Adherence to a lower versus higher intensity physical activity intervention in the Breast Cancer & Physical Activity Level (BC-PAL) Trial

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Abstract:

Purpose: The first aim is to examine adherence to a lower versus higher intensity physical activity (PA) prescription in breast cancer survivors in the Breast Cancer & Physical Activity Level (BC-PAL) Trial. The second aim is to assess associations between baseline characteristics with mean PA adherence in both intervention groups combined. **Methods:** Forty-five participants were randomized to a 12-week, home-based lower (300 min/week, 40-59% heart rate reserve (HRR)) or higher (150 min/week, 60-80% HRR) intensity PA intervention, or no intervention/control. Both intervention groups received Polar A360® trackers and were included in this analysis (n=30). Study outcomes assessed on a weekly basis with the Polar A360® activity tracker throughout the intervention included relative adherence to the prescribed PA interventions (% of PA prescription goal met), and the absolute amount of PA time ≥40% of HRR. Baseline predictors of adherence included demographic characteristics, cardiorespiratory fitness, habitual PA and sedentary time, quality of life measures, and motivational variables from the Theory of Planned Behavior. For our primary aim, a linear mixed model was used to assess the effects of randomization group, time (intervention weeks 1-12), and the interaction of these factors on the natural logarithm of PA adherence. For our secondary aim, the association between each baseline predictor with the natural logarithm of mean weekly PA adherence was assessed, with randomization group added as a covariate. **Results:** Higher relative time within the prescribed HRR zone was noted in the lower versus higher intensity PA groups (e^{β}=3.12, 95% CI=1.97, 4.95). No differences in adherence across time were noted. Social support was inversely associated with relative PA time within the prescribed HRR zone (e^{β}=0.83, 95% CI=0.72, 0.97) and absolute PA time ≥40% of HRR (e^{β}= 0.82, 95% CI: 0.71, 0.93). Baseline VO_{2max} was inversely associated with relative PA adherence (e^{β}=0.98, 95% CI=0.95, 0.99). No other baseline measures were associated with PA adherence. **Conclusions:** There were no significant changes in absolute PA time ≥40% of HRR across time or between groups. However, the lower intensity PA group averaged over 3 times the relative amount of PA within the

prescribed HRR zone compared to the higher intensity PA group. Finally, lower peer support and cardiorespiratory fitness at baseline were associated with higher PA adherence. **Implications for Cancer Survivors:** The recent rise in popularity of commercially available activity trackers provides new opportunities to promote PA participation remotely, and these devices can be used to continuously and objectively measure PA levels as an indicator of intervention adherence. Future studies are needed to explore baseline predictors, facilitators, and barriers to sustained activity tracker use to promote PA behavior change and intervention adherence in cancer survivors. **Trial registration:** This study was registered at www.clinicaltrials.gov (No. NCT03564899) on June 21, 2018.

Keywords: Wearable technology | Physical activity prescription | Intervention adherence | Breast cancer survivorship

Article:

Introduction

The American Cancer Society (ACS) [1, 2] and the American College of Sports Medicine (ACSM) [3] recommend that cancer survivors accumulate at least 150 min/week of moderate-vigorous intensity (40-89% of heart rate reserve, HRR) [4] physical activity (PA) to promote overall health and well-being. PA has been shown to improve health-related quality of life, cancer-related fatigue, biomarkers of metabolic syndrome, cardiotoxicity, and other adverse effects caused by adjuvant treatments in breast cancer survivors [5,6,7,8,9]. Adherence to PA prescriptions (i.e., the extent to which a person's PA level corresponds to the recommendations/prescribed PA goals) [10] in this population, however, may be difficult to achieve and can vary depending on the PA prescription itself and baseline characteristics of the participants [11,12,13,14]. Specifically, a study by Kampshoff et al. [11] assessed predictors of adherence to high (70-85% of heart rate reserve, HRR) versus low-moderate (40-55% of HRR) intensity PA prescriptions in a sample of cancer survivors. Non-statistically significant differences in attendance and compliance with the supervised PA sessions were noted between PA intensity groups. Having higher self-efficacy and lower psychosocial distress was associated with greater adherence to the higher intensity PA prescription, whereas being a non-smoker and having a higher body mass index (BMI) were associated with greater adherence to the low-moderate intensity PA prescription [15]. Other studies also identified cancer stage and treatment history, self-efficacy, BMI, baseline VO_{2max}, baseline PA levels, and body fat % as being common baseline predictors of adherence to PA interventions in breast cancer survivors [12,13,14, 16].

PA randomized controlled trials (RCTs) that are exclusively home-based, or have included unsupervised PA sessions, commonly use self-reported activity logs to monitor PA adherence during at home/unsupervised exercise sessions [7, 12,13,14, 16, 17]. Recent intervention trials [18,19,20,21,22,23,24,25,26,27,28,29,30] conducted in various adult clinical populations have used commercially available activity trackers to assess adherence to their PA prescriptions based on the number of days or weeks with available activity tracker data, and have reported on average high adherence rates (≥85%). Only one study to date has reported baseline predictors of PA adherence measured with a wearable activity tracker in breast cancer patients throughout

chemotherapy treatment [19]. This study recruited 127 women with early-stage breast cancer and used Fitbit® activity trackers to measure participants' adherence to walking 150 min/week. Full adherence to the intervention was only 19%, with fewer steps being associated with having a higher BMI, baseline anxiety, being non-Caucasian, or having low education. Conversely, higher adherence was associated with higher pre-chemotherapy PA levels and higher baseline expectations in improvements of study outcomes following the PA intervention [19].

The Breast Cancer & Physical Activity Level (BC-PAL) Trial was a three-armed, home-based, 12-week RCT aimed at evaluating the effects of prescribing 300 min/week of lower intensity PA (40-59% of HRR) or 150 min/week of higher intensity PA (60-80% of HRR) using the Polar A360® activity tracker, compared to no PA intervention/control, on objective measures of PA and sedentary time, markers of health-related fitness and patient-reported outcomes, in recreationally inactive breast cancer survivors [31]. The selection of the exercise prescriptions for BC-PAL was based on findings from a recent study which reported that breast cancer survivors with the lowest self-reported PA levels had more barriers to PA participation and consistently preferred light-to-moderate intensity PA, whereas more active survivors preferred moderate-vigorous intensity PA [32]. Therefore, it was hypothesized that promoting lower intensity PA (40-59% of HHR) could improve PA adherence and health outcomes in recreationally inactive breast cancer survivors. Furthermore, recently published PA guidelines for cancer survivors from the ACSM Exercise and Cancer Roundtable discussions suggest that more trials are needed to compare different components of PA prescriptions head-to-head, such as low versus high intensity PA [9]. Finally, the Polar A360® activity tracker was selected for this trial because the research team was able to program the target HRR/PA intensity using its "training" application.

The purpose of the current secondary analysis was twofold. First, adherence to the lower versus higher intensity PA prescriptions were compared by using heart rate data obtained from the Polar A360® activity tracker collected throughout the intervention. Second, we assessed the strength of the associations between certain baseline characteristics with mean PA adherence in both intervention groups combined. To our knowledge, this trial is the first to assess PA adherence, and baseline predictors of PA adherence, to two different PA prescriptions using activity trackers in breast cancer survivors.

Methods

Participants and PA interventions

The design and methods for BC-PAL are described in detail elsewhere [31]. This single-center, three-armed, 12-week RCT was conducted in Calgary (Alberta, Canada) between February 2017 and April 2018. The study protocol was approved by the Health Research Ethics Board of Alberta – Cancer Committee. Written informed consent was provided by all participants prior to study participation. A total of 45 women were randomized to either a home-based lower intensity PA intervention, a home-based higher intensity PA intervention, or no PA intervention (control). Eligibility criteria included the following: females aged ≥18 years, diagnosed with histologically confirmed stage I-IIIc breast cancer, completion of all adjuvant treatments (chemotherapy, radiation therapy, and surgery) except for hormonal therapy, self-reported low recreational PA

levels (accumulating ≤60 min of moderate-vigorous intensity recreational PA/week and ≤10,000 steps/day), non-pregnant, able to follow a PA program and received medical clearance from a physician if the interested individual had medical conditions that may impede safe PA participation (e.g., severe arthritis, spinal cord injury, heart or cardiovascular disease), and able to meet with study staff in Calgary on six occasions for data collection. All eligibility criteria were first assessed by self-report over the phone. A further assessment of PA levels using a pedometer over 7 days was done if participants reported achieving ≥10,000 steps/day or ≥60 min/week of recreational PA on occasion or reported having an "active" employment (e.g., housekeeping). Only 1 participant was excluded from testing/not randomized as a result of being too active following PA assessment with the pedometer [31].

Participants randomized to the lower and higher intensity PA interventions were instructed to accumulate 300 min/week of PA at an intensity of 40-59% of HRR (~3-5 METs) or 150 min/week of PA at an intensity of 60-80% of HRR (~6-9 METs), respectively [33, 34]. The total PA volume prescribed to each group was similar (~15-25 MET-hours/week). These participants received a wrist-worn Polar A360® activity tracker to record their heart rate (PA intensity) and PA duration throughout the intervention. The target PA intensity was programmed under the "training" application of this wearable activity tracker. The "training" application allows the user to track continuous heart rate and time "in zone" during PA. The exercise physiologists advised participants to turn on the "training" application when they were engaging in PA and/or recommended that they leave the "training" application on at all times during the day if participants felt that they may forget to turn this feature on while engaging in PA. Any aerobic activity that raises the heart rate into the target heart rate zone was counted as "PA time," including short PA bouts (i.e., <10 min). The activity tracker also provides prompt feedback on heart rate/PA intensity and PA duration that can be used by the user to modify their PA behaviors (e.g., try to increase PA intensity if they are not within the prescribed HRR zone). Participants were instructed to upload their data to the Polar Flow® application at least once per week to minimize the risk of missing data. This also allowed the study exercise physiologists to track their progress and provide informed feedback every 3 weeks. In addition to the activity tracker, participants received a diary with questions on goal setting, the feasibility of the prescribed PA goals, and strategies and barriers to PA participation. They were instructed to complete this diary every 3 weeks, at which time active follow-up discussions by phone or e-mail were initiated by the study exercise physiologists to review data from the Polar A360® activity tracker and diary, as well as reinforce adherence and discuss any problems/barriers to achieving the prescribed PA goals. Lastly, participants randomized to the control group were instructed to maintain their baseline PA levels and did not receive any aspect of the PA interventions during the 12-week intervention period. The present analysis was limited to participants who were randomized to one of the two PA interventions (n = 30) given the study aims of assessing PA adherence to both interventions, and baseline predictors of PA adherence, using data from the Polar A360® activity tracker.

Study outcomes

There were two outcomes for the present secondary analysis: (1) the relative adherence to the prescribed PA interventions (% of PA prescription goal met), and (2) the total absolute amount of PA time ≥40% of HRR. Both outcomes were assessed on a weekly basis with the Polar

A360® activity tracker throughout the 12-week intervention. The Polar A360® device provided 1-s heart rate values captured under the "training" application which were converted into total PA time in minutes/week spent within the prescribed heart rate zone or ≥40% of HRR.

Baseline predictors

Baseline predictors of PA adherence were selected based on scientific plausibility [11,12,13,14, 16, 19, 35,36,37,38,39,40,41,42] and assessed prior to randomization. These included age (years) and elapsed time since the completion of adjuvant treatments (days) as demographic and cancer-related measures, respectively.

Health and fitness measures included BMI (kg/m^2), total fat (kg and %), and lean mass (kg) assessed with a dual X-ray absorptiometry (DXA) scan (Hologic® system, Marlborough, MA, USA), and cardiorespiratory fitness (VO_{2max}) assessed with a multistage, sub-maximal Balke treadmill test [43]. Also included were objective measures of sedentary, light, and moderate-vigorous intensity PA time (minutes/week) assessed over 7 days with a waist-worn accelerometer (ActiGraph® GT3X+, ActiGraph LLC, Pensacola, FL, USA) at a sampling rate of 80 Hz and aggregated to 60-s epoch files for analysis by the ActiLife® software (v6.10.2). We used the Actigraph® Vertical Axis calculations [44] to derive PA and sedentary time outcomes from the accelerometry-measured activity counts/minute. The following cut-points were used to define PA time according to intensity and sedentary time: <100 counts/min (sedentary), 100-760 counts/min (light intensity), and >760 counts/min (moderate-vigorous intensity). We chose these cut-points because they were initially calibrated against a broad range of lifestyle and ambulatory activities assessed under free-living conditions [45], and were recently shown to provide more accurate estimates of moderate-vigorous intensity PA time by capturing a broader range of activities under free-living conditions [46]. An accelerometer, rather than an activity tracker, was used to capture PA and sedentary time as study outcomes because this tool provides a blinded assessment of these behaviors (i.e., the participant cannot readily access their PA and sedentary time data), which is particularly important at the baseline time point and for participants in the control group to avoid influencing their PA behaviors. Furthermore, commercially available activity trackers tend to not be as accurate as research-grade accelerometers in capturing PA outcomes, so it is recommended that RCTs continue to use research-grade accelerometers to assess PA and sedentary time as intervention outcomes [47].

We used the Medical Outcomes Study Short Form-12 (SF-12) survey (version 2) [48, 49] to assess self-reported physical and mental health-related quality of life at baseline. The SF-12 contains 12 items which are used to measure 8 domains of health-related quality of life: (1) physical functioning, (2) role-physical, (3) bodily pain, (4), vitality, (5) role-emotional, (6) social functioning, (7) mental health, and (8) general health. The responses on these eight domains can then be used to create two overall scores related to physical health-related quality of life (physical component summary (PCS) and mental health-related quality of life (mental component summary (MCS)) [48, 49]. The PCS and MCS scores were then transformed and calculated according to the SF-12 (version 2) scoring manual to a theoretical range of 0-100, with higher scores indicating higher levels of health-related quality of life [48]. The PCS and MCS scores from the SF-12 (version 2) have shown strong validity when compared to the SF-36 (R squares of 0.91 and 0.94 for the PCS and MCS scores, respectively) and 2-week test-retest

correlations (0.89 and 0.76 for the SF-12 PCS and MCS scores, respectively) [49]. The SF-12 has also shown acceptable Cronbach's α for PCS (0.85) and MCS (0.76) scores [50].

Motivational variables based on the Theory of Planned Behavior were assessed with single-item questions based on a five-point scale, with 5 indicating greatest agreement with the statement [51]. Cronbach's α cannot be calculated for these single-item scales; however, these single-item scales have been commonly used in PA and cancer survivor studies [38, 52,53,54,55,56,57]. The single items asked participants to anticipate the following: (1) how *beneficial* do you think each PA program will be, (2) how *enjoyable* do you think each PA program will be, (3) how much *support* do you think you will receive from friends and family during the PA program, (4) how *motivated* are you to do each PA program, (5) how *difficult* do you think it will be to do each PA program, and (6) how *confident* are you that you can complete each PA program. All participants responded to each question in the context of being prescribed to the lower and higher intensity PA interventions at baseline. However, the present analyses only included the participants' responses to each question that aligned with their assigned PA intervention. For instance, the responses to each of these questions in the context of being assigned to the lower intensity PA intervention were used for participants randomized to this group.

Finally, categorical predictors (breast cancer stage at diagnosis, type of adjuvant treatment(s) received, race, education, and marital status) were also collected at baseline, but were not assessed for relationship with adherence, due to the small and relatively homogenous study sample (i.e., there were only ≈15-20% of participants in any given comparison group).

Statistical analyses

All analyses were performed using SAS (SAS Enterprise Guide Version 7.13 for Linux, SAS Institute Inc.). Participant baseline characteristics and mean PA adherence throughout the interventions were summarized and presented as means (standard deviations) for continuous variables and as counts (percentages) for categorical variables. Differences in descriptive data between the intervention groups were assessed using an analysis of variance test for continuous variables and a chi-square test for categorical variables.

Since the PA adherence variables (relative time in the prescribed HRR zones and total absolute PA time ≥40% of HRR) were not normally distributed, a natural logarithm transformation was used to satisfy modeling assumptions for these outcome variables. No imputation methods were used to handle missing data on PA adherence. Rather, the number of weeks with available PA adherence data (i.e., any heart rate data measured by the Polar A60® activity tracker) for each participant was used to assess their mean adherence to the intervention. This method was considered a valid approach since only six of the 30 participants randomized to both PA intervention groups had missing PA adherence on any given week of the intervention.

Independent *t*-tests were used to assess differences between PA intervention groups in the number of intervention weeks with activity tracker data, the relative amount of time that participants had the "training" application turned on during these intervention weeks (available heart rate data measured with the Polar A360® in minutes/week divided by 10,080 possible minutes in 1 week), and the relative amount of recorded HR time spent <40% HRR (i.e., HR data

not recorded as PA time). For the primary aim, a linear mixed effect model was used to predict the natural logarithm of PA adherence, with randomization group, time (intervention weeks 1-12) and the interaction of these factors included as fixed effects, and participant included as a random effect. For the secondary aim, the natural logarithm of relative and absolute mean weekly PA adherence were added to a linear model that included each baseline predictor interchangeably and randomization group as a covariate. Effect modification analyses of baseline predictors by randomization group were not conducted because of the relatively small sample size (n = 15 participants per group) and comparability of study outcomes (relative rather than absolute adherence to the prescribed PA intervention) between groups. Given the natural logarithm transformations used, the results from these analyses are presented as $\mathbf{e^{\beta}}$ and can be interpreted as the multiplicative factor by which geometric mean PA adherence is predicted to change for every one unit change in the baseline predictor. Specifically, values of $e^{\beta} <1$, $e^{\beta} = 1$, and $e^{\beta} >1$ indicate negative, null, and positive associations between a baseline predictor and PA adherence, respectively. A greater degree of change (or deviation from 1) indicates that there is a greater decrease ($e^{\beta} <1$) or increase ($e^{\beta} >1$) in PA adherence for every one unit increase in the tested baseline predictor. The associated change in PA adherence from each model was also calculated as a percentage. In this instance, if e^{β} is ≥1, percent change is calculated as $100 \times (e^{\beta} - 1)$, and if e^{β} is <1, percent change is calculated as $-100 \times (1 - e^{\beta})$. Statistical significance was set at $P <0.05$.

Results

A summary of participant characteristics and mean PA adherence rates are presented in Table 1. There were no statistically significant differences in demographics and cancer-related measures between groups. There was a statistically significant difference in mental component scores between groups, with the control group having significantly lower scores at baseline compared to both the higher ($P = 0.01$) and lower ($P = 0.01$) intensity PA groups. Participants randomized to the lower intensity PA group also expressed that this intervention would be more enjoyable compared to participants randomized to the higher intensity PA group ($P = 0.047$). No other statistically significant differences between groups in health and fitness markers, as well as Theory of Planned Behavior PA motivational variables, were noted.

As previously reported [31], Polar A360® heart rate data were available for participants randomized to the lower and higher intensity PA groups on 11.7 ± 0.6 weeks and 11.4 ± 1.4 weeks, respectively ($P = 0.40$). The amount of available heart rate data from the Polar A360® captured with the "training application" (i.e., the amount of time the "training application" was turned on the activity tracker) throughout the intervention was similar between intervention groups (lower intensity PA group: 50.5% ± 6.3% versus higher intensity PA group: 47.2% ± 13.0%; $P = 0.38$). Furthermore, the relative amount of recorded time spent <40% HRR (i.e., HR data not recorded as PA time) was similar between groups (lower intensity PA group: 77.0% ± 12.8% versus higher intensity PA group: 79.9% ± 10.6%; $P = 0.52$).

Table 1. Participant characteristics (*n*=45) and mean physical activity adherence (*n*=30) in the Breast Cancer & Physical Activity Level (BC-PAL) Trial. Calgary, Alberta, Canada, 2017-2018

Measure	Control group (*n*=15) [a]	Higher intensity PA group (*n*=15)[a]	Lower intensity PA group (*n*=15)[a]	*P* value[b]	Combined PA randomization groups (*n*=30)[a]
Demographic measures					
Age (years)	60.1 (8.5)	57.7 (10.4)	57.7 (9.3)	0.73	57.7 (9.6)
Ethnicity: Caucasian	10 (66.7%)	13 (86.7%)	12 (80.0%)	0.41	25 (83.3%)
Education: beyond high school	13 (86.7%)	12 (80.0%)	12 (80.0%)	0.86	24 (80.0%)
Married or common law	11 (73.3%)	13 (86.7%)	11 (73.3%)	0.60	24 (80.0%)
Cancer-related measures					
Cancer treatment: radiation	12 (80.0%)	12 (80.0%)	12 (80.0%)	1.00	24 (80.0%)
Cancer treatment: hormone	11 (73.3%)	13 (86.7%)	12 (80.0%)	0.66	25 (83.3%)
Cancer treatment: chemotherapy	11 (73.3%)	12 (80.0%)	13 (86.7%)	0.66	25 (83.3%)
Breast cancer stage: I	6 (40.0%)	4 (26.7%)	7 (46.7%)	0.25	11 (36.7%)
Breast cancer stage: II	6 (40.0%)	10 (66.7%)	4 (26.7%)		14 (46.7%)
Breast cancer stage: III	3 (20.0%)	1 (6.7%)	4 (26.7%)		5 (16.7%)
Time since end of treatment (days)	1125 (446)	1529 (1370)	888 (621)	0.16	1209 (1095)
Health and fitness					
BMI (kg/m^2)	27.7 (8.8)	31.1 (8.4)	28.7 (4.9)	0.46	29.9 (6.8)
VO_{2max} (mL/kg/min)	17.9 (6.3)	17.2 (8.3)	19.8 (7.9)	0.62	18.5 (8.1)
Body fat (%)	45.5 (6.4)	47.1 (6.2)	45.2 (7.1)	0.71	46.1 (6.6)
Body fat (kg)	33.0 (19.5)	40.0 (14.9)	34.1 (10.5)	0.42	37.1 (13.0)
Lean body mass (kg)	34.7 (8.7)	40.8 (6.8)	37.5 (3.8)	0.06	39.2 (5.7)
SF-12 physical component score	47.9 (7.2)	46.1 (6.3)	46.5 (4.2)	0.72	46.3 (5.2)
SF-12 mental component score	44.2 (15.6)	55.0 (7.1)	54.6 (6.7)	0.01	54.8 (6.8)
Sedentary time (min/week)	3990 (546)	4074 (672)	4200 (630)	0.72	4116 (630)
Light intensity PA time (min/week)	1554 (504)	1512 (546)	1806 (462)	0.25	1638 (546)
Moderate-vigorous intensity PA time (min/week)	630 (420)	630 (294)	714 (294)	0.75	672 (294)
Theory of Planned Behavior PA motivational variables[c]					
Intervention benefit	NA	4.4 (0.7)	4.1 (1.1)	0.43	4.3 (0.9)
Intervention enjoyability	NA	3.9 (0.9)	4.5 (0.6)	0.047	4.2 (0.8)
Social support	NA	3.5 (0.9)	3.9 (1.0)	0.26	3.7 (1.0)
Intervention motivation	NA	4.3 (1.1)	3.8 (0.9)	0.21	4.0 (1.0)
Intervention difficulty	NA	4.2 (1.0)	3.8 (1.5)	0.40	4.0 (1.3)
Intervention confidence	NA	4.5 (0.7)	4.1 (1.5)	0.35	4.3 (1.2)
PA adherence outcomes					
Time in prescribed HRR zone (min/week)	NA[d]	154.2 (91.2)	981.9 (490.1)		NA[e]
Percent of prescribed time in zone (%)	NA[d]	102.8 (60.8)	327.3 (163.4)		215.0 (166.4)
Time above 40% HRR (min/week)	NA[d]	871.4 (395.2)	1223.9 (756.0)		1047.6 (619.2)

BMI body mass index; *HRR* heart rate reserve; *PA* physical activity; *SF-12* Short Form-12; *VO_{2max}* maximum volume of oxygen consumption; *min* minutes

[a]Categorical variables are presented as counts (percentages), while continuous variables are presented as means (standard deviations)

[b]Differences in baseline variables were compared between the 3 intervention groups for all variables, except the Theory of Planned Behavior PA motivational variables which were compared between the 2 PA intervention groups

[c]The participants' responses to each of these motivational variables were chosen based on their assigned PA intervention. For instance, the responses to being assigned to the lower intensity PA intervention were used for

participants randomized to this group. Note that no responses are provided for the control group participants because they were not assigned to either of the PA interventions

[d]PA adherence outcomes were not assessed in control group participants because these participants did not receive a Polar A360® activity tracker as part of the intervention

[e]The combined results were not generated because the prescribed volume of physical activity given to each group was different (i.e., 150 versus 300 min/week)

The accelerometry data captured at baseline and post-intervention in all intervention groups were previously reported [31]. In brief, these results revealed a statistically significant increase in total, moderate-vigorous and light intensity PA time, coupled with a decrease in sedentary and sleep time, in the lower intensity PA group [31]. Mean increases in total and moderate-vigorous intensity PA time were also noted in the higher intensity PA group, whereas no statistically significant changes in PA of all intensities, sedentary, and sleep time were noted in the control group [31].

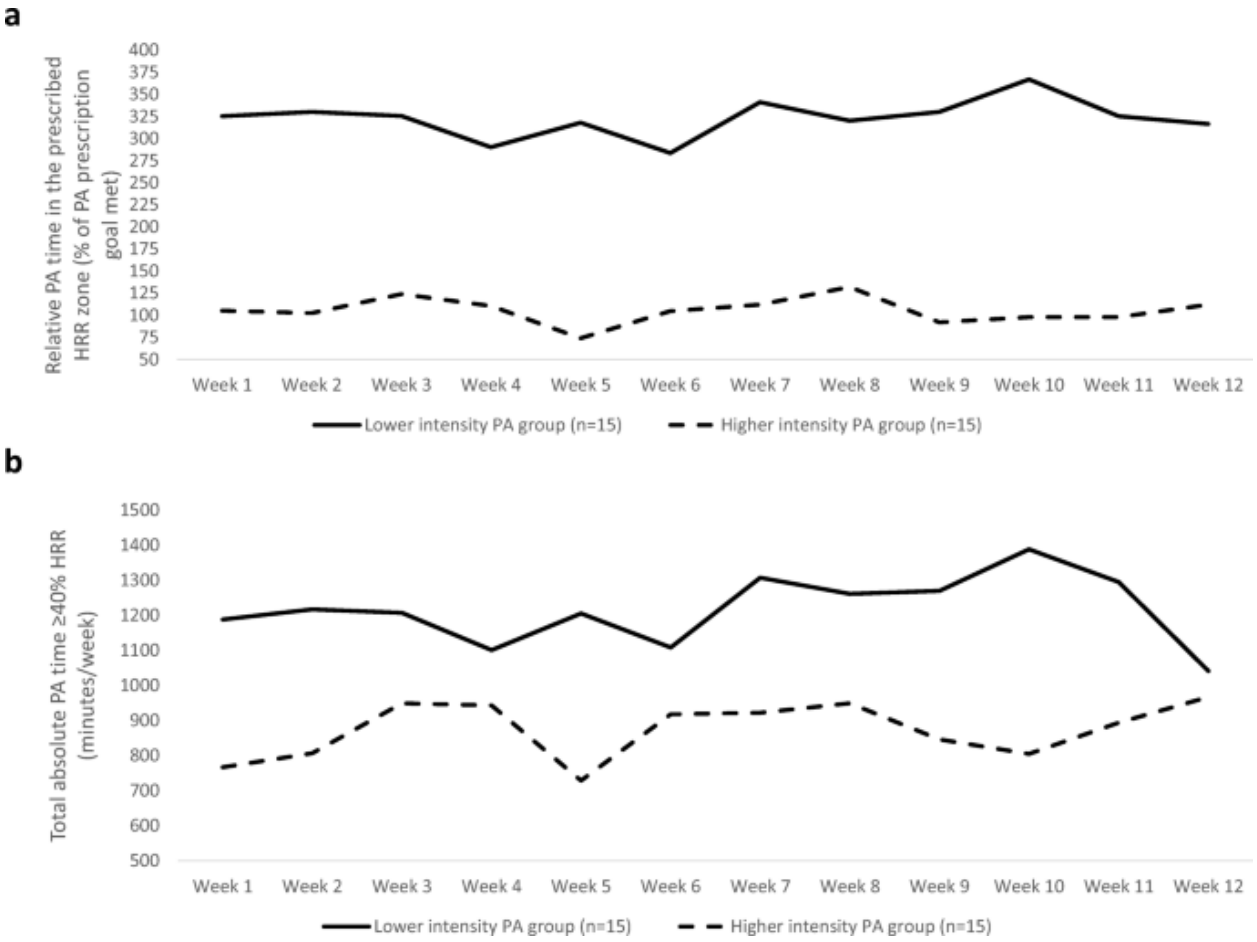

Fig. 1. The changes in a relative PA adherence to the prescribed HRR zones (% of PA prescription goal met) and b total absolute PA time ≥40% of HRR (minutes/week) in the lower and higher intensity PA groups over time from the Breast Cancer & Physical Activity Level (BC-PAL) Trial (*n*=30). Calgary, Alberta, Canada, 2017-2018. Note: HRR, heart rate reserve; PA, physical activity

Figure 1 illustrates the changes in PA adherence variables (relative time in the prescribed HRR zones and total absolute PA time ≥40% of HRR) in both intervention groups over time, and Table 2 presents the linear mixed effect model results for the effects of randomization group, time and randomization group*time interaction on PA adherence. Participants in the lower intensity PA group had a significantly greater geometric mean relative amount of time in the prescribed PA zone by a factor of 3.12 (95% CI: 1.97, 4.95) compared to the higher intensity PA group, or approximately a 312% greater mean PA adherence. The lower intensity PA group also had a greater geometric mean absolute PA time ≥40% of HRR by a factor of 1.54 (95% CI of 0.79, 3.02), or approximately 154% higher than the higher intensity PA group, although this group difference was not statistically significant. No statistically significant effects of time (weeks 1-12) or time*randomization group interaction were noted.

Table 2. The effects of randomization group (lower versus higher intensity PA prescription), time (intervention weeks 1-12), and randomization group*time interaction on physical activity adherence in the Breast Cancer & Physical Activity Level (BC-PAL) Trial (*n*=30). Calgary, Alberta, Canada, 2017-2018

	Randomization group[a]			**Time**			**Time * randomization group interaction**		
Outcome	**e^{β} (95% CI)[d]**	**Associated change in PA adherence[e]**	***P* value**	**e^{β} (95% CI)[d]**	**Associated change in PA adherence[e]**	***P* value**	**e^{β} (95% CI)[d]**	**Associated change in PA adherence[e]**	***P* value**
Relative time in prescribed HRR zone (%)[b,c]	3.12 (1.97, 4.95)	+312%	<0.01	0.97 (0.93, 1.02)	−3%	0.22	1.04 (0.98, 1.10)	+4%	0.19
Absolute time ≥40% HRR[b,c]	1.54 (0.79, 3.02)	+154%	0.20	1.02 (0.96, 1.09)	+2%	0.51	0.99 (0.92, 1.07)	−1%	0.78

[a]The higher intensity PA group is modeled as the reference group

[b]Log-transformed outcomes were used. Beta coefficients and associated confidence intervals were back-transformed (i.e., the values presented are e^{β})

[c]Model takes the form of 'log (PA adherence) = $\beta_0 + \beta_1$ (randomization group) + β_2 (intervention week) + β_3 (randomization group*intervention week) + b_j (participant). Randomization group, intervention week, and randomization group*intervention week interaction are fixed effects, and participant is a random effect

[d]Values of $e^{\beta} < 1$, $e^{\beta} = 1$, and $e^{\beta} > 1$ indicate negative, null, and positive associations between a baseline predictor and physical activity adherence, respectively. A greater degree of change (or deviation from 1) indicates that there is a greater decrease ($e^{\beta} < 1$) or increase ($e^{\beta} > 1$) in physical activity adherence for every one unit increase in the tested baseline predictor

[e]If e^{β} is ≥1, percent change is calculated as $100 \times (e^{\beta} - 1)$, and if e^{β} is <1, percent change is calculated as $-100 \times (1 - e^{\beta})$

Results on the associations between baseline predictors and PA adherence are presented in Table 3. Access to support was inversely associated with the relative amount of time within the prescribed PA zones (e^{β}= 0.83, 95% CI: 0.72, 0.97) and absolute PA time ≥40% of HRR (e^{β}= 0.82, 95% CI: 0.71, 0.93). Baseline VO_{2max} was also inversely associated with the relative amount of time within the prescribed PA zones (e^{β}= 0.98, 95% CI: 0.95, 0.99). Lastly, there were no statistically significant associations between age, baseline body composition, baseline PA and sedentary time, self-reported physical and mental quality of life, and elapsed time since end of adjuvant treatments with PA adherence.

Table 3. The associations between continuous baseline predictors and physical activity adherence in the Breast Cancer & Physical Activity Level (BC-PAL) Trial (*n*=30). Calgary, Alberta, Canada, 2017-2018

	Relative time in prescribed HRR zone (%)[a]			Absolute time ≥40% HRR[a]		
Baseline predictor	e^{β} (95% CI)[b]	*P* value	Associated adherence change[c]	e^{β} (95% CI)[b]	*P* value	Associated adherence change[c]
Intervention benefit[d]	0.923 (0.732, 1.164)	0.48	−7.7%	0.947 (0.759, 1.182)	0.62	−5.3%
Intervention enjoyability[d]	0.857 (0.688, 1.068)	0.16	−14.3%	0.931 (0.752, 1.154)	0.50	−6.9%
Social support[d]	0.834 (0.719, 0.968)	0.02	−16.6%	0.815 (0.712, 0.932)	0.004	−18.5%
Intervention motivation[d]	0.849 (0.659, 1.095)	0.20	−15.1%	0.940 (0.734, 1.204)	0.61	−6.0%
Intervention difficulty[d]	1.032 (0.852, 1.250)	0.74	+3.2%	1.010 (0.841, 1.212)	0.91	+1.0%
Intervention confidence[d]	0.739 (0.540, 1.011)	0.06	−26.1%	0.917 (0.668, 1.258)	0.58	−8.3%
Age (years)	1.010 (0.988, 1.032)	0.37	+1.0%	1.010 (0.990, 1.031)	0.33	+1.0%
BMI (kg/m^2)	1.014 (0.983, 1.045)	0.37	+1.4%	1.012 (0.983, 1.042)	0.42	+1.2%
VO_{2max} (mL/kg/min)	0.975 (0.952, 0.999)	0.04	−2.5%	0.982 (0.959, 1.006)	0.13	−1.8%
Body fat (%)	0.999 (0.967, 1.031)	0.94	−0.1%	0.986 (0.957, 1.015)	0.32	−1.4%
Body fat (kg)	1.004 (0.988, 1.021)	0.58	+0.4%	1.002 (0.986, 1.018)	0.81	+0.2%
Lean body mass (kg)	1.009 (0.971, 1.049)	0.65	+0.9%	1.024 (0.988, 1.061)	0.18	+2.4%
Sedentary time (h/day)	0.987 (0.859, 1.134)	0.85	−1.3%	1.006 (0.881, 1.147)	0.93	+0.6%
Light intensity PA time (h/day)	1.008 (0.848, 1.199)	0.93	+0.8%	0.989 (0.839, 1.166)	0.90	−1.1%
Moderate-vigorous intensity PA time (h/day)	1.017 (0.749, 1.381)	0.91	+1.7%	1.075 (0.805, 1.435)	0.61	+7.5%
SF-12 physical component score	0.990 (0.951, 1.031)	0.62	−1.0%	0.982 (0.946, 1.020)	0.35	−1.8%
SF-12 mental component score	1.014 (0.983, 1.046)	0.37	+1.4%	1.028 (0.999, 1.057)	0.06	+2.8%
Time since end of treatment (days)	1.00 (1.00, 1.00)	0.51	+0.0%	1.000 (1.000, 1.000)	0.31	+0.0%

BMI body mass index; *CI* confidence interval; *HRR* heart rate reserve; *PA* physical activity; *SF-12* Short Form-12; *VO_{2max}* maximum volume of oxygen consumption

[a]Log-transformed outcomes were used. Beta coefficients and associated confidence intervals were back-transformed (i.e., the values presented are e^{β})

[b]Values of e^{β} <1, e^{β} = 1, and e^{β} >1 indicate negative, null, and positive associations between a baseline predictor and physical activity adherence, respectively. A greater degree of change (or deviation from 1) indicates that there is a greater decrease (e^{β} <1) or increase (e^{β} >1) in physical activity adherence for every one unit increase in the tested baseline predictor

[c]If e^{β} is ≥1, percent change is calculated as 100 × (e^{β} − 1), and if e^{β} is <1, percent change is calculated as −100 × (1 − e^{β})

[d]The participants` responses to each of these motivational variables were chosen based on their assigned PA intervention. For instance, the responses to being assigned to the lower intensity PA intervention were used for participants randomized to this group

Discussion

The first aim of this secondary analysis from the BC-PAL Trial was to assess adherence to a lower versus higher intensity PA prescription using a Polar A360® wearable activity tracker in breast cancer survivors. The second aim was to assess the strength of the associations between baseline characteristics with mean PA adherence in these participants. Both groups had high amounts of weekly PA ≥40% of HRR. Although no statistically significant differences in PA adherence were noted across time, participants randomized to the lower intensity PA group did average over 3 times the relative amount of PA time within the prescribed HRR zone compared to the higher intensity PA group. Lastly, lower social support and cardiorespiratory fitness at baseline were associated with higher PA adherence.

Participants randomized to both PA interventions adhered well to wearing the Polar A360® device and to using the "training" application. On average, PA adherence data were available for >11 weeks of the 12-week intervention, and participants in both groups turned on the "training application" for ≥45% of the total time throughout the intervention. Adherence to activity tracker use in the present study is similar to the levels found in other intervention studies that have used commercially available activity trackers to monitor PA adherence, defined as the number of valid days or weeks of wear time [18,19,20,21,22,23,24,25,26,27,28,29,30]. Only two of these studies used non-Fitbit activity trackers as part of their intervention [29, 30]; the first [30] used Withings Pulse® activity trackers because it interfaced with the same platform as a wireless body weight scale provided to breast cancer survivors to prevent weight gain, and the second [29] used the Jawbone Up24® activity tracker to promote PA behavior change in adults with overweight or obesity. One RCT in breast cancer survivors did use a Polar® activity tracker (Polar M400®) as part of a combined activity tracker + social media intervention to promote PA behavior change; however, the mean frequency and duration of use for the activity tracker were only measured by self-report at the end of the intervention and no data captured by the Polar® activity tracker were discussed in the manuscript [58]. Therefore, this study is the first to use a Polar A360® activity tracker to promote PA behavior change in breast cancer survivors and describe the PA adherence data captured with this tracker. This RCT is also the first trial to use the heart rate monitoring feature of the activity tracker to prescribe two different PA interventions and monitor PA adherence based on heart rate data.

Intervention trials that have reported mean PA levels were based on data collected by a Fitbit® device, and primarily focused on steps/day and/or moderate-vigorous intensity PA time quantified by the device's proprietary algorithms as study outcomes [18,19,20,21,22,23,24, 59]. Specifically, Wang et al. [59] reported a statistically significant group by time interaction for changes in steps/day, "fairly/very active" minutes and "total active" minutes captured by the Fitibit One®, with the intervention group having on average higher PA levels over the 6-week intervention, which was mainly driven by large changes in PA levels from baseline to week 1 but not maintained from weeks 2 to 6. Hartman et al. [20] also reported statistically significant changes in moderate-vigorous intensity PA time assessed with the Fitbit One® throughout the 12-week intervention, with moderate-vigorous intensity PA time being highest during weeks 3 and 9 and lowest during weeks 5 and 12 of the intervention. Conversely, Gell et al. [22] reported no statistically significant changes in moderate-vigorous intensity PA time throughout the intervention in the experimental (Fitbit One® + health coaching follow-up messages) and control (Fitbit One® only) groups; however, post hoc analyses revealed that the experimental group had more moderate-vigorous intensity PA minutes compared to the control group during 4 of the 8 intervention weeks. Lastly, a recent meta-analysis assessed the impact of RCTs that used wearable activity trackers to promote PA behavior change in adults living with cardiometabolic disease(s), and reported a statistically significant greater increase in steps/day and moderate-vigorous intensity PA time in the intervention group compared to the control group [60].

In the present study, there were no statistically significant changes in PA adherence over time; however, relative adherence to the lower intensity PA prescription (300 min/week of PA at an intensity of 40-59% of HRR) was approximately 312% greater than relative adherence in the higher intensity PA group (150 min/week of PA at an intensity of 60-80% of HRR).

Furthermore, both intervention groups achieved high amounts of weekly PA time ≥40% of HRR throughout the intervention (>800 min/week). The PA prescriptions in the present study were based on 2018 PA guidelines from the ACSM, which recommends 150-300 min/week of moderate-vigorous intensity (40-89% of HRR) PA for overall health [4, 61]. The PA data captured with the "training" application in the present study are high compared to these guidelines; however, they do align with mean moderate-vigorous intensity PA times (~630-868 min/week) measured in the National Health and Nutrition Examination Survey (NHANES) 2003–2006 [62] and the UK Biobank [63] cohorts with accelerometry and/or doubly labeled water. It is important to note that the comparison of data between these studies should be interpreted with caution since the use of different measurement tools (e.g., commercially available activity trackers, research-grade accelerometers, doubly labeled water), settings (e.g., in-lab versus free-living), and cut-off points (i.e., different algorithms) can lead to differences in the PA levels reported by different studies [46]. Indeed, our results cannot be directly compared to other studies that have used Fitbit® devices [18,19,20,21,22,23,24, 59] because different brands of commercially available activity trackers use their own proprietary algorithms to assess PA levels [64], and they tend not to be equivalent to one another [47]. Furthermore, we chose to use heart rate data captured by the "training" application of the Polar A360®, rather than the PA levels reported by the Polar Flow® platform, to assess adherence to our prescribed PA interventions because we used HRR calculations embedded within the "training" application to deliver the PA interventions. Therefore, future studies using the heart rate tracking features of activity trackers are needed to provide data for comparison.

We also noted an inverse association between access to support from friends and family with relative PA adherence to the prescribed HRR zone and absolute PA time ≥40% of HRR. These findings suggest that lower support from friends and family were associated with greater adherence to the prescribed PA interventions, which does not corroborate previous findings in breast cancer [13, 19, 40] and other [12, 65,66,67,68] populations. Furthermore, a recent systematic review reported that greater PA adherence in cancer survivors is associated with less extensive surgery, low alcohol consumption, higher previous PA adherence/participation, and knowledge and skills about PA, as well as receiving family support and feedback from trainers [42]. We also noted an inverse association between baseline VO_{2max} and relative PA adherence to the prescribed HRR zone, suggesting that lower baseline VO_{2max} is associated with greater PA adherence. Once again, our current results do not corroborate previous findings which have reported greater PA adherence in individuals with higher baseline VO_{2max} [16, 38, 39, 69, 70]. Only one other study to date has assessed the association between baseline predictors of PA adherence to a walking intervention that included a wearable activity tracker [19]. This study reported no statistically significant associations between different constructs of social support and physical function measured with the Short Physical Performance Battery at baseline with PA adherence [19]. It is unclear why our results differ from those reported by Nyrop et al. [19]; hence, additional studies focused on assessing the association between baseline predictors of PA adherence in trials that have included commercially available activity trackers are needed to contribute to this literature.

Strengths of the present study include the use of the Polar A360® activity tracker to assess adherence throughout the 12-week intervention and the inclusion of many physical and psychosocial measures of baseline health. Study limitations include the small and relatively

homogenous sample size which limited our ability to include categorical baseline predictors in our analyses. Although the HRR equation was shown to be one of the most accurate methods for PA intensity prescription in breast cancer patients and survivors [71], a variety of physiological factors (e.g., stress, fluid levels, medication use) may lead to variations in heart rate that are not related to PA throughout the intervention, and would consequently impact our PA adherence data. Furthermore, the study exercise physiologists only advised participants to achieve the prescribed PA minutes on a weekly basis, meaning that some participants wore their activity tracker every day of the week, whereas others accumulated all of their PA minutes over a few days and removed it on the other days of the week. Therefore, we were only able to estimate activity tracker use as the number of valid weeks, rather than the number of valid days, with heart rate data. Although some participants had the "training" application turned on for an extended period of time (e.g., all day/during waking hours), the majority of the recorded HR data that was <40% HRR (i.e., not recorded as PA time) was high (~77-80%) and similar between groups. Despite these results, it is advised that future studies use consistent messaging when advising participants to wear their activity trackers and use its features such as the "training application". It is also advised that future studies use newer models of Polar activity trackers that allow for continuous HR monitoring. We only used single items to measure motivational variables based on the Theory of Planned Behavior to reduce participant burden in completing this questionnaire. This approach is not as accurate as using multi-item assessments of these motivational variables [52]. Lastly, the limited variability in several of our baseline predictor variables, as well as the high values for the Theory of Planned Behavior motivational variables, reduces the possibility of identifying statistically significant associations between variables and may have contributed to our null and sporadic findings.

In summary, both intervention groups had high weekly adherence to wearing the activity tracker, which recorded high amounts of weekly PA ≥40% of HRR. Participants randomized to the lower intensity PA group averaged over 3 times the relative amount of PA within the prescribed HRR zone compared to the higher intensity PA group. However, there were no statistically significant differences across time in PA adherence. Lower social support and cardiorespiratory fitness at baseline were also associated with higher PA adherence.

The recent rise in popularity of commercially available activity trackers provides an opportunity to use these devices to promote PA behavior change, as well as to continuously and objectively measure PA levels as an indicator of intervention adherence [47]. The use of activity trackers may be particularly relevant to promote PA participation in cancer survivors given the relatively low levels of PA that have been recently reported in this population [72,73,74,75]. Indeed, cancer survivors have expressed an interest in using activity trackers to self-monitor PA [76,77,78]. To our knowledge, the present study is the first to use a commercially available activity tracker to provide two different PA prescriptions and use heart rate values captured by this device to assess PA adherence to these interventions. Hence, the present results contribute to our initial understanding of how commercially available activity trackers can be used to prescribe different PA intensities based on HRR, and use the heart rate monitoring features of the device to monitor PA adherence. Additional trials using the heart rate tracking features of activity trackers to prescribe and monitor PA are needed to corroborate our findings. Furthermore, additional studies are needed to explore baseline predictors, facilitators, and

barriers to sustained activity tracker use to promote PA behavior change and intervention adherence in cancer survivors.

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Ethics declarations

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Health Research Ethics Board of Alberta – Cancer Committee (HREBA.CC-16-0711).

Consent to participate

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

Conflict of interest

The authors declare no competing interests.

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