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Relationship between Self-Reported and Objectively-Measured Physical Activity and Subjective Memory Impairment in Breast Cancer Survivors: Role of Self-Efficacy, Fatigue and Distress

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Abstract

Purpose—Many breast cancer survivors report cancer and cancer treatment-associated cognitive change. However, very little is known about the relationship between physical activity and subjective memory impairment (SMI) in this population. The purpose of this study is to examine the relationship between physical activity and SMI and longitudinally test a model examining the role of self-efficacy, fatigue and distress as potential mediators.

Methods—Post-treatment breast cancer survivors (N=1477) completed measures of physical activity, self-efficacy, distress (depression, concerns about recurrence, perceived stress, anxiety), fatigue and SMI at baseline and 6-month follow-up. A subsample (n= 362) was randomly selected to wear an accelerometer. It was hypothesized that physical activity indirectly influences SMI via exercise self-efficacy, distress and fatigue. Relationships were examined using panel analysis within a covariance modeling framework.

Results—The hypothesized model provided a good fit in the full sample ($\chi^2 = 1462.5$, $df = 469$, $p = < 0.001$; CFI= 0.96; SRMR= 0.04) and the accelerometer subsample ($\chi^2 = 961.8$, $df = 535$, $p = < 0.001$, CFI = 0.94, SRMR= 0.05) indicating increased physical activity is indirectly associated with reduction in SMI across time, via increased exercise self-efficacy and reduced distress and fatigue.

Conclusions—Higher levels of physical activity, lower levels of fatigue and distress and higher exercise self-efficacy may play an important role in understanding SMI in breast cancer survivors across time. Future research is warranted to replicate and explore these relationships further.

Keywords

physical activity; breast cancer survivors; subjective memory impairment; fatigue; depression; stress; self-efficacy

BACKGROUND

Increasing evidence indicates that breast cancer survivors may report higher levels of subjective cognitive impairment than healthy age-matched controls [1, 2] and that these discrepancies may persist after treatment cessation [3]. Subjective memory impairment (SMI) is one of the most commonly reported cognitive problems with wide variation in estimates of its prevalence ranging from 14% to 95%, depending on measurement method used [4]. SMI refers to perceived memory difficulties experienced in daily life and satisfaction with memory functioning [4, 5]. Higher levels of subjective cognitive impairment have been independently associated with increased difficulties with activities of daily living, working life, and quality of life in breast cancer survivors [6]. Despite the high frequency of SMI, the data examining SMI in relation to objective neuropsychological assessments of memory impairment and neuroimaging is mixed with some studies observing no associations and others observing associations [4, 5]. However, SMI has been strongly and consistently associated with depression, anxiety and fatigue [5]. Thus, it has been suggested that SMI and other forms of subjective cognitive impairment may be indicative of emotional distress [4]. Because the number of longer-term breast cancer survivors continues to increase and such a large proportion of these women report SMI, it is important to explore potential modifiable psychological and behavioral factors so SMI can be appropriately identified, treated and prevented [3, 7].

Cancer is a complex disease that results in many physical, psychological, and emotional side effects that can persist well beyond active treatment. As a result, cancer survivors often change the way in which they allocate their cognitive resources and effort in order to cope with the disease and its side effects [7]. While there have been several studies exploring the relationship between SMI and anxiety, depression and fatigue in breast cancer survivors, fewer studies have examined whether other cognitive processes/perceptions (e.g. beliefs, perceptions) or behavioral factors (e.g. diet, medication adherence, physical activity) are related to SMI. Two factors that may be of particular interest are self-efficacy and physical activity.

Lower self-efficacy of various types (i.e. interpersonal and instrumental) has been associated with poorer performance on memory tasks in the general population and has been shown to be predictive of cognitive change in older adults [8, 9]. Lower symptom management self-efficacy has been associated with elevated psychological distress [10] while lower exercise self-efficacy has been associated with increased depression and fatigue [11] and poorer quality of life [12] in breast cancer survivors. In addition, symptom management self-efficacy has been shown to mediate the relationship between SMI and depression, anxiety and quality of life in hematological cancer survivors [10]. Changes in resource allocation necessary to cope with breast cancer, may negatively impact women's self-efficacy for regulating and coping with their emotions, thoughts and behaviors which, in turn, may result in perceptions of constrained and impaired memory functioning [7, 13].

In contrast, increased physical activity has been consistently and positively associated with the maintenance and improvement of objectively-measured cognitive functioning, particularly executive functioning and memory [14]. Moreover, higher physical activity [15]

and fitness [16] have been associated with lower SMI in the general population and older adults. Emerging cross-sectional evidence indicates increased moderate to vigorous intensity physical activity and aerobic fitness may also be related to improved cognitive functioning among cancer survivors [17–19]. Physical activity is also consistently, positively associated with improved psychosocial outcomes and quality of life among breast cancer survivors [20]. While physical activity is reciprocally related to exercise self-efficacy (i.e. greater physical activity is associated with greater self-efficacy and vice versa) [21], increasing evidence indicates the relationship between physical activity and psychosocial outcomes (i.e. fatigue, quality of life) may be mediated by exercise self-efficacy in breast cancer survivors [11,12]. As such, the relationship between physical activity and SMI may also be mediated by exercise self-efficacy, alone, and the pathways between physical activity, self-efficacy and other psychosocial factors.

The purpose of the present study was to examine the relationship between physical activity, psychological factors (i.e. stress, depression, anxiety and fear of cancer recurrence), exercise self-efficacy and SMI in a sample of breast cancer survivors at baseline and among potential changes in these variables over the 6 month study period when controlling for baseline associations and stability in measures across time. We hypothesized changes in physical activity participation over the 6-month period would be indirectly associated with changes in SMI via changes in exercise self-efficacy which would, in turn, directly, and indirectly influence changes in SMI, via changes in distress and fatigue (see Figure 1). Specifically: a) increases in physical activity would be directly associated with increases in exercise self-efficacy; b) increases in exercise self-efficacy would, in turn, be associated with reduced distress and fatigue; c) reduced distress would be associated with reductions in fatigue and SMI and d) reduced fatigue would be associated with reduced SMI. This model may provide a better understanding of the potential relationships among PA, psychosocial factors and SMI and inform future investigations and interventions in breast cancer survivors.

METHODS

Participants

This study consists of a subsample of women recruited to participate in a larger study. Women were included in the present study if they were aged 18 years and older, had been diagnosed with breast cancer, were English-speaking, had access to a computer, and had completed active treatment (i.e. chemotherapy and radiation).

Measures

Demographics—Self-reported marital status, age, race, ethnicity, occupation, income, and education were collected.

Health and cancer history—Participants' were asked to indicate (*yes or no*) whether or not they have been diagnosed with a list of 18 different comorbidities (i.e. diabetes, obesity, hypertension). All items with a positive response were summed to obtain total number of comorbidities. Women also self-reported information regarding their breast cancer (i.e. stage

of disease, time since diagnosis in months, treatment regime) and menopausal status at diagnosis. Self-reported height and weight were used to calculate body mass index (BMI).

Subjective Memory Impairment—The Frequency of Forgetting Questionnaire [22] was used to assess the frequency with which participants had forgotten things (e.g. names, where they have put things, directions) on a seven-point Likert scale from 1 (*always*) to 7 (*never*). There are 4 subscales: general memory rating (1 item); general frequency of forgetting (4 items), frequency of forgetting when reading (2 items) and remembering past events (2 items). Items from each subscale were summed to obtain subscale scores and all items were summed to obtain a total score. Lower scores reflect a greater frequency of forgetting. Scale reliability was excellent at baseline and follow-up ($\alpha = 0.89$ for both).

Hospital Anxiety and Depression Scale [23]—This scale assesses the frequency of depressive states (7 items) and anxiety (7 items) over the past week on a 4-point Likert scale from 0 (*not at all*) to 3 (*most of the time*). Individual items for each subscale were summed to achieve total scores ranging from 0 to 21. Higher scores are indicative of greater symptomology. The reliability of both subscales was adequate at baseline ($\alpha = 0.82$; $\alpha = 0.83$) and follow-up ($\alpha = 0.82$; $\alpha = 0.84$) for the depression and anxiety subscale, respectively.

Perceived Stress Scale [24]—This 10-item scale was used to measure participants' perception of stress during the last month on a scale ranging from 0 (*never*) to 4 (*very often*). Positively stated items are reverse scored and all items were summed to obtain a total stress score ranging from 0 to 40 with higher scores indicative of greater perceived stress. The reliability was excellent and baseline and follow-up ($\alpha = 0.90$ at both).

Concerns About Recurrence Scale [25]—The 4-item overall fear of recurrence subscale was used to assess women's concerns about breast cancer recurrence. Scores are given on a 6-point Likert scale that can range from 1 (*not at all*) to 6 (*very*). Total scores were obtained by summing items and dividing by 4 to obtain values between 1 and 6 with higher scores reflecting more concerns about breast cancer recurrence. Reliability was acceptable at baseline and follow-up ($\alpha = 0.97$ for both).

Fatigue Symptom Inventory [26]—This scale was used to assess the severity (4 items), frequency (2 items), and perceived interference (7 items) of fatigue. Items from each scale were summed to obtain subscales, and higher scores are reflective of greater fatigue. The reliability was acceptable at baseline ($\alpha = 0.89$; $\alpha = 0.94$; $\alpha = 0.77$) and 6 months ($\alpha = 0.91$; $\alpha = 0.95$; $\alpha = 0.81$) for the severity, interference, and duration subscales, respectively.

Godin Leisure Time Exercise Questionnaire [27]—This questionnaire assessed participants' frequency of strenuous (e.g., jogging), moderate (e.g., fast walking), and mild (e.g., easy walking) exercise over the past seven days and the average amount of time they participated in these activities. Activity frequencies were multiplied by 9, 5, and 3 metabolic equivalents, respectively, and summed to create a total leisure time activity score.

Actigraph accelerometer (model GT1M, Health One Technology, Fort Walton Beach, FL)—The Actigraph, a valid and reliable objective physical activity measure [28], was used to measure physical activity in a random subsample of the study population. These women were instructed to wear the monitor for seven consecutive days on the non-dominant hip during all waking hours, except for when bathing or swimming. Activity data was collected in one-minute intervals (epochs). A valid day of accelerometer wear was defined as wearing the monitor for 10 hours with no more than 60 minutes of consecutive zero-values. Each minute of wear time was classified according to intensity (counts/min) using commonly accepted activity count cut-points [29] as follows: sedentary (<100), light (100–2019), and moderate to vigorous (≥2020). The number of minutes with intensity counts ≥100 was taken as an estimate of total time spent active for a given day and were divided by number of days of wear time to reach the average daily minutes of physical activity. Only data for individuals with a minimum of 3 valid days of wear time at both time points were included in analyses. All values were adjusted for wear time to control for potential difference between individuals.

Exercise Self-efficacy—The 6-item Exercise Self-Efficacy Scale [30] was used to assess participants' beliefs in their ability to exercise five times per week, at a moderate intensity, for 30 minutes per session at two week increments over the next 12 weeks. The 15-item Barriers Self-Efficacy Scale [30] assessed participants' perceived capabilities to exercise three times per week for 40 minutes over the next two months in the face of barriers to participation. Items from each scale are scored on a 100-point percentage scale with 10-point increments, ranging from 0% (*not at all confident*) to 100% (*highly confident*). For each measure, total scores were calculated using the average confidence rating. The reliability was excellent at baseline ($\alpha = 0.99$; $\alpha = 0.96$) and follow-up ($\alpha = 0.99$; $\alpha = 0.96$) for exercise self-efficacy and barriers self-efficacy, respectively.

Recruitment and Randomization

All study procedures and recruitment methods were approved by the university institutional review board are detailed in prior studies from this sample [11, 12]. Briefly, participants were recruited via an e-blast sent to the Army of Women,[®] a nationwide database to connect women interested in breast cancer-related research with researchers, University e-mail, fliers, print media, and on-line community groups and postings. Of those women who expressed initial interest (N = 2,546), 1631 qualified for participation and completed informed consent (N = 1,631). A sub-group of individuals (n=500) were completely randomly assigned using a pre-populated computer algorithm to wear an accelerometer for 7 days at baseline and 6 months. At 6-month follow-up, 1527 women completed all survey data and 370 had valid accelerometer data at both time points. For the purposes of this study we only included women who were post-treatment (n=1,477 for analyses using self-report and n=362 for analyses using accelerometer data).

Data Collection

Women randomized to the survey only group were sent an individualized secure link to the study questionnaires. Women randomized to wear the accelerometer were sent a link to the study questionnaires on the day their study packet containing an accelerometer, related study

materials and a self-addressed stamped envelope was mailed. All participants were instructed to return study materials within two weeks of receipt. Reminder e-mails for surveys were sent on a bi-weekly basis until questionnaires were complete or participants had been contacted three times, whichever came first. Women were reminded to return accelerometers until they were received by study investigators. Identical procedures were followed for both groups at 6 months.

Data Analysis

Independent sample t-tests were conducted to examine changes among model variables across the 6 month study period. To examine the hypothesized relationships, panel analyses within a covariance framework were conducted in Mplus V6.0 [30]. Panel models are ideally suited to the analysis of hypothesized, theoretically-based relationships. This approach allowed for the examination of the hypothesized relationships at baseline and those same relationships among changes in the constructs at 6 months controlling for all other variables in the model. We conducted two separate panel analyses. The first tested the hypothesized model in all study participants using self-reported physical activity data whereas the second tested the hypothesized model in the accelerometer subgroup only. Age, education, income, body mass index, number of comorbidities, time since diagnosis, disease stage, menopausal status at diagnosis, adjuvant treatment type received (chemotherapy and/or radiation therapy), and current receipt of hormone therapy were controlled for in each of the analyses.

The robust full-information maximum likelihood (FIML) estimator was used in the present study [32] as a result of preliminary analyses indicating missing data were missing at random (MAR). A total of 1,203 women (81.4%) had at least some data at 6 month follow-up. The extent of missing data ranged from 2.4% (Frequency of Forgetting remembering past events subscale) to 9.5% (physical activity) at baseline. Missing data at 6-months ranged from 18.7% (Frequency of Forgetting general memory rating and frequency of forgetting subscale) to 24.1% (anxiety), and was largely the result of loss to follow-up or not completing the full questionnaire battery.

Based on prior research examining the constructs included in our model, the following hypothesized relationships were tested (see Figure 1): (a) a direct path from physical activity to exercise self-efficacy; (b) a direct path from exercise self-efficacy to distress; (c) a direct path from exercise self-efficacy to fatigue and (d) a direct path from distress to fatigue and (e) distress to SMI and from fatigue to SMI. Exercise self-efficacy, fatigue and distress were measured as latent constructs. Self-efficacy used the total scores from the Barrier Self-efficacy Scale and the Exercise Self-Efficacy Scale as indicators. The indicators of fatigue consisted of the three Fatigue Symptom Inventory subscales (interference, duration, and severity) and the indicators of distress were the total scores from the Concerns About Recurrence Scale and Perceived Stress Scale and the depression and anxiety subscale score from the Hospital Anxiety and Depression Scale. SMI was modeled as a latent construct using the 4 subscales of the Frequency of Forgetting Scale. For the accelerometer subsample, physical activity was modeled as a latent construct with the GLTEQ total score and average accelerometer counts as indicators. Stability coefficients were calculated to

reflect correlations between the same variables across time while controlling for the influence of all other variables in the model [33]. In addition, the modification indices were examined for other potential relationships among model constructs and potential reciprocal relationships.

The chi-square statistic assessed absolute fit of the model to the data. The standardized root means residual (SRMR) and Comparative Fit Index⁴⁶ (CFI) were also used to determine the fit of the model. SRMR values approximating 0.08 or less demonstrate close fit of the model while CFI values of .90 and .95 indicate minimally acceptable and good fit value and values, respectively [34].

RESULTS

Participant Characteristics

We recruited a nationwide sample of breast cancer survivors ($M_{age} = 56.3$, $SD = 9.3$) as participants for this study. Demographic and disease characteristics of the sample are presented in Table 1. The majority of the women were white (96.9%) and non-Hispanic/Latino (98.6%). Two-thirds of the sample (67.3%) had at least a college degree, and 86.4% of the sample had an annual household income greater than or equal to \$40,000. The average time since diagnosis was 86.8 (± 70.4) months and the majority of women were diagnosed with ductal carcinoma in situ (19.2%) or early stage disease (67.0% stage I or stage II). The majority of women had received chemotherapy (59.4%) and 43.3% were currently taking some form of hormonal therapy. Finally, 71.9% of the sample reported at least one chronic health condition. Details on specific conditions reported is previously published.

Model Results

Table 2 contains the means, standard deviations, and t-values for each of the factors in the physical activity and SMI model. Briefly, over the six month study period, women experienced a significant ($p < 0.05$) decline in exercise self-efficacy, fatigue severity, fatigue interference, and objective and self-reported physical activity. Fatigue duration and frequency of forgetting when reading significantly increased while barriers self-efficacy, all other frequency of forgetting subscales and depression did not change over the 6-month study period.

Full sample—The proposed model provided a good fit to the data ($\chi^2 = 1030.82$, $df = 320$, $p = < 0.001$; CFI = 0.96; SRMR = 0.04). Overall, the stability coefficients were acceptable and ranged from 0.45 (fatigue) to 0.82 (distress). This model is shown in Figure 2a. Bi-directional correlations and stability coefficients are omitted from the figure for clarity.

At baseline, breast cancer survivors who participated in more physical activity had significantly ($p < 0.05$) higher exercise self-efficacy ($\beta = 0.53$). In turn, more efficacious breast cancer survivors had significantly lower levels of fatigue ($\beta = -0.12$) and distress ($\beta = -0.32$). Survivors who reported higher levels of distress also reported higher levels of fatigue ($\beta = 0.63$). Finally, higher levels of distress ($\beta = -0.31$) and fatigue ($\beta = -0.18$) were associated with lower Frequency of Forgetting scores which is indicative of greater SMI. Additionally, the indirect paths from physical activity to SMI via exercise self-efficacy and

distress, exercise self-efficacy and fatigue and exercise self-efficacy, distress and fatigue were all significant.

At 6-month follow-up, increases in physical activity were significantly associated with increases in exercise self-efficacy ($\beta = 0.27$). In turn, women who reported increases in exercise self-efficacy, reported decreased levels of distress ($\beta = -0.08$) and fatigue ($\beta = -0.12$). Increased levels of distress were associated with increased fatigue levels ($\beta = 0.39$). Finally, higher levels of distress ($\beta = -0.19$) and fatigue ($\beta = -0.10$) were associated with greater SMI. There were statistically significant indirect paths between residual changes in physical activity and residual changes in SMI via residual changes in exercise self-efficacy and distress, exercise self-efficacy and fatigue and exercise self-efficacy, distress and fatigue. The magnitude of associations among model constructs was moderate to high [35] (β range: -0.12 to 0.53) at baseline for all pathways examined. At follow-up, the magnitude of model relationships declined slightly, but the majority were still moderate (β -range: -0.08 to 0.27). This was expected as this model accounts for baseline relationships and stability of measures across time.

Accelerometer Subgroup—The proposed model was an adequate fit to the data ($\chi^2 = 514.68$, $df = 320$ $p = <0.001$, CFI = 0.96, SRMR = 0.04). Results from this model are shown in Figure 2b and are almost identical to those from the whole sample.

Relationship between Model Variables and Demographic and Disease Characteristics

At baseline, in the full sample, older age was significantly associated with less distress ($\beta = -0.29$) and increased exercise self-efficacy ($\beta = 0.10$). Additionally, women who reported more comorbidities reported higher levels of fatigue ($\beta = 0.12$) and distress ($\beta = 0.27$) and lower exercise self-efficacy ($\beta = -0.12$) and self-reported physical activity ($\beta = -0.09$). Higher BMI was associated with higher fatigue ($\beta = 0.07$) and lower exercise self-efficacy ($\beta = -0.12$), self-reported physical activity ($\beta = -0.20$) and SMI ($\beta = 0.07$). Higher income was associated with higher self-efficacy ($\beta = 0.07$). Higher education was associated with lower SMI ($\beta = 0.10$) and greater self-reported physical activity ($\beta = 0.11$). Additionally, longer time since diagnosis was significantly associated with lower fatigue ($\beta = -0.08$) and distress ($\beta = -0.08$). Finally, receipt of chemotherapy was associated with lower SMI ($\beta = 0.12$). At follow-up, higher education was associated with increased fatigue ($\beta = 0.04$) and more advanced disease and increased number of comorbidities were associated with lower self-reported physical activity ($\beta = -0.07$ and -0.05 , respectively). Finally, higher BMI was associated with lower SMI ($\beta = 0.05$).

In the accelerometer subsample, younger age ($\beta = -0.26$), higher education ($\beta = 0.13$), less advanced disease stage ($\beta = -0.14$), longer time since diagnosis ($\beta = 0.14$), fewer comorbidities ($\beta = -0.12$) and lower BMI ($\beta = -0.14$) were all associated with increased accelerometer-assessed physical activity at baseline. No demographic or disease factors were significantly related to accelerometer-assessed activity at follow-up.

CONCLUSIONS

Although physical activity has consistently been shown to be associated with improved objective and self-reported cognitive functioning in the general population and aging adults, few studies have examined these relationships in cancer survivors. To the best of our knowledge, this is the first study to examine the relationship between physical activity, psychosocial factors, exercise self-efficacy, and SMI in any cancer survivor group. As hypothesized, the influence of physical activity on SMI was indirect rather than direct, operating through exercise self-efficacy, distress and fatigue. The hypothesized relationships among changes in these constructs over a 6 month period were supported when controlling for baseline relationships and covariates. Further, the model held in the subsample with objectively measured physical activity.

Our findings regarding an inverse relationships between SMI and psychosocial factors are consistent with other studies in cancer survivors that have demonstrated an inverse negative relationship between cognitive functioning and anxiety [36], depression [37] and fatigue [38]. The observed indirect associations between higher physical activity and higher self-efficacy and lower SMI represent novel findings in breast cancer survivors. These results are consistent with findings from the general population [16] and hematopoietic stem cell transplant survivors [10] that demonstrate an inverse association between self-efficacy and SMI and physical activity and SMI [15]. The present study provides initial evidence to indicate that, in addition to psychosocial well-being, exercise self-efficacy and physical activity may be related to SMI in breast cancer survivors.

The indirect relationships between increased physical activity participation, higher exercise self-efficacy, better psychosocial well-being and higher SMI in this study, provide preliminary evidence to indicate physical activity may be a potentially effective intervention for reducing SMI in breast cancer survivors. Additional, potential mechanisms underlying the relationship between physical activity and SMI and other measures of cognitive functioning include improved cardiorespiratory fitness, increased neurogenesis and changes in neurochemicals (e.g. BDNF, IGF; [14]). Future research is warranted to understand these relationships and potential mechanisms further.

Self-efficacy may exert its influence on distress, fatigue and SMI via its impact on both psychological and biological processes. Cancer is a complex disease that results in many physical, psychological, and emotional side effects that can persist well beyond active treatment. Changes in cognitive resource allocation needed to manage these symptoms may result in lower self-efficacy and compromised executive functioning and increased perceptions of impaired memory functioning [7]. Alternatively, low self-efficacy and high levels of anxiety, depression and stress may be indicative of negative affectivity bias which may lead those experiencing these symptoms to be more aware of memory impairment or interpret lapses in memory more negatively [39]. Negative affectivity may also increase the likelihood of a breast cancer survivor identifying as “sick” which may set in motion a self-perpetuating process whereby “sickness behavior” is increased and symptom self-management, cognitively challenging tasks and healthy behaviors are decreased [39]. In turn, this may lead to decreased self-efficacy for symptom management, cognitive tasks and

health behaviors which may result in further increases in psychosocial problems, cognitive dysfunction and unhealthy behaviors [40]. In experimental studies where self-efficacy is manipulated via false feedback, individuals who receive feedback designed to elevate self-efficacy report more positive well-being and reduced levels of psychological distress, fatigue and state anxiety during a single bout of activity [41]. Thus, prolonged physical activity participation may influence distress, fatigue and SMI through a sustained, additive effect on exercise self-efficacy. Finally, increased exercise self-efficacy may impact distress, fatigue and SMI via its effect on breast cancer survivors' feelings of controllability and the influence of controllability on stress and biomarkers associated with depression and fatigue [42].

While the findings from this study are promising, there are several limitations. First, the study population is relatively homogeneous. Most of the women are white and highly educated with high annual household incomes. Thus, findings from this study may not be generalizable to all breast cancer survivors. Second, this study adopted a longitudinal observational design that spanned only a period of 6 months. While there were statistically significant declines in group-level mean physical activity during the study period, there were no statistically significant changes in group-level mean values for the Frequency of Forgetting Scale for the total score or most subscales. However, the levels of SMI reported in this sample were similar to levels reported in healthy women who were, on average, 10 years older than our sample [43], indicating breast survivors may be experiencing higher levels of SMI at younger ages. These data suggest that while a period of 6 months may be adequate to observe natural changes in physical activity as a result of potential changes in motivation, health status, climate, etc., this may not be a sufficient period of time to observe changes in SMI. Future longitudinal studies should explore these relationships with longer follow-up periods and at various time points during survivorship (i.e. pre-, during, and post-treatment). Additionally, randomized controlled exercise trials are necessary to determine whether model relationships hold as a result of intervention. Finally, we only had measures of self-efficacy specific to exercise. Future studies should include additional measures of self-efficacy (e.g. coping, efficacy to self-manage symptoms) to determine whether these relationships differ based on types of measures used.

Because SMI may be influenced by numerous factors, future research should more comprehensively examine the relationship among physical activity, psychosocial, self-regulatory and physiological parameters to better understand the mechanisms underlying these relationships and to ascertain modifiable intervention targets. Findings from this research could also be used to identify specific subgroups of breast cancer survivors who may be at high risk for SMI so they can receive early intervention to prevent or alleviate these problems and reduce potential negative side effects. While data from this study indicate that increased physical activity may be beneficial for improving self-efficacy and psychosocial well-being and reducing SMI in breast cancer survivors using both self-report and objective measures of activity, future research should explore whether there is an optimal time (pre-, during post-treatment) to intervene or optimal dosage (type and intensity) of activity necessary to elicit or maximize these benefits. Further, the less robust relationship between physical activity and self-efficacy observed in the accelerometer subsample likely reflects the lower bias associated with objective measures, indicating accelerometers should be incorporated in future studies when possible. Finally, future research should explore these

relationships using objective measures of cognitive functioning to develop a better understanding of the role of physical activity in both objective and subjective cognitive functioning.

In summary, this study represents an important first step in exploring the relationship between SMI and physical activity, self-efficacy, and psychosocial factors in a relatively large sample of post-treatment breast cancer survivors using both self-report and objective measures of activity. These findings provide initial support for a psychosocial model of physical activity and SMI grounded in social-cognitive theory and provide preliminary evidence to support an important, modifiable pathway between physical activity and SMI. Thus, it may be particularly important for future physical activity interventions and programs directed at reducing SMI to be designed specifically to target sources of efficacy information. Future studies should seek to replicate, expand and refine this model to improve our understanding of the potential relationship between physical activity and SMI in order to help reduce SMI and enhance breast cancer survivors' overall health and well-being.

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Figure 1.
Hypothesized Psychosocial Model of Physical Activity and SMI

Figure 2a
Baseline

Figure 2b

Figure 2.

Figure 2a. Psychosocial Model of Physical Activity and SMI in Full Sample

Figure 2b. Psychosocial Model of Physical Activity and SMI in Accelerometer Subsample

Note: Dashed lines represent non-significant relationships. Bi-directional correlations and stability coefficients are omitted from the figure for clarity.

Table 1

Participant demographic and disease characteristics

	Full Sample n=1,477	Accelerometer Subsample n=362
Current Age (<i>M</i>, <i>SD</i>)	56.3 (9.3)	56.6 (9.3)
Age at Diagnosis (<i>M</i>)	49.6 (8.9)	49.8 (9.0)
Stage of Disease (%)		
0	21.2	19.2
1	33.0	31.8
2	34.0	35.6
3	10.2	11.4
4	1.6	2.0
Time Since Diagnosis (<i>M</i> months)	86.8 (70.4)	87.2 (71.6)
< 2 years	14.4	10.5
2 to < 5 years	34.3	35.4
5 to < 10 years	28.2	29.8
10 years	23.2	24.3
Experienced Menopause at Diagnosis (%)	48.5	43.6
Treatment Received (%)		
Surgery + CT + RT	38.5	40.9
Surgery + CT	17.1	18.5
Surgery + RT	25.8	25.7
Surgery Only	15.8	14.4
Other	2.7	0.6
Currently on hormonal therapy (%)	43.3	44.8
Race (%)		
White	96.9	96.6
Non-white	3.1	3.4
Ethnicity		
Hispanic	1.4	1.9
# of Comorbidities (%)	1.8 (1.7)	1.7 (1.6)
0	28.1	28.5
1–2	45.1	47.8
3	26.8	23.8
Specific Comorbidities Reported		
Arthritis	33.6	33.7
Depression	20.9	23.0
Osteoporosis	19.0	16.9
Upper GI disease	17.9	13.8
Obesity	17.4	14.4

	Full Sample n=1,477	Accelerometer Subsample n=362
Visual impairment	14.8	12.7
Anxiety or panic disorder	14.7	14.4
Degenerative disc disease	13.5	13.9
Asthma	10.4	10.0
Diabetes	6.5	5.4
COPD, ARDS or emphysema	2.3	2.5
Congestive heart failure or heart disease	2.0	3.1
Hearing impairment	1.8	1.7
Stroke or TIA	1.8	1.4
Neurological disease (i.e. Multiple Sclerosis, Parkinson's Disease)	1.1	0.0
Peripheral vascular disease	1.1	1.4
Heart attack	0.4	0.6
Angina	0.6	0.8
BMI (ml/kg)	26.6 (5.7)	25.9 (5.1)
Education (%)		
High School	7.3	7.8
Some College	25.5	26.3
College Degree	36.1	39.1
Graduate/Professional Degree	31.2	26.8
Annual Household Income (%)		
<\$40,000	13.6	12.8
\$40,000	86.4	87.2

M=mean; SD= standard deviation

Table 2

Mean differences between physical activity, fatigue, distress and SMI between baseline and 6-month follow-up (n=1,477)

	Baseline M (SD)	Month 6 M (SD)	t-statistic	p-value
Physical Activity				
Godin Leisure Time Exercise Total Score	31.4 (21.9)	30.1 (22.2)	2.1	0.04
Average daily accelerometer-assessed moderate and vigorous activity (mins)	21.6 (18.7)	18.5 (19.9)	3.5	0.001
Self-efficacy				
Barriers self-efficacy	47.2 (24.4)	46.2 (24.8)	1.7	0.08
Exercise self-efficacy	73.8 (32.6)	69.6 (34.9)	5.1	<0.001
Distress				
Fear of Recurrence	3.3 (1.4)	3.1 (1.4)	8.2	<0.001
Perceived Stress	12.7 (7.0)	12.7 (6.8)	-0.01	0.99
Anxiety	5.0 (3.3)	4.6 (3.3)	5.8	<0.001
Depression	4.1 (3.6)	4.1 (3.8)	-0.51	0.61
Fatigue				
Severity	3.3 (2.0)	3.0 (2.0)	6.7	<0.001
Interference	1.8 (1.9)	1.6 (1.9)	4.1	<0.001
Duration	2.7 (2.0)	2.9 (2.1)	-4.6	<0.001
Subjective Memory Impairment				
Frequency of Forgetting Total Score	50.1 (9.8)	49.7 (10.1)	1.8	0.07
General Rating of Memory	4.9 (1.4)	4.89 (1.4)	-1.5	0.13
Frequency of Forgetting	23.6 (5.3)	23.6 (5.4)	0.16	0.88
Forgetting When Reading	11.5 (2.6)	11.2 (2.6)	4.1	<0.001
Remembering Past Events	10.2 (2.8)	10.1 (2.9)	1.7	0.10

Note: Accelerometer data is only based on the accelerometer subsample (n=362). All other data are based on the full sample.