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Research Article

Long-Term Physical Activity Trends in Breast Cancer Survivors

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Abstract

Background: Physical activity is associated with reduced mortality and higher quality of life in breast cancer survivors; however, limited data on the prevalence of activity and long-term trends after diagnosis are available.

Methods: A multiethnic cohort of 631 women (18–64 years) with stage 0 to IIIA breast cancer was followed for 10 years. Recreational aerobic activity (MET-h/wk) was ascertained for the year before diagnosis (baseline), 24 months, 5 years, and 10 years after enrollment. Women were classified according to U.S. physical activity guidelines ($\geq$150 min/wk moderate or $\geq$75 min/wk vigorous activity). The OR for meeting guidelines at 5 and 10 years according to baseline factors was estimated using logistic regression. The change in MET-h/wk was predicted using linear regression.

Results: Prediagnosis, 34% of women met physical activity guidelines; 34.0%, 39.5%, and 21.4% met guidelines at 24 months, 5 years, and 10 years after enrollment, respectively. Less than 8% of survivors met guidelines at all follow-up periods. Over 10 years, recreational aerobic activity decreased by a mean $\pm$ SD of 4.3 $\pm$ 16.2 MET-h/wk. Meeting guidelines pre-diagnosis was strongly associated with meeting guidelines at 5 years [OR (95% confidence interval; CI): 2.76 (1.85–4.1)] and 10 years [OR (95% CI): 3.35 (2.13–5.28)]. No other demographic or prognostic factors were significantly associated with the 10-year change in MET-h/wk.

Conclusion: The vast majority of early breast cancer survivors do not meet national exercise recommendations 10 years postdiagnosis.

Impact: Physical activity levels are low in breast cancer survivors across the 10 years postdiagnosis; nonetheless, the predictors of activity in this population remain poorly understood. *Cancer Epidemiol Biomarkers Prev; 22(6); 1153–61. ©2013 AACR.*

Introduction

With 2.9 million female breast cancer survivors living in the United States and another 80,000 added each year (1), there is considerable interest in factors that promote the long-term health and well-being of these women. Available evidence supports a positive effect of postdiagnosis exercise participation on quality of life, fatigue, and body image (2), as well as the prevention, attenuation, or reversal of other persistent adverse treatment effects including pain, depression, and weight gain (3, 4). Regular physical activity is associated with reduced all-cause mortality (5) as well as extended survival from breast cancer (5, 6, 7–9), even among women who were inactive prior to diagnosis (5, 8). Because a significant number of all metastases and recurrences occur more than 5 years after the initial diagnosis (i.e., overall cumulative incidence of developing distant metastases is 20% at 4 years, 30% at 8 years, and 36% at 12 years; refs. 10–14), physical activity may be a modifiable factor to improve the prognosis and quality of life of long-term survivors.

A previously published report describing physical activity levels among breast cancer survivors in the Health, Eating, Activity and Lifestyle (HEAL) study up to 30 months postdiagnosis indicated that, on average, participants decreased their total activity by approximately 2 hours per week from prediagnosis to postdiagnosis (15). In a recent analysis from the Women's Health Initiative Observational Study and clinical trials, postdiagnosis physical activity levels decreased among 25% of women with breast cancer and were unchanged in 35%

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over a maximum of 6 years of follow-up (5). Age-related declines in physical activity are well documented (16, 17); however, the degree to which a breast cancer diagnosis affects long-term physical activity participation has not been well characterized, in part, because of the difficulty in maintaining a cohort of survivors over an extended period of time.

Identifying opportunities for physical activity promotion by characterizing physical activity participation after breast cancer diagnosis and treatment is important given that breast cancer survivors represent a large and growing population of women (18) for whom postdiagnosis modifiable lifestyle factors are of particular interest. Accordingly, the purpose of this report is to describe the level of physical activity participation in a multiethnic cohort of breast cancer survivors who were followed for 10 years after their initial postdiagnosis assessment.

Materials and Methods

Setting, patients, and recruitment

The HEAL study is a multiethnic prospective cohort study that enrolled 1,183 women with a first primary breast cancer (Stage 0–IIIA) identified from Surveillance Epidemiology and End Results (SEER) registries in New Mexico, Los Angeles County, California, and Western Washington. The purpose of the HEAL study is to determine whether lifestyle, hormones, and other exposures affect breast cancer prognosis (8, 19, 20). The study design, procedures, and data collection methods have been previously described in detail (20, 21). Briefly, in New Mexico, 615 women ($\geq$18 years) diagnosed between July 1996 and March 1999, and living in Bernalillo, Santa Fe, Sandoval, Valencia, or Taos counties were recruited. In Western Washington, 202 women (age range: 40–64 years) diagnosed between September 1997 and September 1998, and living in King, Pierce, or Snohomish counties were recruited. In Los Angeles County, 366 African American women (age range: 35–64 years) diagnosed between May 1995 and May 1998 who had participated in the Los Angeles portion of the Women's Contraceptive and Reproductive Experiences (CARE) Study or in a parallel case-control study of *in situ* breast cancer were added to the HEAL cohort.

All study protocols were approved by the Institutional Review Boards of each participating center, in accordance with an assurance filed with and approved by the U.S. Department of Health and Human Services. Written informed consent was obtained from each participant. Women completed an interview approximately 6 months after diagnosis (baseline), and were contacted for follow-up assessments at 24 months, 5 years, and 10 years after enrollment. At the 10-year follow-up, 631 women completed a physical activity assessment and are included in this analysis (New Mexico: $n = 315$; Western Washington: $n = 202$; and Los Angeles County: $n = 366$). Of these, 631 and 606 reported physical activity at 24 months and 5 years, respectively. One woman had incomplete physical activity data at baseline and is, therefore, excluded from some analyses.

Data collection

Physical activity. At the Western Washington and New Mexico sites, physical activity data were collected using an interview-administered questionnaire developed on the basis of the validated Modifiable Activity Questionnaire (MAQ; ref. 22). The type, duration, and frequency of sports/recreational and household activities carried out in the past year were assessed. At the Los Angeles County site, a lifetime history of physical activity was obtained at baseline by asking respondents to recall any/all activities carried out for at least 1 h/wk. The ages at which the activity was done and the number of years the activity was done were recorded, as well as the average number of hours per week during the period of activity. All follow-up assessments (i.e., at 24 months, 5 years, and 10 years) were standardized across sites, again on the basis of the MAQ, and subjects were asked specifically about physical activities during the year prior to the interview.

Given the reported association between recreational aerobic activity and breast cancer prognosis in the literature (5, 6, 7–9), we chose to focus our analysis on this type of activity. Sixteen recreational physical activities (fast walking, jogging, running, hiking, aerobics, bicycling, swimming, tennis, golf, skiing, nordic track, fast dancing, bowling, rowing, horseback riding, and light calisthenics) were consistently assessed across all timepoints and were coded into composite variables for analysis: (i) a continuous variable of MET-h/wk of moderate to vigorous sports/recreation aerobic activity; and (ii) a 3-level categorical variable representing activity sufficient to meet current physical activity guidelines for all adults ($\geq$150 min/wk moderate activity or $\geq$75 min/wk vigorous activity or an equivalent combination) in the United States (23), which was coded as no activity, activity not sufficient to meet guidelines, or meeting guidelines; 150 min/wk of moderate activity is equivalent to approximately 9 MET-h/wk.

For participants from the Western Washington and New Mexico sites, weekly average energy expenditure was computed from reported recreational aerobic activities by assigning MET values for each activity using the revised Compendium of Physical Activities (24). A MET is defined as the ratio of associated metabolic rate for a specific activity divided by resting metabolic rate (3.5 mL of O_2 per kg of body weight) such that a 2-MET activity requires 2 times the resting metabolic energy expenditure as sitting quietly. Each reported activity was categorized as light (<3 METs), moderate (3–6 METs), or vigorous (>6 METs) intensity. Because participants from the Los Angeles County site were added to the HEAL cohort after baseline data collection, total aerobic activity in the year prior to diagnosis was constructed from the lifetime history measure of physical activity that provided METs for each year prior to diagnosis. Follow-up physical

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activity was ascertained as for the other 2 sites. At each timepoint, reported activities were converted to MET-h/wk. A physical activity guideline variable, as described above, was derived in a manner compatible with data from the other 2 sites.

Covariates. Demographic information, including standard measures of age, education, and race/ethnicity (African American, Hispanic, or non-Hispanic White), was collected at baseline, as was information on personal and family medical history, smoking, and age at menopause. Measured height and weight at study enrollment were used to compute body mass index (BMI) as weight (kg)/height (m)^2 for participants from Washington and New Mexico. Disease stage was based on the American Joint Committee on Cancer (AJCC) stage of disease classification obtained from the Surveillance, Epidemiology and End Results (SEER) registry records. Breast cancer treatment data were obtained from medical record abstraction and SEER data and were coded as: surgery only; surgery with radiation, or any chemotherapy. Use of tamoxifen was obtained from medical record abstraction and self-reported use at the baseline and 24-month assessments; tamoxifen users were defined as women who used tamoxifen at any time through to the 24-month follow-up period. Menopausal status at baseline was determined using an algorithm (25) that assigned women into pre-, post-, or unclassifiable menopausal status on the basis of age, date of last menstruation, hysterectomy and oophorectomy status, and levels of serum estradiol, estrone, and follicle-stimulating hormone. Comorbid medical conditions were assessed at the 24-month interview by asking participants to report which of 18 medical conditions plus other cancers had ever been diagnosed by a physician, and whether their current activities were limited by any of these conditions. A comorbidity summary score was generated on the basis of the number of medical conditions that limited current activities, categorized as either 0 or 1 or more conditions.

Information on a limited number of covariates was reassessed via self-reported questionnaire at the 5-year and 10-year follow-ups. Changes in marital status, employment, smoking status, and BMI over the 10-year follow-period were, therefore, also considered as predictors of the 10-year change in MET-h/wk. The change in BMI was modeled as a continuous variable. Changes in marital status, employment and smoking status were initially modeled as dichotomous variables (Y/N). Subsequently, the following specific changes were also examined: (i) married or living with partner to other (widowed, divorced, separated); (ii) employed to not employed (including retirement, disability, or other leave); and (iii) current smoker to former smoker.

Statistical analysis

Participant characteristics according to physical activity (0, >0 to 9, or ≥9 MET-h/wk) in the year prior to diagnosis were compared using analysis of variance and χ^2 tests as appropriate. The baseline characteristics of women followed through 10 years and those with missing data were also compared. Linear regression was used to describe the associations between baseline demographic and prognostic factors and physical activity levels (MET-h/wk) at each follow-up, as well as at the 10-year change in MET-h/wk. The ORs for meeting physical activity guidelines at 5 and 10 years after diagnosis were calculated using logistic regression, with and without adjustment for age and BMI as continuous variables. The ORs for increasing (sufficient to meet physical activity guidelines) or decreasing activity over time were similarly calculated according to baseline demographic and prognostic factors. A variety of predictor variables were considered, including: age (<55 vs. ≥55 years at baseline), race/ethnicity/study site (as only African American women were recruited in LA county), education (<college grad, ≥college grad), BMI (<25 vs. ≥25 kg/m^2), smoking status (current vs. never/former), physical activity in the year prior to diagnosis (MET-h/wk), menopausal status (pre vs. post), breast cancer stage at diagnosis (Stages 0 or I vs. Stages II or IIIa), initial breast cancer treatment (surgery only vs. surgery + radiation or any chemotherapy), estrogen receptor (ER) status (ER positive vs. ER negative), tamoxifen use (never vs. ever), the presence of 1 or more female relatives with history of breast cancer (Y/N), and activity-limiting comorbidities (≥1 vs. 0). In the linear models estimating the 10-year change in MET-h/wk, changes in marital status, employment, smoking status, and BMI were additionally examined as covariates.

Statistical analyses were carried out using SAS software, Version 9.2 (SAS Institute, Cary, N.C.; ref. 26). All tests were 2-sided and statistical significance was set at $P < 0.05$.

Results

Characteristics of HEAL participants according to their level of recreational aerobic physical activity in the year prior to diagnosis, as reported at baseline entry into the study, are presented in Table 1. Overall, 37.5% of women reported doing no recreational aerobic activity, 28% reported doing an average of more than 0 to 9 MET-h/wk, and 34% reported doing more than 9 MET-h/wk on average during the year prior to their breast cancer diagnosis.

The mean level of activity in MET-h/wk remained relatively stable over 5 years of follow-up (mean change ± SD: 0.59 ± 16.2 MET-h/wk), with a dramatic decrease occurring between 5 and 10 years postdiagnosis (mean change ± SD: −4.90 ± 14.1 MET-h/wk). This general pattern was evident irrespective of age, BMI, race/ethnicity, or treatment type (Fig. 1).

A substantial proportion of survivors engaged in little or no activity throughout the follow-up period, with 42.0%, 40.7%, and 59.1% reporting less than 3 MET-h/wk (roughly equivalent to walking at an average pace of 2 to 2.9 mph for 1 hour) at 24 months, 5 years, and 10 years after enrollment, respectively. Figure 2 shows the percentage of survivors meeting current U.S. physical activity

Table 1. Baseline characteristics of HEAL breast cancer survivors according to average MET-h/wk of recreational aerobic activity reported for year prior to breast cancer diagnosis

	Physical activity, year prior to diagnosis								
	ALL		0 MET-h/wk $n = 236$		>0–9 MET-h/wk $n = 167$		≥9 MET-h/wk $n = 227$		
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	***P***
Age	54.3	9.2	54.1	9.0	53.9	8.1	54.8	10.1	0.38
BMI (kg/m^2)[a]	26.5	5.5	27.9	6.0	27.4	5.9	25.0	4.2	<0.001
	n	%	*n*	%	*n*	%	*n*	%	
Ethnicity									<0.001
Non-Hispanic White	391	62.0	84	35.6	135	80.8	171	75.4	
Black	160	25.4	128	54.2	7	4.2	25	11.0	
Hispanic	67	10.6	22	9.3	20	12.0	25	11.0	
Other	13	2.1	2	0.9	5	3.0	6	2.6	
Education									<0.001
<High School	21	3.3	14	5.9	2	1.2	5	2.2	
High School and/or some college	352	55.8	153	64.8	81	48.5	117	51.5	
≥College grad	258	40.9	69	29.2	84	50.3	105	46.3	
Menopausal status									0.49
Pre	219	34.7	80	33.9	53	31.7	86	37.9	
Post	381	60.4	141	59.8	106	63.5	133	58.6	
Unknown	31	4.9	15	6.4	8	4.8	8	3.5	
Smoking									0.0002
Never	309	49	111	47.0	90	53.9	107	47.1	
Former	250	39.6	82	34.8	62	37.1	106	46.7	
Current	72	11.4	43	18.2	15	9.0	14	6.2	
Stage[b]									0.74
In situ	153	26.3	57	24.2	44	26.4	52	22.9	
Stage 1	246	42.3	85	36.0	67	40.1	93	41.0	
Stage II–IIIa	182	31.3	74	31.4	47	28.1	61	26.9	
ER status[c]									0.15
Positive	350	24.1	126	74.1	97	80.8	127	85.2	
Negative	95	78.6	44	25.9	23	19.2	27	17.5	
Treatment									0.09
surgery only	196	31.1	87	36.9	47	28.1	62	27.3	
surgery + radiation	236	37.4	74	31.4	65	38.9	96	42.3	
chemotherapy (any)	199	31.5	75	31.8	55	32.9	69	30.4	
Tamoxifen									0.06
No	359	56.9	149	63.1	86	51.5	123	54.2	
Yes	272	43.1	87	36.9	81	48.5	104	45.8	
≥1 female relative with history of breast cancer									0.35
No	339	53.7	139	58.9	88	52.7	112	49.3	
Yes	243	38.5	80	33.9	66	39.5	96	42.3	

P, between-group differences were tested using analysis of variance and χ^2 tests as appropriate
[a]not measured in participants from LA county
[b]*n* = 50 missing
Never smoker = smoked <100 cigarettes in lifetime.
Menopausal status at study enrollment was determined on the basis of age, date of last menstruation, hysterectomy, and oophorectomy status, and serum levels of estradiol, estrone, and follicle-stimulating hormone.
[c]*n* = 1,683, excluded due to: not done (*n* = 82), borderline (*n* = 1), unknown (*n* = 22), not in chart (*n* = 81)
Female relatives included sisters, mother, daughters, grandmother, aunt, or nieces; 49 women responded 'Don't know' regarding 1 or more female relative diagnosed with breast cancer.
Tamoxifen use included any use up until the 24-month follow-up.

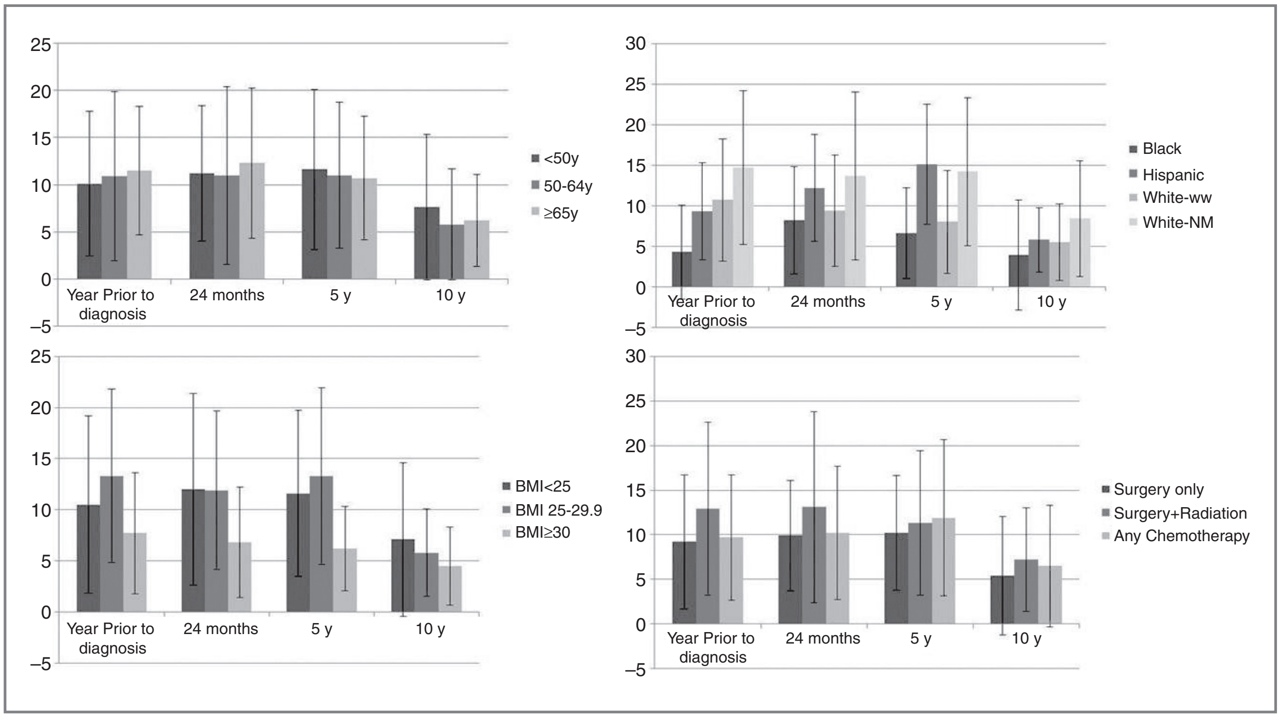
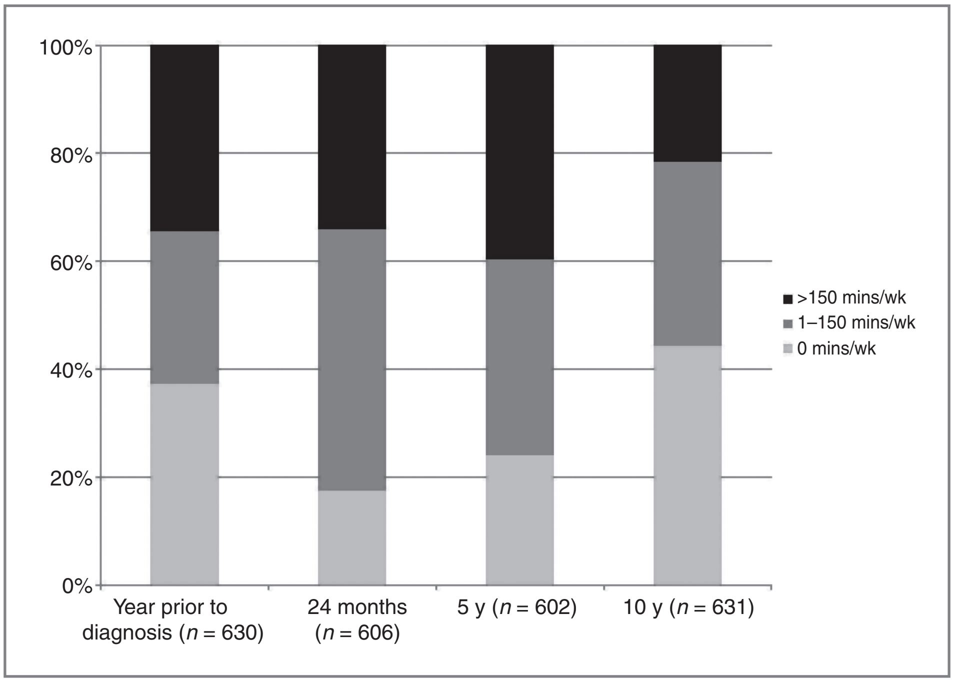


Figure 1. Average MET-h/wk of moderate-to-vigorous aerobic exercise among breast cancer survivors over 10 years of follow-up according to (i) age, (ii) BMI, (iii) race/ethnicity and study site, and (iv) initial breast cancer treatment.

recommendations (23) at each follow-up period. Only 49 women (7.8%) met physical activity guidelines at all timepoints. In contrast, 226 (35.9%) women were insufficiently active to meet physical activity guidelines at any follow-up period, and an additional 135 (21.4%) met guidelines at only 1 timepoint. Sixty-two (9.8%) initially inactive women became sufficiently active to meet current guidelines between baseline and the 10-year follow-up period. Seventy-one women (11.3%) were missing physical activity at 1 or more intermediary timepoints.

In linear regression models, only baseline BMI (P = 0.029) was significantly associated with the 10-year

Figure 2. Percentage of breast cancer survivors meeting aerobic physical activity recommendations over 10 years of follow-up.



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change in MET-h/wk of physical activity. After adjusting for baseline age and BMI in logistic regression models, no demographic or prognostic factor was significantly positively associated with the likelihood of meeting physical activity guidelines at the 5- or 10-year follow-up, apart from being Hispanic (5 years only) and meeting the guidelines in the year prior to diagnosis (Table 2). Being African American or a current smoker was associated with a lower relative likelihood of meeting physical activity recommendations at 5 years only. Changes in BMI, smoking status, marital status, or employment status during the 10-year follow-up were not significantly associated with the 10-year change in physical activity (MET-h/wk).

Discussion

In this cohort of breast cancer survivors, mean aerobic recreational physical activity levels remained relatively constant up to 5 years postdiagnosis with a substantial drop between 5 and 10 years. Only a very small proportion (12.3%) of initially inactive women became sufficiently active to meet physical activity guidelines over 10 years of postdiagnosis follow-up, while the majority of breast cancer survivors were insufficiently active to meet current physical activity guidelines throughout 10 years of follow-up.

Prevalence estimates from the 2007 Behavioral Risk Factor Surveillance System (BRFSS), an ongoing population-based survey of U.S. adults 18 years or older, indicated that 60.4% of women self-reported sufficient moderate-to-vigorous activity (all domains) to meet physical activity recommendations (27). The 2008 National Health Interview Survey (NHIS) estimated that 39.9% of women 18 years or older met physical activity recommendations through recreational activities, with little change over the past 10 years (28). Both of these estimates are higher than those observed in our cohort of breast cancer survivors. Similar to our findings, the prevalence of sufficient

Table 2. Relative odds of meeting physical activity guidelines at 5 and 10 years after diagnosis, according to select baseline demographic and prognostic factors

	OR (95% CI)	
Variable	**5-year postdiagnosis**	**10-year postdiagnosis**
Age <55 years at diagnosis ($n = 344$)	1.00	1.00
Age ≥55 years at diagnosis ($n = 287$)	1.06 (0.73–1.56)	0.95 (0.64–1.39)
BMI <25.0 kg/m^2 ($n = 388$)	1.00	1.00
BMI ≥25.0 kg/m^2 ($n = 343$)	0.86 (0.62–1.21)	1.01 (0.68–1.49)
Non-Hispanic White ($n = 391$)	1.00	1.00
Hispanic ($n = 67$)	1.82 (1.07–3.09)	0.94 (0.51–1.74)
African American ($n = 160$)	0.37 (0.24–0.57)	0.28 (0.16–0.51)
≥College grad ($n = 372$)	1.00	1.00
≥College grad ($n = 258$)	1.34 (0.91–1.96)	1.20 (0.78–1.85)
Never or former smoker ($n = 559$)	1.00	1.00
Current smoker ($n = 72$)	0.32 (0.14–0.73)	0.54 (0.22–1.35)
In situ or Stage 1 ($n = 399$)	1.00	1.00
Stage II–IIIA disease ($n = 182$)	0.84 (0.54–1.31)	0.66 (0.89–1.11)
Estrogen-receptor negative ($n = 95$)	1.00	1.00
Estrogen-receptor positive ($n = 350$)	0.67 (0.35–1.29)	0.66 (0.33–1.31)
Surgery only ($n = 196$)	1.00	1.00
Surgery + radiation ($n = 236$)	1.24 (0.78–1.96)	1.66 (0.97–2.84)
Any chemotherapy ($n = 199$)	1.23 (0.74–2.04)	1.57 (0.87–2.83)
No female relative with breast cancer[b] ($n = 388$)	1.00	1.00
1+ female relative(s) with breast cancer ($n = 243$)	1.38 (1.01–1.88)	1.04 (0.638–1.60)
No comorbidity[a] ($n = 469$)	1.00	1.00
Presence of ≥1 comorbidity ($n = 140$)	0.73 (0.44–1.20)	0.85 (0.48–1.50)
Do not meet PA guidelines prediagnosis ($n = 414$)	1.00	1.00
Meet PA guidelines prediagnosis ($n = 216$)	2.76 (1.85–4.10)	3.35 (2.13–5.28)

Abbreviations: CI, confidence interval; BMI, body mass index; PA, physical activity.
ORs are adjusted for age and baseline BMI.
[a]Information on comorbidities was collected at 24-month follow-up.
[b]Includes 49 women who responded 'Don't know' regarding 1 or more female relatives diagnosed with breast cancer; female relatives included sisters, mother, daughters, grandmother, aunt, or nieces.

activity was lower with advancing age; however, sex-specific estimates by age were not reported, limiting our ability to make direct comparisons.

Our study and both population-based surveys noted above are limited by the reliance on self-reported physical activity data. Recent accelerometer-based estimates of physical activity from the 2003–04 and 2005–06 National Health and Nutrition Examination Survey (NHANES) showed that women without a history of breast cancer participated in moderate-to-vigorous intensity activity for a mean 10.6 min/d, while women with a history of breast cancer participated for a mean 3.7 min/d (29). Thus, the true prevalence of activity in our cohort is likely to be even lower than reported. Future studies of this population will benefit from directly measured physical activity assessment methods and the availability of data from longitudinal and age-stratified population-based cohorts of U.S. women without breast cancer for direct comparison.

Our inability to identify many significant predictors of long-term physical activity participation suggests that the factors influencing physical activity behaviors in breast cancer survivors are complex and may differ from those in the general population. Additional consideration of psychosocial factors and issues related to pain management, fatigue, and specific treatment effects may help to better understand the unique issues faced by cancer survivors and their impact on physical activity participation. Moreover, issues related to perceived neighborhood safety and access to parks and other active recreational opportunities may also be an issue that is particularly relevant to inner city residents such as those from Los Angeles County (30), and could explain, in part, the lower levels of activity reported by African American women in this study.

The finding that prediagnosis physical activity is a strong predictor of postdiagnosis activity up to 10 years after diagnosis is consistent with data from the general population (31) and supports population-wide physical activity promotion. However, a breast cancer diagnosis may provide a unique opportunity to promote the uptake of physical activity among previously inactive women and, therefore, it is important to investigate specific factors associated with physical activity participation in cancer survivors.

In an analysis of women 50 to 79 years of age from the Women's Health Initiative (5), recreational physical activity between pre- and postdiagnosis increased in 40% of women, remained unchanged in 35%, and decreased in 25%. Although estimates of the magnitude of change were not published, these results are similar to those from the current study in which 44% of women reported a net increase in activity over the 10-year follow-up, while 33% remained unchanged (within 1 MET-h/wk of baseline level) and 23% had decreased recreational activity. Our observation of a sizeable drop in activity participation between 5- and 10-year follow-up, despite no loss to follow-up in the analysis sample, and across virtually all subgroups of women, was somewhat surprising. It seems unlikely that this pattern reflects aging alone, given the consistency and magnitude of the trend across all age groups. Whether this reflects a cohort effect or a unique aspect of the cancer survivorship experience is unclear. The ability to make comparisons to other cancer survivor cohorts will be informative in clarifying this issue. The HEAL cohort represents 1 of the few breast cancer survivor cohorts with repeated assessments of physical activity following diagnosis and with 10-year follow-up data on physical activity and outcomes and, thus, provides valuable information on the long-term trends in recreational physical activity participation in this population. However, the current cohort is likely affected by some degree of healthy subject bias given that the women successfully followed for 10 years were younger (54.3 vs. 56.5 years), were less likely to smoke (11.4% vs. 17%), less likely to have stage II or IIIa disease (51.3% vs. 69.5%), less likely to have 1 or more physical activity-limiting comorbidities (33.7% vs. 23.0%) at baseline, and were more likely to meet physical activity guidelines prior to diagnosis (34.3 vs. 24.0%) than those without physical activity data at the 10-year follow-up. Given the manner in which the HEAL cohort was formed, other limitations of this study include the lack of uniform eligibility criteria between study sites, the different questionnaire for self-reported physical activity assessment used at baseline at 1 of the study sites, incompatible assessments of BMI over time between the study sites and the inability to separate race and study site, given that only African American women were recruited from Los Angeles County and 96% of Hispanic women were recruited in New Mexico. In addition, because complete breast cancer recurrence data is not available for the HEAL cohort, this potentially important confounder could not be considered. Finally, for this analysis, we chose to focus only on patterns of recreational aerobic physical activity rather than total activity, including household, transportation, and occupational activities. However, previous analyses that examined multiple domains of activity in this cohort and others suggest that postdiagnosis recreational physical activity is most strongly associated with breast cancer survival (8, 32).

Although cancer treatment is commonly associated with fatigue, pain, and other adverse side effects (33, 34), interventional studies suggest that women undergoing intensive therapy for breast cancer are able to be physically active during and following treatments (35–39). We did not observe any differences in postdiagnosis physical activity according to treatment type in our cohort. However, while regular physical activity participation is a modifiable lifestyle factor with the potential to improve the cancer survival experience, and is endorsed by the American College of Sports Medicine and American Cancer Society (4), a relatively small proportion of breast cancer survivors are regularly active.

In this cohort, only 8% of breast cancer survivors were sufficiently active to consistently meet physical activity guidelines throughout the 10 years after diagnosis, while 40% to 60% of survivors engaged in little or no activity throughout the follow-up period. Given its health

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benefits, ongoing recommendations for physical activity should be made by all healthcare providers caring for breast cancer survivors (40). However, future research should seek to identify the key determinants of exercise across survivorship so that interventions can be appropriately tailored.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

Authors' Contributions

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References

1. DeSantis C, Siegel R, Bandi P, Jemal A. Breast cancer statistics, 2011. CA Cancer J Clin 2011;61:409–18.
2. Duijts SF, Faber MM, Oldenburg HS, van Beurden M, Aaronson NK. Effectiveness of behavioral techniques and physical exercise on psychosocial functioning and health-related quality of life in breast cancer patients and survivors – a meta-analysis. Psychooncology 2011;20:115–26.
3. Schmitz KH, Speck RM. Risks and benefits of physical activity among breast cancer survivors who have completed treatment. Womens Health 2010;6:221–38.
4. Schmitz KH, Courneya KS, Matthews C, Demark-Wahnefried W, Galvao DA, Pinto BM, et al. American College of Sports Medicine roundtable on exercise guidelines for cancer survivors. Med Sci Sports Exerc 2010;42:1409–26.
5. Irwin ML, McTiernan A, Manson JE, Thomson CA, Sternfeld B, Stefanick ML, et al. Physical activity and survival in postmenopausal women with breast cancer: results from the women's health initiative. Cancer Prev Res 2011;4:522–9.
6. Holmes MD, Chen WY, Feskanich D, Kroenke CH, Colditz GA. Physical activity and survival after breast cancer diagnosis. JAMA 2005;293: 2479–86.
7. Holick CN, Newcomb PA, Trentham-Dietz A, Titus-Ernstoff L, Bersch AJ, Stampfer MJ, et al. Physical activity and survival after diagnosis of invasive breast cancer. Cancer Epidemiol Biomarkers Prev 2008;17: 379–86.
8. Irwin ML, Smith AW, McTiernan A, Ballard-Barbash R, Cronin K, Gilliland FD, et al. Influence of pre- and postdiagnosis physical activity on mortality in breast cancer survivors: the health, eating, activity, and lifestyle study. J Clin Oncol 2008;26:3958–64.
9. Sternfeld B, Weltzien E, Quesenberry CP Jr, Castillo AL, Kwan M, Slattery ML, et al. Physical activity and risk of recurrence and mortality in breast cancer survivors: findings from the LACE study. Cancer Epidemiol Biomarkers Prev 2009;18:87–95.
10. Hess KR, Pusztai L, Buzdar AU, Hortobagyi GN. Estrogen receptors and distinct patterns of breast cancer relapse. Breast Cancer Res Treat 2003;78:105–18.
11. Voduc KD, Cheang MC, Tyldesley S, Gelmon K, Nielsen TO, Kennecke H. Breast cancer subtypes and the risk of local and regional relapse. J Clin Oncol 2010;28:1684–91.
12. Wang Y, Yin Q, Yu Q, Zhang J, Liu Z, Wang S, et al. A retrospective study of breast cancer subtypes: the risk of relapse and the relations with treatments. Breast Cancer Res Treat 2011;130:489–98.
13. Iturbe J, Zwenger A, Leone JP, Verdera PP, Vallejo C, Romero A, et al. Treatment of early breast cancer, a long-term follow-up study: the GOCS experience. Breast J 2011;17:630–7.
14. Hess KR, Esteva FJ. Effect of HER2 status on distant recurrence in early stage breast cancer. Breast Cancer Res Treat 2013;137:449–55.
15. Irwin ML, Crumley D, McTiernan A, Bernstein L, Baumgartner R, Gilliland FD, et al. Physical activity levels before and after a diagnosis of breast carcinoma: the Health, Eating, Activity, and Lifestyle (HEAL) study. Cancer 2003;97:1746–57.
16. Caspersen CJ, Pereira MA, Curran KM. Changes in physical activity patterns in the United States, by sex and cross-sectional age. Med Sci Sports Exerc 2000;32:1601–9.
17. Hagstromer M, Troiano RP, Sjostrom M, Berrigan D. Levels and patterns of objectively assessed physical activity – a comparison between Sweden and the United States. Am J Epidemiol 2010;171: 1055–64.
18. Parkin DM, Bray F, Ferlay J, Pisani P. Global cancer statistics, 2002. CA Cancer J Clin 2005;55:74–108.
19. McTiernan A, Rajan KB, Tworoger SS, Irwin M, Bernstein L, Baumgartner R, et al. Adiposity and sex hormones in postmenopausal breast cancer survivors. J Clin Oncol 2003;21:1961–6.
20. Irwin ML, McTiernan A, Baumgartner RN, Baumgartner KB, Bernstein L, Gilliland FD, et al. Changes in body fat and weight after a breast cancer diagnosis: influence of demographic, prognostic, and lifestyle factors. J Clin Oncol 2005;23:774–82.
21. Irwin ML, McTiernan A, Bernstein L, Gilliland FD, Baumgartner R, Baumgartner K, et al. Physical activity levels among breast cancer survivors. Med Sci Sports Exerc 2004;36:1484–91.
22. Kriska A. Modifiable activity questionnaire. Med Sci Sports Exerc 1997;29:S79–S8.
23. United States Department of Health and Human Services. Physical activity guidelines for Americans. U.S. Department of Health and Human Services. Accessed at: www.health.gov/paguidelines; 2008
24. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc 2000;32:S498–504.
25. Alfano CM, Smith AW, Irwin ML, Bowen DJ, Sorensen B, Reeve BB, et al. Physical activity, long-term symptoms, and physical health-related quality of life among breast cancer survivors: a prospective analysis. J Cancer Surviv 2007;1:116–28.
26. SASInstitute. SAS/STAT Software: changes and enhancements through release 9.1. SAS Institute. Cary, NC, 2001–02.

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27. Adabonyan I, Loustalot F, Kruger J, Carlson SA, Fulton JE. Prevalence of highly active adults–Behavioral Risk Factor Surveillance System, 2007. Prev Med 2010;51:139–43.
28. Carlson SA, Fulton JE, Schoenborn CA, Loustalot F. Trend and prevalence estimates based on the 2008 Physical Activity Guidelines for Americans. Am J Prev Med 2010;39:305–13.
29. Lynch BM, Dunstan DW, Healy GN, Winkler E, Eakin E, Owen N. Objectively measured physical activity and sedentary time of breast cancer survivors, and associations with adiposity: findings from NHANES (2003–2006). Cancer Causes Control 2010;21:283–8.
30. Casagrande SS, Whitt-Glover MC, Lancaster KJ, Odoms-Young AM, Gary TL. Built environment and health behaviors among African Americans: a systematic review. Am J Prev Med 2009;36:174–81.
31. Borodulin K, Makinen TE, Leino-Arjas P, Tammelin TH, Heliovaara M, Martelin T, et al. Leisure time physical activity in a 22-year follow-up among Finnish adults. Int J Behav Nutr Phys Act 2012;9:121.
32. Ballard-Barbash R, Friedenreich CM, Courneya KS, Siddiqi SM, McTiernan A, Alfano CM. Physical activity, biomarkers, and disease outcomes in cancer survivors: a systematic review. J Natl Cancer Inst 2012.
33. Knobf MT. Symptoms and rehabilitation needs of patients with early stage breast cancer during primary therapy. Cancer 1990;66:1392–401.
34. Shimozuma K, Ganz PA, Petersen L, Hirji K. Quality of life in the first year after breast cancer surgery: rehabilitation needs and patterns of recovery. Breast Cancer Res Treat 1999;56:45–57.
35. Hayes S, Rye S, Battistutta D, Yates P, Pyke C, Bashford J, et al. Design and implementation of the Exercise for Health trial – a pragmatic exercise intervention for women with breast cancer. Contemp Clin Trials 2011;32:577–85.
36. Chou FY, Dodd MJ, Paul SM. Timing and sustainability of an exercise intervention in women with breast cancer during and after cancer treatment. Oncol Nurs Forum 2012;39:91–7.
37. Djuric Z, Ellsworth JS, Weldon AL, Ren J, Richardson CR, Resnicow K, et al. A diet and exercise intervention during chemotherapy for breast cancer. Open Obes J 2011;3:87–97.
38. Rahnama N, Nouri R, Rahmaninia F, Damirchi A, Emami H. The effects of exercise training on maximum aerobic capacity, resting heart rate, blood pressure and anthropometric variables of postmenopausal women with breast cancer. J Res Med Sci 2010;15:78–83.
39. Swenson KK, Nissen MJ, Henly SJ. Physical activity in women receiving chemotherapy for breast cancer: adherence to a walking intervention. Oncol Nurs Forum 2010;37:321–30.
40. Doyle C, Kushi LH, Byers T, Courneya KS, Demark-Wahnefried W, Grant B, et al. Nutrition and physical activity during and after cancer treatment: an American Cancer Society guide for informed choices. CA Cancer J Clin 2006;56:323–53.

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