Measuring and understanding adherence in a home-based exercise intervention during chemotherapy for early breast cancer

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Abstract

Purpose Ensuring and measuring adherence to prescribed exercise regimens are fundamental challenges in intervention studies to promote exercise in adults with cancer. This study reports exercise adherence in women who were asked to walk 150 min/week throughout chemotherapy treatment for early breast cancer. Participants were asked to wear a Fitbit^{TM} throughout their waking hours, and Fitbit steps were uploaded directly into study computers.

Methods Descriptive statistics are reported, and both unadjusted and multivariable linear regression models were used to assess associations between participant characteristics, breast cancer diagnosis, treatment, chemotherapy toxicities, and patient-reported symptoms with average Fitbit steps/week.

Results Of 127 women consented to the study, 100 had analyzable Fitbit data (79%); mean age was 48 and 31% were non-white. Mean walking steps were 3956 per day. Nineteen percent were fully adherent with the target of 6686 steps/day and an additional 24% were moderately adherent. In unadjusted analysis, baseline variables associated with *fewer* Fitbit steps were: non-white race ($p = 0.012$), high school education or less ($p = 0.0005$), higher body mass index ($p = 0.0024$), and never/almost never drinking alcohol ($p = 0.0048$). Physical activity variables associated with *greater* Fitbit steps were: pre-chemotherapy history of vigorous physical activity ($p = 0.0091$) and higher self-reported walking minutes/week ($p < 0.001$), and higher outcome expectations from exercise ($p = 0.014$). Higher baseline anxiety ($p = 0.03$) and higher number of chemotherapy-related symptoms rates "severe/very severe" ($p = 0.012$) were associated with fewer steps. In multivariable analysis, white race was associated with 12,146 greater Fitbit steps per week ($p = 0.004$), as was self-reported walking minutes prior to start of chemotherapy ($p < 0.0001$).

Conclusions Inexpensive commercial-grade activity trackers, with data uploaded directly into research computers, enable objective monitoring of home-based exercise interventions in adults diagnosed with cancer. Analysis of the association of walking steps with participant characteristics at baseline and toxicities during chemotherapy can identify reasons for low/non-adherence with prescribed exercise regimens.

Keywords Exercise · Chemotherapy · Breast cancer · Intervention adherence

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Introduction

Women diagnosed with breast cancer are often sedentary at diagnosis [1, 2] and many reduce their physical activity during and after breast cancer treatment [3–5]. Achieving and maintaining guideline-recommended levels of physical activity (150 min/week) [6, 7] can be especially challenging during chemotherapy [8, 9]. Over the past several decades, a

large and growing number of studies have tested the impact of exercise in adults diagnosed with cancer, especially in women diagnosed with breast cancer [10, 11]. Most of these studies have entailed exercise under *supervised* conditions, at specified times and places and with research staff present to ensure fidelity to prescribed exercise regimens. Over the past decade, however, there has been growing interest in *home-based* intervention studies, where participants meet the study's exercise requirements at times and places of their choosing, and without direct research staff support and supervision. For physical activity, as in other behavior modification interventions, encouraging and ensuring *exercise adherence* is a fundamental challenge. In fact, a recent Cochrane Review of exercise in women receiving adjuvant therapy for breast cancer concluded that in 22 of the 32 studies included in the review, reported exercise adherence was so low that the review authors concluded that the results from these studies were at a high risk for bias [12]. For home-based intervention studies, an additional challenge beyond actual exercise adherence is the *measurement* of adherence in the absence of supervisory research staff to observe participants as they complete their exercise regimens.

In lieu of direct observation, one option for independent assessment of unsupervised activity levels is to ask participants to wear an accelerometer that provides highly accurate measures of movement duration and intensity [13]. Examples of research-grade accelerometers include ActiGraph, Actiheart, Actiwatch, GENEActiv, and AticPaL [14] which are generally worn for brief observation periods of 1 or 2 weeks, although newer technologies using adhesive patches are designed for longer observation. Another option is the growing variety of commercially available fitness trackers that are less expensive and comfortable to wear over several weeks or months. Examples of these activity trackers include products offered by Apple Watch, Fitbit, Jawbone, Microsoft Band, Samsung Gear Fit, Garmin, and Polar [14–16]. Commercial devices have been strongly validated as a measure of steps per minute/hour/day [16–18]. An important advantage of both research-grade accelerometers and commercial-grade fitness trackers is that data collected through these devices can be uploaded directly into research databases for independent monitoring of participant activity levels and easy access for data analysis for reports and manuscripts [19]. There is a need and an opportunity to increase the use of validated activity trackers for independent assessment of adherence to home-based physical activity interventions through direct uploading of tracker data. There is also a need for detailed reporting on how adherence is defined a priori and measured and for the identification of barriers and facilitators to activity adherence.

Here, we report initial findings from a longitudinal, observational study of a home-based intervention in women diagnosed with early stage breast cancer who were given a Fitbit Zip^{TM} and asked to walk for exercise throughout their chemotherapy, with Fitbit data uploaded directly into research computers. We provide a priori definition of adherence, and investigate patient level predictors of adherence to walking the intervention-required 150 min/week. For our analysis, we draw on the Physical Activity Adherence Model (PAAM) [20] which posits that baseline physical (age, body mass index, breast cancer diagnosis, and treatment), psychological (anxiety, depression, self-efficacy, outcome expectations), and social variables (social support, social activity), as well as history of previous physical activity, activities of daily living, and adverse events during treatment (chemotherapy toxicities, patient-reported symptoms) may be predictive of physical activity adherence during chemotherapy treatment.

Participants and methods

This study was reviewed and approved by the University of North Carolina (UNC) at Chapel Hill Lineberger Comprehensive Cancer Center (LCCC) Protocol Review Committee and the UNC Institutional Review Board (IRB).

Study participants

The investigation reported here is part of a larger parent study to assess the impact of a walking intervention during breast cancer chemotherapy on biomarkers and patient-reported outcomes (6-month data collection for main results is still underway) (NCT02167932). For the parent study, we recruited women age 21–64 diagnosed with histologically confirmed early stage breast cancer (Stage I–III) who were about to start adjuvant or neoadjuvant chemotherapy (a companion study of breast cancer patients age 65 and older is still accruing participants, NCT02328313). There were no eligibility restrictions with regard to physical activity prior to breast cancer diagnosis; patients could be either sedentary or active. Research staff asked treating clinicians if patients were able to perform moderate-intensity physical activity and whether there were any comorbidity that would advise against participation in the study. Clinician-approved patients were approached during a clinic visit prior to the start of chemotherapy, informed of the study, and invited to participate by providing written informed consent.

The intervention

All consented patients participated in the same physical activity intervention. Participants were asked to walk safely and comfortably at a pace that was sustainable throughout their chemotherapy treatment, with no specific instructions

about walking intensity. They were asked to aim for 150 min a week in any time increments they preferred (such as 10, 20, or 30 min at a time). Participants received a Fitbit Zip™ (Fitbit Inc., San Francisco CA) that they were instructed to wear during all waking hours. A Fitbit account (www.fitbit.com) was set up at study enrollment, and Fitbit data was uploaded directly into the research database during regularly scheduled chemotherapy treatments. Participants also received a 1-page "Walking during Chemotherapy" motivational flyer, a copy of a Walk with Ease workbook [21] with tips for starting and sustaining self-directed walking, and a printed walking exercise log to record daily minutes of walking for leisure, pleasure, or exercise.

Both the Fitbits and walking logs were considered important components of the intervention. Participants could see their daily activity levels on their Fitbit, which allowed them to monitor and self-regulate their physical activity [22]. Participants could also self-assess how their activity levels affected their quality of life, such as fatigue, sleep quality, and joint pain or stiffness. This highly personalized feedback was important to the intervention because it can improve the study participant's self-efficacy for exercise [23] and their outcome expectations from exercise [24] which, in turn, may encourage intervention adherence. Daily activity logs can be similarly motivational and educational [25].

Definition of walking adherence

In adult women, 5000 steps per day or 35,000 steps per week are considered a sedentary lifestyle [26]. We used this as the *baseline minimum steps* without the additional walking requested in our intervention. Prior studies of women diagnosed with breast cancer have estimated baseline (pre-treatment) steps ranging from 5437 to 6907 per day [27–29]. To estimate the number of steps to achieve *the additional 150 min* of walking/week requested for our intervention, we assumed a comfortable walking pace for women age 65 or younger at 60 steps/minute (well below the "moderate" walking rate of 100 steps/minute [30]) and multiplied this by 150 min to determine 9000 steps/week. Adding sedentary lifestyle (35,000 steps/week) to interventional walking (9000 steps/week), we defined "walking adherence" as 44,000 steps per week or on average 6286 steps/day.

Measures

Walking activity

Fitbit steps were uploaded during chemotherapy visits and summed by week. Self-reported physical activity was also collected at baseline (pre-chemotherapy) using two questions: (1) how many days a week do you go for a walk for at least 10 min, for any reason, in and around your neighborhood or elsewhere and (2) how much time do you usually spend per day when you go for a walk in or around your neighborhood or elsewhere. The behavioral risk factor surveillance system (BRFSS) health behaviors questionnaire [31] was administered at baseline to inquire about engagement in vigorous physical activity for at least 10 min that causes heavy sweating or large increases in heart rate or breathing—number of times per week and number of minutes each time (this questionnaire also includes items about smoking history and alcohol use).

Function/physical performance

At baseline, participants were assessed using three measures: physician-assessed and patient-reported Karnofsky performance status (KPS) [32], Timed Up and Go (TUG) test [33], and short physical performance battery (SPPB) [34], which includes repeated chair stands, balance testing, and 8-foot walk to derive a summary score.

Patient-reported measures

At baseline, participants completed questionnaires pertaining to their quality of life: functional assessment of cancer therapy-breast (FACT-B Version 4) [35], functional assessment of chronic illness therapy-fatigue (FACIT-F Version 4) [36], mental health index-13 (MHI-13) [37], medical outcomes survey (MOS) physical function [38], instrumental activities of daily living (IADL) [39], MOS social support [40], and MOS social activity [41]. Participants also completed questionnaires pertaining to their outcome expectations from exercise (OEE) [42] and perceived self-efficacy for fatigue self-management (PSEFSM) [43].

Chemotherapy toxicities

Research staff reviewed the electronic medical records (EMR) of participants throughout their chemotherapy for evidence of toxicities including hospitalizations and dose delays, dose reductions, and treatment discontinuations. Further, at each chemotherapy visit, participants completed a patient-reported symptom monitoring (PRSM) form [44] to rate their symptoms over the past 7 days as none, mild, moderate, severe, or very severe. The PRSM is similar to the PRO-CTCAE (patient-reported Common Terminology Criteria for Adverse Events/CTCAE) [45, 46], which was not available at the time our study was launched.

Medical chart review

EMR were reviewed for data pertaining to breast cancer diagnosis and treatment, height, weight, and body mass index (BMI).

Demographics

Participants provided information regarding their age, race, education, marital status, living arrangements, and employment status.

Statistical considerations

Descriptive statistics are reported. Unadjusted linear regression models were used to assess the association between baseline participant characteristics, breast cancer diagnosis, treatment, chemotherapy toxicities, and patient-reported symptoms with average walking steps/week. For each patient, their average Fitbit steps per week were calculated based on total steps divided by weeks receiving chemotherapy (range 6–12 weeks). Due to limited sample size, covariates for the final multivariable model were chosen based on strength of bivariate association with Fitbit steps as well as clinical significance and representation in the PAAM conceptual model. All analyses were conducted using SAS Version 9.3 (Cary NC).

Results

Study sample

Of 127 women consented to the study, 100 had analyzable Fitbit data (79%). Seventeen women were excluded from our analysis because they did not have any Fitbit data when we attempted to upload data from their Fitbit address. Of these 17 women, five nevertheless had well-maintained printed diaries recording walking minutes per day. An additional 10 women were excluded because they had 3 weeks or less of Fitbit data. The 27 women who were excluded from the final sample were less likely to be married ($p = 0.01$), had lower FACT-G physical wellbeing ($p = 0.05$), and had worse fatigue ($p = 0.04$). They also had more hospitalizations during chemotherapy ($p = 0.02$) and more dose delays ($p = 0.03$).

Study participant characteristics

Demographics

Baseline characteristics for the final sample ($N = 100$) are presented in Table 1. Mean age was 48 (range 24–64), 31% were non-white, 31% had a high school education or less, 41% were not married, 21% were living alone, and 43% were not employed more than 32 h per week. With regard to BMI, 30% were normal weight, 34% were overweight, and 36% were obese.

Function and lifestyle

At baseline, KPS scores were rated 80 or higher by 100% of clinicians and by 87% of participants. Fifteen percent of participants required 14 s or more to complete the Timed Up and Go test. Mean score on the short physical performance battery was 11 (on a scale from 0 to 12). Most participants reported never smoking (63%) and never/almost never drinking alcohol (59%). Forty-one percent reported never engaging in vigorous physical activity or doing so only a few times a month, and mean self-reported walking minutes per week was 133 (range 0–420).

Function

Forty-eight percent of participants scored high on the MOS Physical Function scale based on their responses to questions pertaining to limitations in walking (one/several blocks, more than a mile), climbing stairs (one/several flights), bending/kneeling/stooping, bathing/dressing, lifting/carrying groceries, moderate activities (moving a table/pushing a vacuum cleaner/bowling/playing golf), and vigorous activities (running/lifting heavy objects/participating in strenuous sports). Eighty-eight percent scored high in Instrumental Activities of Daily Living (IADLs): using the telephone, getting to places outside walking distance, shopping for groceries or clothes, preparing meals, doing housework, taking medications, and handling money matters.

Quality of life and self-efficacy

A minority of participants reported that physical or emotional problems interfered with their social activities (21%), or that their emotional support (6%) or tangible support (8%) was low. Participants rated their overall quality of life as moderately high (FACT-G summary score of 87 on a 0–108 scale) and their fatigue as moderate (43 on a 0–52 scale). On the mental health index, 27% scored depressed and 47% scored anxious. Outcome expectations from exercise were generally high (4 on a 1–5 scale), as was perceived self-efficacy for fatigue self-management (7.6 on a 1–10 scale).

Breast cancer diagnosis, treatment, toxicities, and symptoms

Thirty percent of participants had Stage 3 breast cancer, 57% had a mastectomy, 51% received neoadjuvant chemotherapy, and 42% were treated with three or four chemotherapy drugs. Chemotherapy-related toxicities were reflected in hospitalizations (18% of participants), dose reductions

Table 1 Study participant characteristics

Variable (*N*=100)	Mean (SD) or number (percent)
Demographics	
Age	48.3 (SD 9.4) (range 24–64)
Race	
White	69 (69%)
African American or other	31 (31%)
Education	
High school or less	32 (31%)
More than high school	70 (69%)
Married	
No	39 (41%)
Yes	57 (59%)
Living alone	
No	65 (79%)
Yes	17 (21%)
Employed more than 32 hours a week	
No	36 (43%)
Yes	47 (57%)
Research staff assessed	
Body mass index (BMI)	28.5 (SD 6.1) (range 20–47)
Normal (18.5–25)	29 (30%)
Overweight (25–30)	33 (34%)
Obese I (30–35)	19 (20%)
Obese II (greater than 35)	15 (16%)
Karnofsky performance status (KPS 80 or higher)	
Professional KPS	99 (100%)
Patient KPS	83 (87%)
Timed up and go test	
Less than 14 s	84 (85%)
14 s or more	15 (15%)
Short physical performance battery (SPPB)—summary score (0 = worst to 12 = best performance)	11.0 (SD 1.5) (range 6–12)
Participant reported	
Smoking history	
Never smoked	59 (63%)
Smoked in the past	24 (26%)
Current smoker	10 (11%)
Alcohol use	
No or almost never	56 (59%)
Yes	39 (41%)
Health behavior questionnaire (HBQ): vigorous physical activity	
Never or a few times a month	38 (41%)
1–2 times a week	19 (20%)
3 or more times a week	36 (39%)
HBQ: vigorous minutes per week	33.8 (SD 25.3) (range 0–180)
Total self-reported walking minutes per week for exercise or pleasure	133.1 (SD 107.8) (range 0–420)
Physical function score (range 0–20)	17.4 (SD 3.7) (range 3–20)
Lower function (score < 20)	49 (52%)
High function (score 20)	45 (48%)
Instrumental activities of daily living (IADL) score (range 0–14) (0 = low function, 14 = high function)	13.8 (SD 0.6) (range 10–14)
Lower function (score < 14)	11 (12%)
Higher function (score 14)	84 (88%)

Table 1 (continued)

Variable	Mean (SD) or number (percent)
Social activity limit score (range 0–100)	65.1 (SD 17.8) (range 25–100)
Lower social activity (score < 50)	20 (21%)
Higher social activity (score 50 or higher)	75 (79%)
Social support-emotional score (range 0–100)	88.2 (SD 21.2) (range 3–100)
Lower social support (score < 50)	6 (6%)
Higher social support (score 50 or higher)	89 (94%)
Social support-tangible score (range 0–100)	86.0 (SD 22.5) (range 6–100)
Lower social support (score < 50)	8 (8%)
Higher social support (score 50 or higher)	87 (92%)
Functional assessment of cancer therapy-general (FACT-G) composite score (range 0–108) (higher score = higher wellbeing)	87.1 (SD 15.5) (range 36–108)
FACT-G physical wellbeing (range 0–28)	24.6 (SD 4.1) (range 11–28)
FACT-G social/family wellbeing (range 0–28)	23.8 (SD 5.4) (range 4–28)
FACT-G emotional wellbeing (range 0–24)	18.7 (SD 4.2) (range 1–24)
FACT-G functional wellbeing (range 0–28)	20.0 (SD 6.0) (range 0–28)
FACIT-fatigue (range 0–52) (reverse scored so that higher score = lower fatigue)	43.3 (SD 8.7) (range 14–52)
Composite FACT-G/FACIT-fatigue score (range 0–160)	130.4 (SD 22.8) (range 63.6–160)
Mental health index (MHI)-depressed (range 0–43)	8.7 (SD 7.3) (range 0–35)
Less depressed (score < 12)	67 (73%)
More depressed (score = or > 12)	25 (27%)
Mental health index (MHI)-anxious (range 0–20)	6.0 (SD 3.7) (range 0–16)
Less anxious (score < 6)	50 (53%)
More anxious (score = > 6)	44 (47%)
Outcome expectations from exercise scale (range 1–5) (higher score = higher expectations)	4.2 (SD 0.9) (range 1–5)
Perceived self-efficacy for fatigue self-management scale (range 1–10) (higher score = higher efficacy)	7.6 (SD 2.1) (range 1–10)
Breast cancer diagnosis, treatment, chemotherapy events, symptoms	
Breast cancer stage	
I	18 (19%)
II	50 (51%)
III	29 (30%)
Breast cancer surgery prior to chemotherapy	
None	1 (1%)
Lumpectomy	42 (42)
Mastectomy	57 (57)
Chemotherapy	
Neoadjuvant	51 (51%)
Adjuvant	49 (49%)
Total number of chemotherapy drugs taken	
1 or 2 drugs	58 (58%)
3 or 4 drugs	42 (42%)
Hospitalized during chemotherapy	18 (18%)
Dose reduction during chemotherapy	34 (34%)
Dose delay during chemotherapy	22 (22%)
Dose discontinuation of chemotherapy	15 (15%)
Patient-reported symptom monitoring (PRSM)	
Constipation	
None, mild	64%
Moderate	23%
Severe, very severe	13%

Table 1 (continued)

Variable	Mean (SD) or number (percent)
Diarrhea	
None, mild	70%
Moderate	23%
Severe, very severe	7%
Nausea	
None, mild	67%
Moderate	23%
Severe, very severe	10%
Vomiting	
None, mild	93%
Moderate	5%
Severe, very severe	2%
Fatigue, lack of energy	
None, mild	39%
Moderate	45%
Severe, very severe	16%
Aching joints	
None, mild	73%
Moderate	21%
Severe, very severe	6%
Aching muscles	
None, mild	77%
Moderate	16%
Severe, very severe	7%
Tingling, numbness in hands, feet	
None, mild	81%
Moderate	15%
Severe, very severe	4%
Anxiety	
None, mild	64%
Moderate	25%
Severe, very severe	11%
Feeling sad, unhappy	
None, mild	77%
Moderate	17%
Severe, very severe	6%
Insomnia	
None, mild	45%
Moderate	38%
Severe, very severe	17%
Total number of PRSM systems that were “moderate, sometimes” during chemotherapy	
0 symptoms	22 (22%)
1–2 symptoms	30 (30%)
3–4 symptoms	26 (26%)
Greater than 4 symptoms	22 (22%)
Total number of PRSM systems that were “severe/very severe, quite a bit/very much, most/all of the time” during chemotherapy	
0 symptoms	20 (20%)
1–2 symptoms	24 (24%)
3–4 symptoms	18 (18%)
Greater than 4 symptoms	38 (38%)

(34%), dose delays (22%), and dose discontinuations (15%). Patent-reported symptoms reported during chemotherapy treatment as "severe/very severe", "quite a bit/very much" or "most/all of the time" included insomnia (17%), fatigue (16%), constipation (11%), and anxiety (11%). Eighteen percent of patients reported 3–4 symptoms and 38% reported more than four symptoms as "severe/very severe", "quite a bit/very much", or "most/all of the time".

Walking adherence

Mean Fitbit steps per week during chemotherapy were 27,689 (SD 18,767) or 3956 per day. Fitbit steps per week over 12 weeks of chemotherapy are plotted and summarized in Fig. 1 as box-and-whisker plots in which the 25th, 50th (median), and 75th percentile are marked by the bottom, middle, top sides of the box, respectively. The whiskers extend out a maximum of 1.5 times the interquartile range (75th to 25th percentile). Using the a priori standard of 44,000 steps per week or 6286 steps per day, only 19% of participants were fully adherent with the a priori exercise target (Fig. 2). An additional 24% were moderately adherent (4000–6000 steps/day).

Associations with fitbit walking steps

Table 2 presents unadjusted associations between baseline characteristics of participants, breast cancer diagnosis and treatment, and chemotherapy-related toxicities (events and symptoms) with average Fitbit steps per week. Baseline variables associated with *fewer* Fitbit steps were non-white race ($p = 0.012$), having a high school education or less

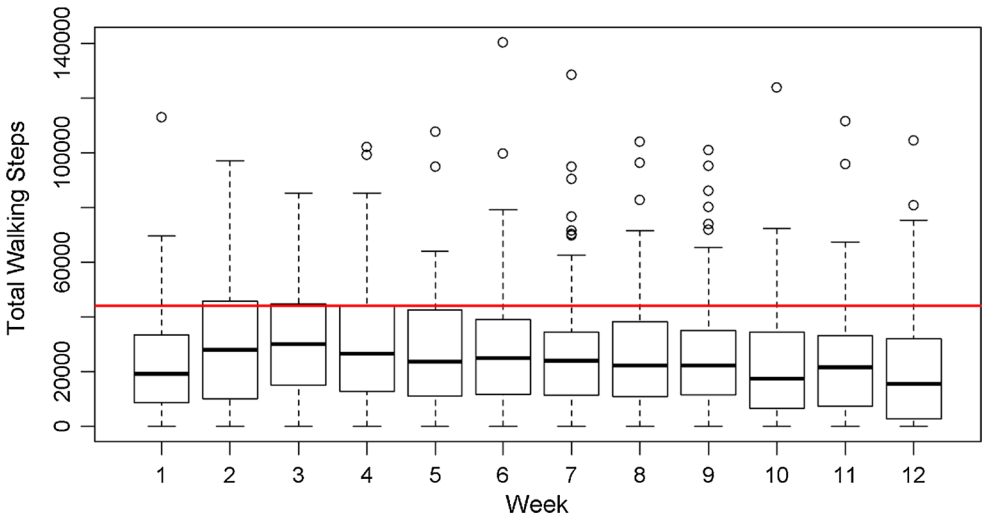

Fig. 1 Average Fitbit steps per week during chemotherapy (red line is target of 44,000 steps/week)

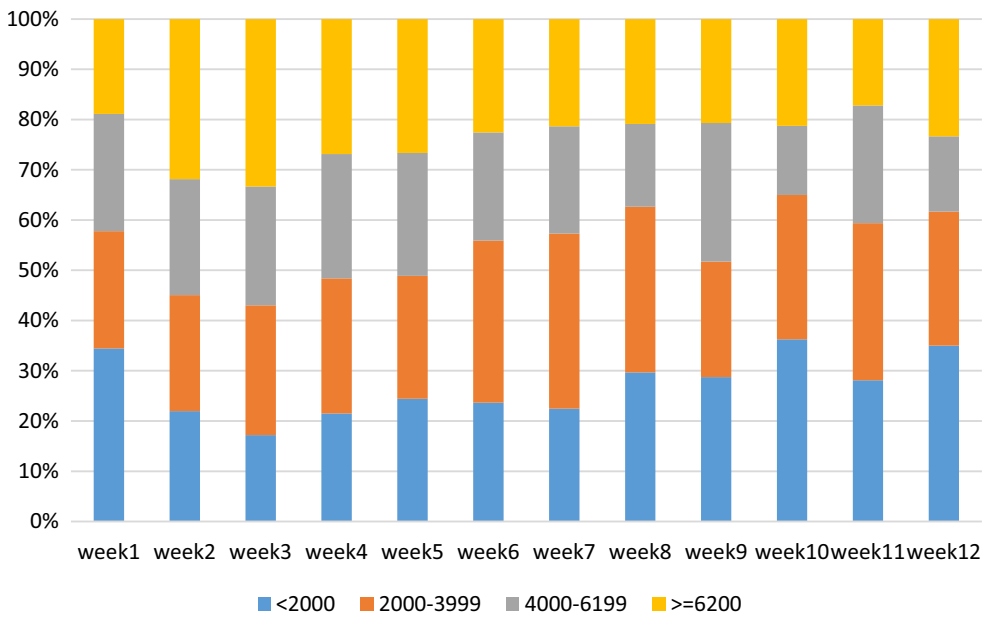

Fig. 2 Fitbit steps per week (%)

Table 2 Unadjusted analysis of associations with mean walking steps per week (*N*=100)

Variable	Estimate	*p* value
Demographics		
Age	322.7 (SE 198.4)	0.107
Race (White is referent)		
African American or other	− 10099.9 (SE (3948.8)	***0.012***
Education (more than high school is referent)		
High school or less	− 14092.8 (SE 3918.8)	***0.0005***
Married (yes is referent)		
No	− 7452.8 (SE 3904.4)	0.059
Living alone (yes is referent)		
No	− 424.0 (SE 5493.0)	0.939
Employed > 32 h/week (yes if referent)		
No	3846.8 (SE 4342.4)	0.378
Research staff assessed		
Body mass index (BMI)	− 952.2 (SE 304.6)	***0.0024***
Short physical performance battery (SPPB)	89.1 (SE 1425.6)	0.950
Participant reported		
Smoking history (current/past is referent)		
Never smoked	1106.8 (SE 4137.7)	0.790
Alcohol use (yes is referent)		
No/almost never	− 11070.9 (SE 3830.1)	***0.0048***
Health behavior questionnaire (HBQ): vigorous physical activity (never/few times is referent)*		
At least once a week	10424.8 (SE 3908.9)	***0.0091***
Walking minutes per week	79.9 (SE 16.7)	***< 0.0001***
Physical function score	1310.9 (SE 516.1)	***0.013***
Instrumental activities of daily living (IADL)	4395.7 (SE 3065.0)	0.155
Social activity limitation score	206.2 (SE 108.9)	0.061
Social support-emotional score	126.1 (SE 92.6)	0.177
Social support-tangible score	68.2 (SE 87.8)	0.439
Functional assessment of cancer therapy-general (FACT-G)	287.8 (SE 121.2)	***0.020***
FACT-G physical wellbeing	1193.1 (SE 454.3)	***0.010***
FACT-G social/family wellbeing	509.1 (SE 352.3)	0.152
FACT-G emotional wellbeing	259.8 (SE 458.3)	0.572
FACT-G functional wellbeing	828.0 (SE 313.5)	***0.010***
FACIT-fatigue	773.8 (SE 207.4)	***0.0003***
FACT-G/FACIT-fatigue total score	245.9 (SE 81.0)	***0.0031***
Mental health index (MHI)-depressed	− 450.9 (274.8)	0.104
Mental health index (MHI)-anxious	− 1154.5 (SE 524.0)	***0.030***
Outcome expectations from exercise scale	4978.0 (SE 1996.5)	***0.014***
Perceived self-efficacy for fatigue self-management scale	290.6 (SE 971.9)	0.766
Breast cancer diagnosis, treatment, chemotherapy events, symptoms		
Breast cancer stage (stage III is referent)		
I	− 3223.9 (SE 5674.2)	0.571
II	3368.8 (SE 4413.8)	0.447
Breast cancer surgery prior to chemotherapy (none is referent)		
Lumpectomy	10147.7 (SE 19156.0)	0.868
Mastectomy	10083.8 (SE 19097.3)	
Chemotherapy (neoadjuvant is referent)		
Adjuvant	− 1431.6 (SE 3770.5)	0.705
Total number of chemotherapy drugs	− 34.5 (SE 2699.1)	0.990
Duration of chemotherapy treatment	− 26.5 (SE 501.3)	0.958

Table 2 (continued)

Variable	Estimate	*p* value
Chemotherapy dose frequency	1373.3 (SE 2107.1)	0.516
Hospitalized during chemotherapy (yes is referent)		0.751
No	1561.2 (SE 4907.2)	
Dose reduction during chemotherapy (yes is referent)		
No	7264.5 (SE 3913.7)	0.066
Dose delay during chemotherapy (yes is referent)		
No	4751.8 (SE 4528.1)	0.297
Dose discontinuation of chemotherapy (yes is referent)		
No	7241.9 (SE 5231.7)	0.169
Total number of PRSM symptoms that were "moderate, sometimes" during chemotherapy	− 259.3 (SE 850.2)	0.761
Total number of PRSM symptoms that were "severe/very severe" during chemotherapy	− 2859.4 (SE 1117.9)	***0.012***

Bold print identifies *p* values that are significant ($p < 0.05$)

PRSM patient-reported symptom monitoring

($p = 0.0005$), higher Body Mass Index ($p = 0.0024$), and never/almost never drinking alcohol ($p = 0.0048$). Physical activity variables associated with *greater* Fitbit steps during chemotherapy were history of vigorous physical activity ($p = 0.0091$), higher self-reported walking minutes/week ($p < 0.001$) prior to chemotherapy, and higher outcome expectations from exercise ($p = 0.014$).

Higher baseline values in the following measures (where higher scores indicate higher quality of life) were correlated with greater Fitbit steps during chemotherapy: physical function score ($p = 0.013$), overall FACT-G Score ($p = 0.020$), FACT-G/Physical Wellbeing ($p = 0.010$), FACT-G/Functional Wellbeing ($p = 0.010$), FACIT-fatigue ($p = 0.0003$), and overall quality of life (FACT-G/FACIT-fatigue) ($p = 0.0031$). Higher anxiety as measured by the MHI Anxiety score was inversely associated with Fitbit steps ($p = 0.03$). A higher number of chemotherapy-related symptoms reported as "severe/very severe" was also associated with fewer Fitbit steps ($p = 0.012$).

To create a parsimonious model for our limited sample, the multivariable model (Table 3) was limited to variables that were highly significant at $p < 0.01$ in unadjusted analysis and measured different domains: race, education, BMI, total score for FACT-G/FACIT-fatigue, outcome expectations from exercise, PRSM symptom "severe/very severe", and self-reported walking minutes/week at baseline. In this model, white race was associated with 12,146 greater Fitbit steps per week on average ($p = 0.004$) after adjustment for other variables. Similarly, self-reported walking minutes prior to chemotherapy was associated with increased Fitbit steps during chemotherapy ($p < 0.0001$); for every 30 min of increased self-reported walking minutes at baseline, average Fitbit steps per week during chemotherapy increased by 2370 (30 min times 79). The amount of variance in Fitbit steps/week explained by the model was 36% (adjusted R-square = 0.36).

Table 3 Multivariable analysis of associations with mean walking steps per week ($N = 100$)

Variable	Estimate	*p* value
Race: white	12146 (SE 4120.5)	***0.004***
Education	6236.6 (SE 4060.7)	0.129
Body mass index	− 267.1 (SE 312.8)	0.396
Total FACT-G/FACIT-F score	96.7 (SE 97.5)	0.324
Outcome expectations from exercise	389.4 (SE 1950.0)	0.842
Total number of chemotherapy-related symptoms patient-reported as "severe/very severe"	6236.6 (SE 4060.7)	0.129
Self-reported walking minutes/week at baseline	79.0 (SE 17.3)	***< 0.0001***

Bold print identifies *p* values that are significant ($p < 0.05$)

Model: $p < 0.0001$

Adjusted R-squared = 0.36

Discussion

In this home-based exercise intervention, women with early stage breast cancer were asked to walk 150 min a week throughout their chemotherapy treatment and to wear a Fitbit during their waking hours. Intervention implementation appeared feasible, with 79% of participants having analyzable Fitbit data; however, full intervention adherence was observed in only 19% of participants. In multivariable analysis limited to variables that were highly significant ($p < 0.01$) in unadjusted analyses and representing different domains, white race and higher number of self-reported walking minutes/week prior to start of chemotherapy were significant predictors of greater Fitbit steps during chemotherapy.

Our study contributes to the literature pertaining to home-based exercise interventions in breast cancer patients undergoing chemotherapy by defining exercise adherence, a priori and analyzing adherence using Fitbit data that were uploaded directly into research computers. Adherence to a study's administrative requirements is important to report, such as the proportion of participants who completed questionnaires and diaries. However, the *assessment of exercise impact* on primary and secondary outcomes requires measures of actual exercise throughout the study period. In this regard, our study points to the advantages of independent measurement of exercise adherence through the use of commercially available activity trackers. To date, only a few studies of home-based exercise interventions in breast cancer patients have included pedometers or activity trackers that are worn throughout chemotherapy. Of these studies, four measured exercise adherence based on participant *self-report* of walking steps [20, 27, 47, 48] and only one study directly uploaded pedometer or tracker steps into study computers [49]. All of these studies have small sample sizes, while our study was conducted in a relatively larger sample of women ($N = 100$).

The average of 3956 steps per day reported in our study is below the average steps reported in other intervention studies of women walking throughout 10–12 weeks of chemotherapy for early breast cancer [47, 49]. Our intervention was selected because it requires minimal staff and oversight, to mirror as closely as possible what could be feasible during a busy clinic visit—guidance and motivational materials at the onset of chemotherapy and minimal interactions with participants when Fitbit data were uploaded during chemotherapy visits. We found that reasons for sub-optimal walking were not related to breast cancer treatment, adverse events, or patient-reported symptoms. Instead, it is likely that our minimalist intervention was not sufficiently motivational for some participants to encourage them to make an extra effort to walk throughout chemotherapy or there were other barriers to their exercise adherence [25, 50–52]. Or, some participants may not have worn their Fitbit throughout their waking hours. For future low-intensity interventions, we would consider targeting patient groups who were least likely to achieve the walking goal, including non-white women and those with low levels of baseline physical activity, for more intensive assistance and encouragement to walk throughout chemotherapy. We would also consider including brief, semi-structured motivational conversations with participants when Fitbit data are uploaded during chemotherapy visits, and instructions to focus on achieving *steps per day* rather than just walking minutes per week. Nevertheless, our study demonstrates that for some patient groups, a low-intensity intervention may be sufficient to encourage maintenance of physical activity during the chemotherapy period [50, 53]. Our finding of the positive influence of exercise history prior to treatment has been observed in other studies as well [9, 20, 54]; women who were exercising prior to their breast cancer diagnosis are more likely to continue exercising during treatment.

It is a limitation of our study that we did not check the uploaded Fitbit data until all participants had completed their chemotherapy. If we had checked the data periodically throughout chemotherapy, we would have identified participants without Fitbit data and investigated possible reasons. For example, the five participants who maintained printed exercise logs but did not have Fitbit data would suggest a tracker malfunction rather than a deliberate decision not to wear a Fitbit. Periodic checking of Fitbit data would also identify participants who were not wearing their Fitbit throughout their waking hours, thereby contributing to the low average Fitbit steps observed in our study. It would also have been an improvement on the study if a post-chemotherapy survey had inquired about barriers and facilitators to wearing a Fitbit throughout their waking hours.

Our study suggests that wearing an activity tracker throughout chemotherapy is feasible and acceptable [55]. The activity tracker can provide real-time feedback that may increase physical activity self-awareness, self-regulation, and self-monitoring [15, 55, 56]. The growing availability of relatively inexpensive commercially available activity trackers to collect 24-7 data that can be directly accessed by study investigators provides an important opportunity for home-based intervention studies to include independent assessments of physical activity adherence. Low-cost trackers worn over extended periods also present an opportunity for an evolving area of research focused on the interface of physical activity and on-going monitoring of patient-centered symptoms and outcomes during active treatment for a variety of cancer diagnoses [57]. This is an evolving area of research, but there is already promising evidence of the value of attention to physical activity in making objective estimates of treatment-related symptoms and declines in function and quality of life, in addition to or in lieu of patient-reported outcomes [57–61].

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