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Distinct trajectories of moderate to vigorous physical activity and sedentary behavior following a breast cancer diagnosis: the Pathways Study

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Abstract

Purpose To identify distinct trajectories of total moderate-to-vigorous physical activity (MVPA) and sedentary behavior following a breast cancer diagnosis and their correlates.

Methods The analysis examined 3000 female breast cancer survivors within Kaiser Permanente Northern California between 2006 and 2013. Self-reported time spent on total MVPA and sedentary behaviors were assessed at baseline (mean = 1.8 months post-diagnosis) and at 6 and 24 months follow up. Trajectory groups were identified using group-based trajectory modeling and K-means for longitudinal data analysis. Trajectory groups were named by baseline activity level (high, medium, or low) and direction of change (increaser, decreaser, or maintainer).

Results Trajectory analyses identified three MVPA trajectories [high decreaser (7%), medium decreaser (35%), low maintainer (58%)] and four sedentary behavior trajectories [high maintainer (18%), high decreaser (27%), low increaser (24%), and low maintainer (31%)]. Women with higher education (ORs: 1.63–4.37), income (OR: 1.37), dispositional optimism (ORs: 1.60–1.86), and social support (OR: 1.33) were more likely to be high or medium decreasers of MVPA (all $P < 0.05$). High maintainers and high decreasers of sedentary behavior were more likely to have higher education (OR: 1.84) and social support (ORs: 1.42–1.86), but lower income (OR: 0.66; all $P < 0.05$).

Conclusions In the 24 months following breast cancer diagnosis, 42% of survivors decreased MVPA and 73% maintained or increased time on sedentary behavior. Socioeconomic status and stress coping at diagnosis predicted subsequent PA trajectory.

Implications for Cancer survivors It is important to prioritize exercise intervention and counseling during early stage of breast cancer survivorship, especially in survivors who are at high risk of becoming physically inactive post-diagnosis.

Keywords Physical activity · Cancer survivors · Breast cancer · Trajectory analysis · Group-based trajectory modeling · K-means

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Introduction

Physical activity (PA), especially moderate-to-vigorous physical activity (MVPA), has been shown to reduce cancer and non-cancer deaths for breast cancer and other cancer survivors [1, 2]. Cancer survivors are recommended to engage in at least 150 min/week of MVPA to improve long-term survival [3–5]. However, large population-based surveys in the US have shown that 63–71% of breast cancer survivors do not meet this recommendation [6, 7]. To help breast cancer survivors achieve and maintain the recommended PA level, it is important to understand how women change their PA following a breast cancer diagnosis.

To date, only a limited number of observational studies have examined changes in PA following a breast cancer diagnosis, with results suggesting that women may reduce time spent on MVPA following a breast cancer diagnosis [8–13]. Previous studies of PA change following a breast cancer diagnosis are limited by their analytical approach, which tested the mean change in PA between two time points. These analyses assumed monotonic change over time and ignored the variability in PA change trajectories, leading to over-simplified conclusions of change in PA post-diagnosis. Methods that are designed to derive latent groups of longitudinal trajectories are more suitable to understand the post-diagnostic change in PA, which helps identify subgroups of patients whose activities are most affected by a cancer diagnosis. Group-based trajectory modeling (GBTM) is a commonly used analytical method to identify developmental trajectory groups based on the shape parameters of trajectory curve [14]. This analytic method tests for non-linear trajectories, allowing for flexible and less biased estimates of the trajectory curve. To our knowledge, only one prior study has used GBTM to estimate changes in MVPA during the first year after diagnosis among 199 Canadian breast cancer survivors, which identified five distinct trajectories of MVPA [15]. Prior studies have not assessed trajectories of MVPA changes in a large, population-based sample. Moreover, few studies examined changes in sedentary behavior, which has been associated with higher mortality in colorectal cancer survivors independent of MVPA [16, 17] and may be associated with worse outcomes for breast cancer survivors.

Predictors of unfavorable changes in PA following a cancer diagnosis have not been well described. Previous studies suggest that breast cancer survivors who receive chemotherapy and experience treatment complications are more likely to decrease MVPA after diagnosis [9, 13]. Other factors such as lower socioeconomic status (SES) [18–22] and higher stress are associated with physical inactivity in the general population [23–25], and maybe indicators of survivors who make unfavorable changes in PA after a cancer diagnosis.

This analysis addresses these research gaps by identifying distinct trajectories of MVPA and sedentary behavior among breast cancer survivors over the first 24 months following diagnosis. The analysis used data from the Pathways Study, a population-based prospective cohort of 4505 women newly diagnosed with invasive breast cancer at Kaiser Permanente Northern California (KPNC). Based on previous studies [8–12, 15], we expected to observe 5 distinct PA trajectories following a breast cancer diagnosis, including (1) maintenance of baseline PA level, (2) a stable increase or decrease in PA, or (3) a temporary increase or decrease in PA. We also evaluated the associations between PA trajectories with SES, psychosocial factors related to stress and coping, and cancer treatment side effects. Ultimately, the purpose of this analysis is to identify subgroups of women who could be prioritized for exercise interventions following a breast cancer diagnosis.

Methods

Study participants

As previously described, the Pathways Study is a population-based prospective cohort of women newly diagnosed with invasive breast cancer at KPNC from January 2006 to April 2013 [26]. Eligibility criteria included women who were at least 21 years of age at diagnosis and a current KP member, had a recent diagnosis of invasive breast cancer, had no previous history of malignant cancer, spoke English, Spanish, Cantonese, or Mandarin, and lived within a 65-mile radius of a field interviewer. Women were recruited using rapid case ascertainment methods. Most participants were recruited within 2 months post-diagnosis (mean time = 1.8 months, range = 0.3–7.2 months); 34% had started radiation therapy, 46% started chemotherapy, and 40% started hormonal therapy by enrollment [26]. The study protocol was approved by the institutional review board of all collaborating institutions. Written informed consent was obtained from all participating subjects.

Baseline and follow-up data collection

Baseline demographic factors, behavioral factors including self-reported diet and PA, psychosocial, and quality-of-life measures were collected during an in-person interview. Clinical and tumor characteristics were obtained from the KPNC Cancer Registry approximately 4 months post-diagnosis. During follow-up, data on PA were repeatedly collected at 6 and 24 months via mailed questionnaires.

Measurement of physical activity

The Pathways Study collected physical activity data using the Arizona Activity Frequency Questionnaire (AAFQ) [27], which assesses the frequency and duration of daily household,

recreational, transportation, and sedentary behaviors. The questionnaire is divided into four main sections: job or work-related activities, activities not related to paid or volunteer work, recreational activities, and transportation. Respondents reported the frequency, duration, and intensity of each activity they engaged in at least once a month during the previous 6 months. Each activity is assigned a standard metabolic equivalent value (MET) [28], with one MET being defined as the energy required to sit quietly. This analysis used data on time spent engaged in MVPA and SB. Moderate PA is defined as activities equivalent in intensity to brisk walking or bicycling (3–6 METs). Vigorous PA is defined as activities that produce large increases in breathing or heart rate, such as jogging, aerobic dance or bicycling uphill (>6 METs). Therefore, time spent engaged in MVPA is defined as time spent in all activities of ≥3 METs. Sedentary behaviors included time spent sitting while commuting, in the workplace, in the domestic environment, and during leisure time. Typical sedentary behaviors include TV viewing, computer use, or sitting in an automobile (1–1.5 METs).

Key variables

Clinical characteristics

Breast cancer and other clinical characteristics were obtained from the KPNC Cancer Registry and the electronic health record (EHR), including family history of breast cancer (yes and no), menopausal status (pre- and post-menopause), American Joint Committee on Cancer (AJCC) stage (I-IV), number of positive lymph nodes (0, 1, and 2+), tumor estrogen/progesterone receptor (ER/PR) positivity (positive and negative), human epidermal growth factor receptor 2 (HER2) positivity (positive and negative), breast cancer surgery type (lumpectomy, mastectomy, and none), and cancer treatment received (chemotherapy, hormonal therapy, and radiation therapy).

Psychosocial measures and cancer-treatment side effects

Psychosocial variables for analysis included baseline depressive symptoms, dispositional optimism, and social support. The scales and scoring of these psychosocial measures are summarized in Table S1. We also included measures of commonly reported cancer treatment-related side effects, including chemotherapy-induced peripheral neuropathy (CIPN) and loss of physical well-being (PWB) from baseline to 6 months, which are also described in the Table S1.

Statistical analysis

The primary goal of this analysis was to identify latent groups of PA trajectories following a breast cancer diagnosis and to identify predictors of trajectory groups. The analysis used semi-parametric, group-based trajectory modeling (GBTM) procedures as proposed by Nagin [14] to identify the optimal number of trajectory groups and estimate their shape parameters. The outcome variables were time spent on MVPA and sedentary behavior from baseline to 6 and 24 months follow-up. For each outcome, a single-group model saturated with quadratic parameters was tested initially, and then one additional group was included in each successive model. We tested models composed of one to six trajectory groups to find the optimal number of trajectories. Model fit was assessed based on the Bayesian Information Criterion (BIC), whereby the model with the lower BIC was favored. The final model was selected based on parsimony, interpretability and prior knowledge of common PA patterns in breast cancer survivors [14, 29]. The selected models were evaluated using the average posterior probability of assignment for each group, odds of correct classification, and by comparing the actual and estimated proportion of groups [14]. Trajectory groups were labeled by the relative level of baseline MVPA or sedentary behavior (high, medium, or low) and the direction of change (increaser, decreaser, or maintainer).

The analyses were restricted to participants who had ≥2 PA assessments by the 24-month follow-up, which accounted for 67% of all participants. To evaluate the influence of loss to follow-up on trajectory group identification, a sensitivity analyses was performed by applying inverse probability weights (IPW) [30] to the standard GBTM based on the probability of remaining in the follow-up through 24 months. A further validation analysis was conducted to examine if the optimal number of clusters identified through GBTM produced similar trajectory groups using a fully non-parametric method, K-means for longitudinal data (KmL) [31]. The best model was selected between GBTM and IPW-weighted GBTM first, then compared with results from KmL analysis. Group memberships under IPW-weighted GBTM were preferred if they were found to be discordant with membership identified with unweighted GBTM (Cohen's kappa<0.8). The KmL-based trajectory groups were preferred if (1) they identified different trajectory groups compared to the GBTM, or (2) the KmL- and GBTM-based trajectories identified the same groups but the two sets of group membership were discordant, as evidenced by a Cohen's kappa<0.8. Using the best trajectory group membership derived from the three models, multinomial logistic regression was used to further evaluate the association between SES, psychosocial factors, and cancer treatment side effects with each PA trajectory. In sensitivity analyses, we assessed the change in the associations between these characteristics and the PA trajectory group when baseline PA was adjusted.

GBTM was performed using the PROC TRAJ command in SAS [32]. KmL was implemented in R using the "kml" package [33]. All statistical tests were performed with $\alpha = 0.05$.

Results

Participant characteristics

Of the 4505 women in the Pathways Study, 3000 participants with ≥2 MVPA assessments and 2997 participants with ≥2 sedentary behavior assessments by the 24-month follow-up were included in this analysis. Among included participants, approximately 62% had complete data at all 3 time points, 38% had data at 2 time points. Table 1 summarizes the demographic and clinical characteristics of participants included in this analysis. Briefly, the mean age at diagnosis was 59 years (range: 26–94), and participants were enrolled at 2 months following diagnosis (range: 0–8 months) on average. Approximately 69% were non-Hispanic White, 6% non-Hispanic Black, 12% non-Hispanic Asian, and 11% Hispanic. Almost all participants were diagnosed with stage I-III breast cancer.

Table 1 Sample characteristics

Variable		N	%
Age	<50	563	19%
	50–59	797	27%
	60–70	961	32%
	70+	679	23%
Race/ethnicity	Non-Hispanic White	2079	69%
	Non-Hispanic Black	182	6%
	Non-Hispanic Asian	355	12%
	Hispanic	315	11%
	Other	69	2%
Education	High school or less	426	14%
	Some college	1016	34%
	College or above	1555	52%
Household income	<$50 K	1317	44%
	$50 K-$89 K	1376	46%
	$90 K+	307	10%
Menopausal status	Premenopausal	795	27%
	Postmenopausal	2205	74%
Tumor stage	I	1660	55%
	II	1024	34%
	III	284	9%
	IV	32	1%
Number of positive lymph nodes	0	131	4%
	1	645	22%
	2+	2224	74%
HER2 positivity	Negative	2492	87%
	Positive	387	13%
ER/PR positivity	Negative	473	16%
	Positive	2522	84%
Breast cancer surgery type	Lumpectomy	1381	46%
	Mastectomy	1597	53%
	None	22	1%
Received chemotherapy	Neoadjuvant	127	4%
	Adjuvant	1258	42%
	No	1607	54%
Received hormonal therapy	Yes	2250	76%
	No	728	24%
Received radiation therapy	Yes	1341	45%
	No	1657	55%
Depressive symptom	Low	2249	77%
	High	689	23%
Dispositional optimism	Low	1984	67%
	High	956	33%
Perceived social support	Low	951	32%
	High	1990	68%
Worse physical well-being at 6 months	No	2088	78%
	Yes	603	22%
Worse CIPN at 6 months	No	1338	66%
	Yes	684	34%

Abbreviations: HER2, human epidermal receptor 2; ER, estrogen receptor; PR, progesterone receptor; CIPN, chemotherapy induced peripheral neuropathy

Identification of physical activity trajectory groups

A three-group GBTM was considered optimal for MVPA, and a four-group GBTM was considered optimal for sedentary behavior (model fitting parameters are shown in Table S2). Both models met the criteria for adequate model fit (Table S3). The KmL-based trajectory groups were selected because the GBTM- and KmL-based MVPA trajectory group memberships were discordant, and KmL identified different sedentary behavior groups compared to the GBTM-based sedentary behavior trajectory groups. The three MVPA trajectory groups included high decreasers (7%), medium decreasers (35%), and low maintainers (58%). The four trajectory groups of sedentary behavior included high maintainers (18%), high decreasers (27%), low increasers (24%), and low maintainers (31%) (Fig. 1).

Mean activity level by trajectory groups

Among MVPA trajectory groups, the high decreaser and medium decreaser spent 18 h/week and 9 h/week on total MVPA at baseline, and decreased 2.4–3.0 h/week at 6 months (all $P < 0.01$, Table S4); the low maintainer group reported a 2.7 h/week of total MVPA at baseline and decreased 0.5 h/week MVPA at 6 months ($P < 0.01$, Table S4). The decrease in total MVPA was largely due to decreases in household chores and recreational activities, and did not include changes in transportation-related MVPA (Fig. S1A). For SB, the mean baseline sedentary time was 22.6–28.0 h/week for the high maintainers and high decreasers, and 11.3–15.4 h/week for low maintainers and low increasers. The low increasers reported an average increase of 4.7 h/week of SB by 6 months and 4.6 h/week of SB by 24 months; the high decreaser group reported an average decrease of 6.8 h/week of sedentary behavior by 6 months and 5.4 h/week by 24 months (all $P < 0.01$, Table S4). The increases and decreases in sedentary behavior were primarily driven by time spent driving, reading, socializing, and watching TV (Fig. S1B).

Predictors of physical activity trajectory groups

Moderate to vigorous physical activity. In univariable analyses, age, race/ethnicity, education, household income, menopausal status, tumor stage, number of lymph nodes removed, cancer treatment received, baseline psychosocial factors, and cancer treatment side effects were statistically significantly associated with MVPA and sedentary behavior trajectory groups (Table S5 and S6). In multivariable analyses including

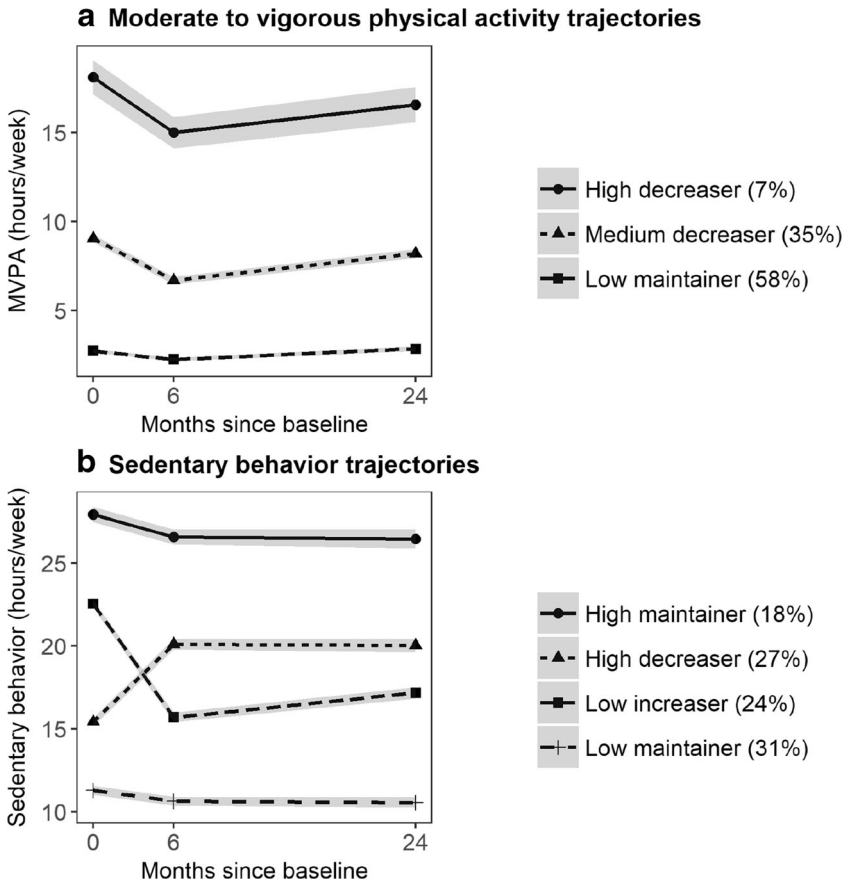

Fig. 1 Distinct trajectories of physical activity during the 24 months following a breast cancer diagnosis among the Pathways Study participants. This figure shows the group mean and 95% confidence interval for each distinct trajectory of moderate to vigorous physical activity (Fig. 1A) and sedentary behavioral (Fig. 1B) during the first 24 months following a breast cancer diagnosis. Trajectory groups are labeled by the relative level of baseline behavior (high, medium, or low) and the direction of change (increaser, decreaser, or maintainer)

these factors, participants with higher education [OR ranged between 1.63 (95% CI: 1.16–2.30) to 4.37 (95% CI: 1.84–10.40)], higher income (OR = 1.37, 95% CI: 1.09–1.72), were more optimistic [OR ranged between 1.60 (95% CI: 1.28–2.00) to 1.86 (95% CI: 1.26–2.76)], and reported higher social support (OR = 1.33, 95% CI: 1.06–1.67) were more likely to be high decreasers and medium decreasers compared to low maintainers (all $P < 0.05$, Table 2). Contrary to our

Table 2 Multinomial logistic regression of predictors for moderate to vigorous physical activity trajectory following a breast cancer diagnosis

	High decreaser vs. Low maintainer[a]		Medium decreaser vs. Low maintainer[a]	
Predictors	OR (95% CI)	P	OR (95% CI)	P
Education (ref = high school or less)				
Some college	3.47 (1.44, 8.36)	0.01	1.63 (1.16, 2.30)	<0.001
College and above	4.37 (1.84, 10.40)	<0.001	2.03 (1.46, 2.83)	<0.001
Income (ref = <$50 K)				
$50 K-$89 K	1.47 (0.97, 2.24)	0.07	1.37 (1.09, 1.72)	0.01
$90 K+	0.98 (0.46, 2.12)	0.96	1.03 (0.71, 1.49)	0.88
Depressive symptoms (high vs. low)	1.25 (0.79, 1.96)	0.34	0.95 (0.73, 1.23)	0.71
Optimism (high vs. low)	1.86 (1.26, 2.76)	<0.001	1.60 (1.28, 2.00)	<0.001
Social support (high vs. low)	1.23 (0.80, 1.88)	0.34	1.33 (1.06, 1.67)	0.01
Worse PWB at 6 months (yes vs. no)	0.97 (0.60, 1.55)	0.89	1.03 (0.80, 1.33)	0.82
Worse CIPN at 6 months (yes vs. no)	0.92 (0.60, 1.40)	0.68	0.84 (0.67, 1.06)	0.14
Age at diagnosis (ref = age < 50)				
50–59	1.20 (0.64, 2.27)	0.57	1.57 (1.07, 2.30)	0.02
60–70	0.83 (0.38, 1.81)	0.64	1.71 (1.07, 2.72)	0.02
70+	0.27 (0.11, 0.69)	0.01	1.05 (0.63, 1.74)	0.86
Race/ethnicity (ref = Non-Hispanic White)				
Non-Hispanic Black	0.78 (0.35, 1.72)	0.54	0.82 (0.53, 1.28)	0.39
Non-Hispanic Asian	0.41 (0.22, 0.77)	0.01	0.62 (0.45, 0.86)	<0.001
Hispanic	0.49 (0.23, 1.07)	0.07	0.89 (0.62, 1.27)	0.52
Other	1.84 (0.69, 4.87)	0.22	1.02 (0.52, 2.01)	0.95
Postmenopausal (yes vs. no)	0.84 (0.45, 1.56)	0.59	0.65 (0.45, 0.95)	0.03
Stage (ref = Stage I)				
Stage II	0.84 (0.53, 1.34)	0.47	1.03 (0.80, 1.33)	0.82
Stage III	0.39 (0.16, 0.96)	0.04	0.69 (0.45, 1.06)	0.09
Stage IV	0.84 (0.15, 4.60)	0.84	0.31 (0.07, 1.45)	0.14
Number of lymph node removed				
1 vs. 0	0.62 (0.21, 1.87)	0.40	2.76 (1.33, 5.75)	0.01
2+ vs. 0	0.69 (0.24, 1.97)	0.49	2.24 (1.10, 4.56)	0.03
ER/PR status (Positive vs. negative)	0.72 (0.32, 1.63)	0.43	1.15 (0.75, 1.75)	0.53
Surgery (ref = lumpectomy)				
Mastectomy	1.54 (1.00, 2.37)	0.05	1.07 (0.85, 1.35)	0.57
None	0.60 (0.05, 6.75)	0.68	NE	NE
Chemotherapy (ref = none)				
Neoadjuvant	0.28 (0.07, 1.10)	0.07	1.19 (0.65, 2.17)	0.57
Adjuvant	0.58 (0.35, 0.97)	0.04	0.90 (0.68, 1.18)	0.44
Hormonal therapy (yes vs. no)	1.41 (0.70, 2.84)	0.34	0.91 (0.64, 1.29)	0.59
Radiation therapy (yes vs. no)	0.87 (0.55, 1.36)	0.54	0.91 (0.71, 1.16)	0.43

OR odds ratio; *CI* confidence interval; *NE* not estimable; *HER2*, human epidermal growth factor receptor 2; *ER*, estrogen receptor; *PR* progesterone receptor; *CIPN*, chemotherapy-induced peripheral neuropathy; *PWB*, physical well-being

a. Trajectory groups were labeled by the relative level of baseline behavior (high, medium, or low) and the direction of change (increaser, decreaser, maintainer)

hypotheses, cancer treatment side effects as assessed by physical well-being and CIPN symptoms were not associated with MVPA trajectory groups (Table 2). However, the observed associations between education, income, optimism, and social support were not statistically significant after adjusting for baseline MVPA (Table S7).

Sedentary behavior. Participants with higher education (OR = 1.84, 95% CI: 1.15–2.94), lower household income (OR = 0.66, 95% CI: 0.48–0.90), and higher perceived social support [OR ranged between 1.42 (95% CI: 1.08–1.87) to 1.86 (95% CI: 1.34–2.57)] were more likely to be high maintainers or high decreasers of SB, compared to the low maintainers (all $P < 0.05$, Table 3). Cancer treatment side effects as assessed by physical well-being and CIPN symptoms were not associated with sedentary behavior trajectory groups (Table 3). Higher education remained statistically significantly associated with being high maintainers vs. low maintainers after adjusting for baseline sedentary behaviors (Table S8).

Discussion

This analysis showed that the majority of breast cancer survivors in the Pathways Study reduced or maintained a low level of MVPA in the 24 months following diagnosis. Specifically, 42% of women reported medium to high level MVPA at baseline but decreased their engagement in MVPA by 2–3 h/week during the first 6 months following diagnosis. Over the 24 months following breast cancer diagnosis, approximately one-quarter of women increased and another one quarter decreased time spent on sedentary behavior by 4–6 h/week. This analysis identified characteristics that were predictive of PA trajectories. Higher education, higher dispositional optimism, and higher perceived social support were commonly associated with more favorable MVPA and sedentary behavior trajectory groups. However, these associations were not statistically significant after adjusting for baseline PA, except for the association between higher education, and maintaining higher SB. In addition, participants who were older, non-Hispanic Asian, postmenopausal, had higher tumor stage, more lymph nodes removed, and received adjuvant chemotherapy were more likely to be in the unfavorable MVPA trajectories. Younger age and non-Hispanic Asian or Hispanic race were associated with the least sedentary trajectories. These factors could be used to identify women who are most likely to follow unfavorable PA trajectories following a breast cancer diagnosis.

To our knowledge, only two studies have reported the typical trajectories of MVPA patterns following a breast cancer diagnosis. Using a hospital sample of 199 breast cancer patients in Montreal, Canada, Brunet et al. analyzed data on recreational MVPA collected every 3 months during the first year following a breast cancer diagnosis using GBTM analysis [15]. Contrary to our analyses, Brunet et al. reported that 11% of survivors followed an increasing trajectory of MVPA, and that the majority of women (75%) were at least somewhat active (>1.5 h/week of MVPA). Because participants enrolled in that study were women seeking lifestyle changes post diagnosis, a healthy volunteer effect may explain the differences in MVPA trajectory patterns between the Montreal study and ours. In another cohort study of 548 early stage breast cancer survivors recruited from New York City and Dallas, Lucas et al. analyzed the trajectory of recreational MVPA data collected at 6, 12, and 18 months post diagnosis [34]. Similar to our analyses, Lucas et al. identified 3 distinct MVPA trajectory groups, with 43% of survivors having consistently low MVPA (<0.3 h/week). However, Lucas et al. did not observe decreased MVPA from baseline to 6 months, most likely because baseline MVPA data were not available. In addition, differences in the measurement of MVPA may contribute to the difference in findings. While the current analysis defined MVPA as the total time spent on household chores, recreational activities and transportation, previous studies limited to recreational MVPA only, which may significantly underestimate the overall MVPA level in an older population.

The trajectory analyses revealed that most participants in the Pathways Study reduced or maintained a low level of MVPA in the 24 months following diagnosis. Although higher SES and better psychosocial well-being were associated with being in a trajectory with higher MVPA, these participants decreased MVPA at 6 months, with a slight recovery at 12 months. These findings suggest that cancer survivors who are physically active and have little barriers to engaging in PA may still experience significant loss of MVPA after cancer diagnosis, especially during cancer treatment. Patients should receive education and counseling on the impact of treatment on their daily activities and strategies to prevent loss of activity. More research is needed to better understand the physical and mental barriers to PA during cancer treatment.

Changes in SB showed greater dynamics and variation. For instance, a quarter of participants were “high decreasers” who reduced time spent on SB from 23 h/week (or about 3.2 h/day) at baseline to 16 h/week (or about 2.2 h/day) at 6 months, approaching the recommended 2 h/day limit on SB [35–37]. Another quarter of women changed from spending 2 h/day on SB at baseline to 3 h/day at 6 months. The relatively larger change in SB vs. MVPA suggests that breast cancer survivors may be more likely to change activities of lower intensity after treatment. This observation highlights the need for health education and exercise interventions that not only promote MVPA but also encourage reducing sedentary time.

This study highlighted several predictors of changes in PA in breast cancer survivors. Higher education and higher income strongly predicted higher MVPA in breast cancer survivors, which is consistent with the previous studies showing a direct association between SES and physical activity in the general population [18–22]. The association between low SES and physical inactivity suggests that more resources

Table 3 Multinomial logistic regression of predictors for sedentary behavior trajectory following a breast cancer diagnosis

	High maintainer vs. Low maintainer[a]		High decreaser vs. Low maintainer[a]		Low increaser vs. Low maintainer[a]	
Predictors	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Education (ref = high school or less)						
Some college	1.41 (0.87, 2.30)	0.16	1.22 (0.82, 1.81)	0.33	1.13 (0.75, 1.71)	0.55
College and above	1.84 (1.15, 2.94)	0.01	1.02 (0.70, 1.51)	0.91	1.03 (0.69, 1.54)	0.88
Income (ref = <$50 K)						
$50 K-$89 K	0.66 (0.48, 0.90)	0.01	1.02 (0.76, 1.35)	0.92	0.85 (0.64, 1.15)	0.29
$90 K+	0.64 (0.38, 1.09)	0.10	1.14 (0.73, 1.78)	0.55	0.93 (0.58, 1.49)	0.77
Depressive symptoms (high vs. low)	1.00 (0.68, 1.45)	0.98	1.23 (0.91, 1.67)	0.18	1.18 (0.86, 1.62)	0.30
Optimism (high vs. low)	1.31 (0.96, 1.79)	0.09	1.16 (0.88, 1.52)	0.30	1.08 (0.81, 1.44)	0.60
Social support (high vs. low)	1.86 (1.34, 2.57)	<0.001	1.42 (1.08, 1.87)	0.01	1.26 (0.95, 1.67)	0.11
Worse PWB at 6 months (yes vs. no)	1.12 (0.78, 1.61)	0.53	1.08 (0.79, 1.47)	0.63	1.13 (0.82, 1.56)	0.45
Worse CIPN at 6 months (yes vs. no)	1.21 (0.88, 1.68)	0.25	1.16 (0.87, 1.54)	0.32	1.29 (0.96, 1.73)	0.09
Age at diagnosis (ref = age < 50)						
50–59	0.92 (0.50, 1.71)	0.80	0.98 (0.63, 1.53)	0.94	0.89 (0.56, 1.42)	0.63
60–70	2.15 (1.06, 4.38)	0.03	1.20 (0.70, 2.07)	0.51	1.43 (0.81, 2.53)	0.22
70+	3.35 (1.56, 7.19)	<0.001	2.38 (1.31, 4.34)	<0.001	2.00 (1.06, 3.77)	0.03
Race/ethnicity (ref = non-Hispanic White)						
non-Hispanic Black	0.73 (0.37, 1.42)	0.35	1.15 (0.67, 2.00)	0.61	1.64 (0.98, 2.76)	0.06
non-Hispanic Asian	0.36 (0.22, 0.61)	<0.001	0.74 (0.51, 1.07)	0.11	0.54 (0.36, 0.81)	<0.001
Hispanic	0.28 (0.15, 0.53)	<0.001	0.87 (0.59, 1.29)	0.49	0.55 (0.35, 0.86)	0.01
Other	1.60 (0.58, 4.36)	0.36	2.69 (1.11, 6.50)	0.03	1.07 (0.38, 3.03)	0.89
Postmenopausal (yes vs. no)	1.41 (0.78, 2.52)	0.25	1.26 (0.82, 1.93)	0.30	1.11 (0.70, 1.76)	0.65
Stage (ref = Stage I)						
Stage II	0.85 (0.59, 1.22)	0.39	0.94 (0.69, 1.28)	0.69	0.87 (0.63, 1.21)	0.41
Stage III	0.82 (0.46, 1.49)	0.52	0.50 (0.30, 0.85)	0.01	0.72 (0.43, 1.20)	0.21
Stage IV	1.35 (0.25, 7.38)	0.73	1.26 (0.30, 5.33)	0.75	1.88 (0.45, 7.86)	0.39
Number of lymph node removed						
1 vs. 0	1.17 (0.49, 2.79)	0.72	1.44 (0.67, 3.07)	0.35	2.08 (0.91, 4.74)	0.08
2+ vs. 0	1.64 (0.72, 3.75)	0.24	1.62 (0.79, 3.35)	0.19	2.40 (1.09, 5.26)	0.03
ER/PR status (Positive vs. negative)	0.93 (0.51, 1.68)	0.80	0.87 (0.51, 1.48)	0.60	1.10 (0.64, 1.89)	0.73
Surgery (ref = lumpectomy)						
Mastectomy	0.89 (0.64, 1.24)	0.48	1.06 (0.80, 1.42)	0.68	1.08 (0.80, 1.46)	0.63
None	NE	NE	0.72 (0.14, 3.69)	0.70	0.55 (0.09, 3.34)	0.51
Chemotherapy (ref = none)						
Neoadjuvant	0.73 (0.27, 1.99)	0.54	1.23 (0.58, 2.61)	0.59	2.04 (0.99, 4.19)	0.05
Adjuvant	1.19 (0.80, 1.77)	0.38	1.23 (0.87, 1.72)	0.24	1.28 (0.90, 1.83)	0.17
Hormonal therapy (yes vs. no)	0.97 (0.60, 1.59)	0.91	1.28 (0.81, 2.01)	0.29	0.89 (0.56, 1.40)	0.61
Radiation therapy (yes vs. no)	1.00 (0.71, 1.41)	0.99	0.86 (0.64, 1.16)	0.32	0.86 (0.63, 1.17)	0.33

OR, odds ratio; *CI*, confidence interval; *NE*, not estimable; *HER2*, human epidermal growth factor receptor 2;

ER, estrogen receptor; *PR* progesterone receptor; *CIPN*, chemotherapy-induced peripheral neuropathy; *PWB*, physical well-being

a. Trajectory groups were labeled by the relative level of baseline behavior (high, medium, or low) and the direction of change (increaser, decreaser, maintainer)

should be provided to the low-income, low-education group of breast cancer survivors to facilitate adherence to PA recommendations. However, the associations of SES and income with SB were more complex: patients with higher education but lower household income were more like to maintain a higher level of SB. It is possible that different types of SB are associated with different SES factors. In previous studies, higher education is often associated with computer use and

reading [38, 39], while lower income is associated with TV watching [40, 41]. Future analyses could examine the association between SES and different types of SB in cancer survivors. Further, our results suggest that higher dispositional optimism and greater social support at the time of breast cancer diagnosis may be promoters of engagement in MVPA. This finding is in line with previous studies that explained the individual differences in lifestyle choices following a breast cancer diagnosis using the stress and coping model [42]. In breast cancer survivors, depressive symptoms are the most common stress-related symptoms [23, 43, 44], and depressive symptoms are associated with physical inactivity in breast cancer survivors [15, 45]. In contrast, greater dispositional optimism has been associated with more brisk walking and vigorous physical activities in older women [46, 47]. In addition, higher perceived social support may facilitate stress coping and is linked to increased health behavior, specifically exercise, in cancer survivors [48]. Finally, cancer treatments may also disrupt normal PA, especially during the phase of active treatment [24, 25]. Our results suggest that greater extent of surgery as measured by lymph nodes removed and receipt of adjuvant treatment were more common among participants who reported decreasing MVPA and increasing SB. However, the association between cancer treatment side effects and trajectories of PA behaviors was not evident in this study.

A key advantage of this analysis is the use of multiple analytical methods to identify distinct physical activity trajectories. Unlike other members of the finite mixture model family, such as the growth mixture modeling (GMM) [49], which identifies latent classes of growth patterns based on the underlying subpopulation, the GBTM identifies latent classes of growth patterns based on the shape parameters of growth curves. In addition, GBTM addresses missing data using Full Information Maximum Likelihood (FIML) estimation, which is unbiased and more efficient than methods that delete observations with incomplete data [50]. The use of KmL provides another robust method to validate the trajectory found in GBTM, adding confidence to the reproducibility of our findings.

This analysis also has limitations to consider. An important limitation is the self-reported PA data, which are subject to measurement error comprised of bias and random error. In this analysis, while 58% of participants were "low maintainers" of MVPA, they still reported engaging in 2.73 h/week of MVPA at baseline, which exceeded the American Cancer Society's recommended amount of MVPA for cancer survivors (≥2.50 h/week) [3], suggesting self-reported PA data may overestimate the actual MVPA level. The magnitude of overestimation is considerable in a previous study based on the National Health and Nutrition Examination Study (NHANES) 2005–2006, which showed that the US adults reported 398 min/week of MVPA on average, yet the accelerometer-based estimate of average MVPA was only 62 min/week [51]. The overestimation of MVPA may be due in part to sedentary individuals having the tendency to report any MVPA instead of MVPA that lasts for at least 10 min [52]. Alternatively, SB may be underestimated because SB was defined as sitting activities only, while recent research has indicated that stationary standing activities may not actually be metabolically more active than sitting [53].

In addition, self-reported physical activity data may be inaccurate due to social desirability bias, which refers to the tendency to over- or under-report particular behaviors in order to avoid being viewed negatively [54]. Further, because the trajectory groups are essentially latent variables derived based on the intercept (baseline PA) and slope (rate of PA change) of individual trajectories, both baseline PA, and the rate of change are integral components of the trajectory group definition. Therefore, it is difficult to separate predictors of baseline PA and predictors of PA change when using trajectory groups as the outcome. In sensitivity analyses adjusted for baseline PA, only higher education remained statistically significantly associated with the high maintainer trajectory group of SB, suggesting other predictors of SB trajectory (i.e., income and social support) were mostly associated with the intercept component that defines SB trajectory. In addition, 38% of participants only completed 2 of the 3 PA assessments, which limited the accuracy and validity of the PA trajectories identified in this sample. Finally, this analysis may also suffer from selection bias, as more than 50% of eligible women chose not to enroll in the Pathways Study, and the sample may over-represent women who are employed with health insurance benefits in an integrated health system. Finally, the lack of systematic assessments of cancer treatment side effects may contribute to the null association between cancer treatment-related side effects and PA trajectory groups.

In summary, this analysis indicates that more than 40% of breast cancer survivors decreased time spent on MVPA and 73% maintained or increased sedentary behavior after cancer diagnosis. Socioeconomic status, dispositional optimism, and perceived social support were predictive of post-diagnostic PA trajectory. Given the potential benefit of PA on the overall survival of breast cancer patients, it is important to prioritize interventions aimed at decreasing sedentary time and increasing MVPA in breast cancer survivors who are at high risk of becoming physically inactive post-diagnosis. Our results show that patients most likely decrease MVPA over the course of cancer treatment, suggesting the period from diagnosis to treatment is a good time for health education to prevent loss of PA. In addition, as optimism and social support predict PA trajectories, PA intervention could be delivered through avenues such as patient support groups and other familial/social events to strengthen its effectiveness. Furthermore, because the majority of observational studies rely on self-reported PA data, which are known to be inaccurate and biased, future studies that employ objectively measured PA are necessary to better understand the pattern of PA change in breast cancer survivors.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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