [26], in future applications the delivery schedule should be optimised to allow for earlier access to modules, whilst not overloading participants with too much information or too many tasks to complete (e.g., via the delivery of weekly modules and fortnightly action planning or vice versa).

Impact of module delivery schedule on physical activity behaviour

The evaluated interventions had comparable effects on aerobic physical activity behaviour. This may be owing to the equal availability of action plans across groups. Recent meta-analyses have shown that the use of action plans in physical activity behaviour change interventions are associated with greater intervention effects [28] and that action plans have small-to-medium intervention effects when employed as standalone interventions [50]. Thus, it is possible that the use of action plans in the current study led to ceiling effects, which limits capacity to both produce and identify between group differences. However, it is also possible that exposure to computer-tailored advice led to ceiling effects, regardless of how this advice was presented. While previous reviews of computer-tailored interventions suggest that multiple module interventions may be more effective than single module interventions, these have not been directly compared and there are certainly instances where single module computer-tailored interventions have been effective [51, 52]. Given that computer-tailoring is also associated with increased effect-sizes [16], it is also possible that the provision of tailored advice (in any form) led to ceiling effects. Future research with a control condition is needed to elucidate these effects. It is possible that module delivery schedule has little impact on aerobic activity in this context (i.e., where most participants are undertaking some aerobic activity already and are motivated to improve activity levels further).

In contrast, significant group differences were observed for resistance-based activity, with greater behaviour change observed among study completers allocated to the monthly module group compared to those allocated to the single module group. It may be that when behaviour change is more challenging, receiving a greater number of modules spread out over time is better (or at least more optimal when provided alongside weekly action plans). Self-efficacy and behavioural capability for resistance-training are generally low among breast cancer survivors [53], and addressing these determinants may require on-going support and encouragement, more so than aerobic activity. Further research is needed to clarify these findings.

Table 5 Treatment effects on resistance-training at the 3-month follow-up (for study completers)

	Predicting increase in resistance-training						Predicting odds of any resistance training					
	Weekly module vs single module		Monthly module vs single module		Weekly module vs monthly module		Weekly module vs single module		Monthly module vs single module		Weekly module vs monthly module	
	Coefficient (CI)	IR (CI)	Coefficient (CI)	IR (CI)	Coefficient (CI)	IR (CI)	Coefficient (CI)	IR (CI)	Coefficient (CI)	IR (CI)	Coefficient (CI)	IR (CI)
Resistance-training score	0.43 (−0.07, 0.93)	1.53 (0.93, 2.53)	0.63 (0.15, 1.11)*	1.88 (1.16, 3.04)	−0.20 (−0.70, −0.30)	0.81 (0.49, 1.40)	0.19 (−0.75, 1.15)	0.19 (−0.75, 1.14)	−0.29 (−1.20, 0.62)	−0.29 (−1.20, 0.61)	0.20 (−0.75, 1.14)	0.19 (−0.75, 1.15)

$^*p \leq 0.01$

Strengths and limitations

This study has several strengths. The evaluated interventions were systematically developed based on sound behavioural theory and evidence, the evaluation was conducted using a randomised design, objective measures of website usage were used and sensitivity analyses were conducted to explore the impact of missing data. Some limitations should also be acknowledged. Self-report measures were used for most study outcomes, which may introduce response biases. While our sample was fairly representative of the target group, high drop-out was a significant issue, and more so among those with lower levels of resistance-training at baseline. This may limit the generalisability and interpretability of findings. Additional strategies to improve retention (e.g., incentives, limiting questionnaire items, telephone contact with a research assistant) are recommended in future studies of this nature.

Conclusion

Overall, our study suggests that web-based interventions promoting physical activity among breast cancer survivors can produce positive behaviour changes and that system design does matter for both engagement and behavioural outcomes. Delivering tailored modules on a monthly schedule, when combined with weekly action planning may lead to better outcomes than delivering only one module or delivering modules on a weekly schedule. Further research examining the independent effects of action plans and tailored modules is needed to isolate the effects, as is research examining additional strategies to engage users in online interventions.

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Compliance with ethical standards

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Conflict of interest All authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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

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