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Physical Activity and Fatigue in Breast Cancer and Multiple Sclerosis: Psychosocial Mechanisms

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Abstract

Objective—To examine the role of self-efficacy and depression as potential pathways from physical activity to fatigue in two study samples: breast cancer survivors (BCS; N=192) and individuals with multiple sclerosis (MS; N=292).

Methods—We hypothesized that physical activity would be indirectly associated with fatigue through its influence on self-efficacy and depressive symptomatology. A cross-sectional path analysis (BCS) and a longitudinal panel model (MS) were conducted within a covariance modeling framework.

Results—Physical activity had a direct effect on self-efficacy, and in turn, self-efficacy had both a direct effect on fatigue and an indirect effect through depressive symptomatology in both samples. In the MS sample, physical activity also had a direct effect on fatigue. All model fit indices were excellent. These associations remained significant when controlling for demographics and health status indicators.

Conclusions—Our findings suggest support for at least one set of psychosocial pathways from physical activity to fatigue, an important concern in chronic disease. Subsequent work might replicate such associations in other diseased populations and attempt to determine whether model relations change with physical activity interventions, and the extent to which other known correlates of fatigue such as impaired sleep and inflammation can be incorporated into this model.

Keywords

Breast Cancer; Multiple Sclerosis; Self-Efficacy; Physical Activity; Depression; Fatigue

Introduction

Fatigue is one of the most commonly reported and enduring symptoms experienced as a result of chronic disease and its treatment. Disease-related fatigue often reflects ‘a subjective feeling of tiredness, weakness or lack of energy’ (1) and results in reduced quality of life (2,3) and ability to function and lead a “normal” life (3,4). Breast cancer survivors (BCS) and individuals with multiple sclerosis (MS) report generally high rates of disease-related fatigue. An estimated 70-99% of breast cancer patients experience some fatigue during treatment (5) and greater than 50% of BCS continue to suffer fatigue post-treatment (6,7). Approximately, 75-95% of

individuals with MS report fatigue and its disabling effect is a major reason for unemployment in this population (8).

The etiology of fatigue in BCS and MS is unclear and a number of potential correlates have been identified including: demographic characteristics; disease and treatment variables, psychosocial influences, inflammation, immune dysregulation, disability, body composition, comorbidities, and inactivity leading to impairments in cardiorespiratory fitness and muscle function (8-15). One important behavior that has been identified as having the potential to reduce fatigue levels in the general population (16) and more specifically in BCS (17,18) and individuals with MS (19) is physical activity.

Whether the effects of physical activity on fatigue are direct or operate indirectly through other mechanisms has not been well-established. However, depression has consistently been reported to be highly correlated with fatigue in BCS (7,20) and fatigue is considered an important symptom of clinical depression (21). Experimental evidence suggests that treatment for depression is associated with subsequent reductions in fatigue in persons with MS (2). Additionally, physical activity participation has been associated with reductions in depression in BCS (22,23) and those with MS (24). Thus, one potential path from physical activity to fatigue may be through depression.

One of the more proximal and consistent outcomes of physical activity is self-efficacy (25). Self-efficacy expectations reflect the individual's beliefs in their personal capabilities and have been demonstrated to mediate the effects of behavior on levels of depression. For example, Cutrona and Troutman (26) reported the effects of social support on post-partum depression were mediated by self-efficacy, and Maciejewski, Prigerson, and Mazure (27) have demonstrated that self-efficacy mediates the effects of stressful life events on depressive symptoms. In addition, lower levels of self-efficacy have been associated with higher levels of fatigue in BCS (28). This evidence suggests changes in self-efficacy associated with physical activity may have both direct and indirect effects on fatigue in this population. Indeed, Trojan and colleagues (15) have reported that self-efficacy was significantly associated with general, physical, and mental fatigue. Thus, one might hypothesize that the most immediate effect of physical activity would be on self-efficacy. In turn, self-efficacy would be expected to influence fatigue through its effect on depression, and potentially to also have a direct effect on fatigue. It is worth noting that the effects of self-efficacy on behavior are typically regarded as situation-specific. However, Bandura (29,30) has cogently noted that self-efficacy in one domain may well have an effect on behaviors in other domains. Given that physical activity is associated with lower levels of depression and fatigue, it is theoretically consistent to expect self-efficacy for physical activity to be related to levels of depression and fatigue.

As noted earlier, a host of other factors that are generally not considered to be readily modifiable have also been associated with fatigue in diseased populations. These have included demographic characteristics (7), health status variables including body composition (31,32) and disability (33-35), and disease-related factors such as treatment status, time since diagnosis, menopausal symptoms, and comorbidities (6,28). Whether such factors have implications for physical activity, self-efficacy, depression, and fatigue relationships is not known.

We reanalyzed data from two previously published studies to test the proposed psychosocial model of physical activity effects on fatigue. We hypothesized that physical activity's influence on fatigue is indirect through its direct effect on self-efficacy which, in turn, has both a direct effect on fatigue and an indirect effect through depression. Thus, less active BCS and individuals with MS would be less efficacious, which would lead to higher levels of depression, and in turn, greater levels of fatigue. Testing the hypothesized relationships in BCS and MS is important as, in both cases, these disease states result in increased levels of depressive

symptoms and fatigue following diagnosis. In addition, there is good evidence to suggest that both physical activity and self-efficacy are associated with reductions in fatigue and depressive symptoms. In Study 1, we tested the model using a secondary data analysis of a cross-sectional sample of BCS (36). In Study 2, we attempted to replicate and validate the model using secondary data analysis in a 6 month longitudinal sample of individuals with MS (37). In addition, in this latter study, we used entirely different measures of all key constructs as well as an objective measure of physical activity at both time points. This approach is advantageous for several reasons. First, it allowed us to test the model in a different chronic disease population using an improved study design. Second, if the associations hold as hypothesized, this would support the veracity of model relationships independent of the type of measure used. Finally, the longitudinal model permitted an examination of relationships among changes in model constructs after controlling for baseline values and correlations among the same variables across time. A final set of analyses tested the hypothesized model in both samples controlling for the effects of demographic (i.e., age, income, education), health status [body mass index (BMI) and disability status], and medical and clinical factors (i.e., time since diagnosis, treatment status, disease stage/type, menopausal status, and the presence of comorbidities).

We note that original data sets used to test the proposed model had entirely different purposes. In one, we examined correlates of self-efficacy in BCS. In the other, we examined potential mediators of the physical activity and quality of life relationship in individuals with MS. In the data analyses currently reported, we included assessment of depressive symptomatology and have used these extant data sets to achieve an entirely different and unique goal; testing a social cognitive model of the physical activity and fatigue relationship in a cross-sectional and longitudinal manner in which we propose that this relationship can be explained by pathways through self-efficacy and depression.

Study1: Breast Cancer Survivors

Method

Participants, Recruitment, and Procedure—Complete recruitment procedures have been reported elsewhere (36). Briefly, women diagnosed with invasive breast cancer between January 1997 and December 2002 were contacted via the Illinois Cancer Registry and provided with information relative to study purposes. Initially, 768 breast cancer survivors were identified with 165 unreachable or deceased. Of the remaining 603, 254 self-disclosed contact information via US mail and were sent a battery of questionnaires assessing demographics, health status, and all study variables. A total of 192 usable questionnaires were returned for a response rate of 76% among those agreeing to participate and 32% overall (36). The study protocols along with waiver of consent were approved by the local institutional review board.

Measures

Health Status: In addition to basic demographic data, BCS participants self-reported height and weight from which body mass index was calculated (BMI; weight in kg/height in m²), time since breast cancer diagnosis, whether they were currently receiving treatment or not, disease stage, menopausal status, and the presence of comorbidities likely to be exacerbated by exercise [see Rogers (36)].

Physical Activity: Physical activity was assessed using the Godin Leisure Time Exercise Questionnaire, a widely used self-report measure with proven reliability and validity (38). Participants were asked to self-report how many times on average they do moderate or vigorous exercise for more than 15 minutes during their free time during a typical 7-Day period. The time spent in each type of activity was summed to provide the total weekly minutes currently spent in moderate and vigorous leisure-time physical activity.

Self-Efficacy: Self-efficacy for physical activity was measured by a scale validated by Rogers et al. (39) and composed of four items reflecting confidence in capabilities to walk briskly for 20 minutes, jog for 10 minutes, climb 3 flights of stairs without stopping, and exercise hard for 20 minutes. Participants rated their levels of confidence for successfully completing each task from 0% -100% and all values were aggregated and divided by the total number of items. The measure demonstrated excellent internal consistency in the present study ($\alpha = .95$). Scores on this measure range from 0 to 100.

Depression: To assess depression, the 20-item Center for Epidemiologic Studies Depression Scale [CES-D (40)] was administered. Participants were asked to indicate the response that reflects how frequently they felt or behaved in a certain way during the past week. Responses to each item ranged from 0 ("rarely or none of the time" (less than 1 day)) to 3 ("all of the time" (5-7 days)), and all items were summed to provide a range of scores from 0-60 with higher scores reflecting greater depressive symptomatology. Examples of items from this scale include "I felt that I was just as good as other people" and "I felt hopeful about the future." The psychometric properties of the measure have been well-documented and internal consistency in the present study was excellent ($\alpha = .85$).

Fatigue: Fatigue was measured with the 13-item fatigue subscale from the Functional Assessment of Cancer Therapy-Fatigue [FACT-F (41)]. Participants were asked to indicate the severity of each of the fatigue symptoms as it applied to the past 7 days on a Likert scale from 0 (not at all) to 4 (very much). Scores were aggregated to achieve a total fatigue score ranging from 0 to 52 with higher scores indicating higher levels of fatigue. It should be noted that we did not reverse score the FACT-F items, as is common in the oncology literature when the scale is used as a quality of life indicator. Therefore, a higher score indicates greater fatigue. This, we believe, avoids confusion for those unfamiliar with the measure. Examples of items from this questionnaire include "I am able to do my usual activities" and "I am frustrated by being too tired to do things I want to do." The measure possesses excellent psychometric qualities and demonstrated good internal consistency in the present study ($\alpha = .94$).

Data Analysis: Initially, the associations among the key model variables were examined by correlational analyses. We then tested the proposed model using covariance modeling with the full-information maximum likelihood (FIML) estimator in Mplus 5.2 (42). Use of the FIML estimator is an optimal procedure when missing data are present, as it has been demonstrated to produce reliable standard error estimates in Monte Carlo studies (43).

In this sample, we had complete data for all subjects on all key variables, except self-efficacy where 1% ($n = 2$) of the data were missing. To determine the adequacy of model fit we used several commonly utilized measures: the chi-square goodness of fit statistic; the comparative fit index (CFI); and the standardized root mean square residual (SRMR) (44,45). Ideally, the chi-square statistic should be nonsignificant but can be strongly influenced by sample. In combination, values of .95 and greater for the CFI and .08 or less for the SRMR reflect good model-data fit (45).

Model Testing—The model tested examined the following hypothesized paths: direct effects of physical activity on self-efficacy and an indirect effect on fatigue through self-efficacy and depression; a direct effect of self-efficacy on depression and an indirect effect on fatigue through depression; and finally, a direct effect of depression on fatigue. Additionally, the hypothesized model was also tested when controlling for any possible effects of demographics (i.e., age, education, employment, income), time since diagnosis, breast cancer stage, current treatment, menopausal status, body mass index, and comorbidities.

Results

Participant characteristics

Recruitment yield and descriptive statistics relative to demographic and health status data for the BCS sample have been presented elsewhere (36). The sample was primarily white (98%), older (M age = 64 yrs $\pm$ 11.5), postmenopausal (87%), and almost half of the sample (49%) had an annual income of $\geq$ \$50,000 per year. Fifty percent of the sample was in cancer stage I or II. Mean values for primary model constructs were as follows: moderate plus strenuous minutes of physical activity per week (M = 124.02 $\pm$ 241.78), efficacy for physical activity (M = 42.67 $\pm$ 32.39), BMI (M = 27.51 $\pm$ 5.60), depression (M = 10.95 $\pm$ 9.04), and fatigue (M = 14.15 $\pm$ 11.11). These values have previously been reported by Rogers et al (36) with the exception of the depression scores. In general, the sample was low active, overweight, low efficacious, and with generally low levels of depression and fatigue.

Correlations among Model Constructs—Table 1 details the correlations among physical activity, self-efficacy, depression, and fatigue. All of the correlations are significant and in the expected direction suggesting, at the very least, the hypothesized pattern of relationships is tenable.

Path Model of Physical Activity to Fatigue Relationships—The hypothesized path model provided an excellent fit to the data ($\chi^2 = 1.48$, df = 2, $p = .48$; SRMR = 0.02, CFI = 1.00). The standardized path coefficients for this model are shown in Figure 1 and the model accounted for 45.2% of the variation in fatigue. All paths are significant and support a psychosocial model to explain the physical activity and fatigue relationship that suggests a pivotal role for self-efficacy.

As can be seen in Figure 1, the relationship between fatigue and depression is fairly robust ($\beta = .51$), and one might argue this may reflect an overlap between fatigue and CES-D items which are somatic in nature [see Visser & Smets, (46)]. Therefore, we re-ran the analyses described above using a depression score which excluded the six items assessing “somatic and retarded activity” symptoms. The fit of the model was almost identical to the previously described model ($\chi^2 = 1.48$, df = 2, $p = .45$; SRMR = 0.03, CFI = 1.00). However, the path between depression and fatigue was reduced from .51 to .34 and the R^2 was reduced from .45 to .33. The standardized path coefficients for this model are shown in Figure 1 in parentheses. Total and indirect effect parameters, standard errors, and p-values are shown in Table 2.

Effects of Covariates on Hypothesized Relationships—We next tested the previous model while statistically controlling for the previously described covariates. This model also was an excellent fit to the data ($\chi^2 = 2.10$, df = 2, $p = .35$; SRMR = 0.01, CFI = 1.00). In general, the magnitude and direction of the hypothesized relationships were unaffected by the inclusion of the covariates in the model. However, the direct path from self-efficacy to fatigue increased from -.36 to -.48. The full model accounted for 42% of the variance in fatigue. All standardized parameter estimates of hypothesized model constructs after controlling for covariates are shown in Figure 2.

There were a number of significant relationships among the covariates and the model components. For example, a lower BMI ($\beta = -.20$, $p = .004$) and longer time since diagnosis ($\beta = .19$, $p = .01$) were associated with greater physical activity. Being younger ($\beta = -.20$, $p = .001$), having fewer comorbidities ($\beta = -.23$, $p < .001$), and having a lower BMI ($\beta = -.32$, $p < .001$) were associated with greater self-efficacy. Younger BCS ($\beta = -.27$, $p < .001$) and those with more comorbidities ($\beta = .14$, $p = .05$) reported higher levels of depression. Finally, being older ($\beta = -.17$, $p = .02$) and currently on treatment ($\beta = -.17$, $p = .006$) were associated with increased levels of fatigue.

Study 2: Multiple Sclerosis

Method

Participants, Recruitment, and Procedures—Recruitment of the MS sample was conducted through Greater Illinois, Gateway, and Indiana chapters of the MS society and complete details have been previously reported (37). Briefly, potential participants received an announcement of study details via mail, the *MS Connection* quarterly publication, or email and contacted the study coordinator by telephone or electronic mail. Of 387 potential participants, 340 passed initial screening and were mailed an informed consent of which 300 were returned with a further 8 participants subsequently withdrawing from participation. Thus, the final sample ($N = 292$) was composed of 245 women and 47 men. Following screening and completion of informed consent, participants were mailed a battery of questionnaires and an accelerometer along with a self-addressed stamped envelope for return postal service. A follow-up telephone call was made to assure delivery of the packet. The accelerometer was worn for a 7-day period followed by completion of the measures of demographics, self-efficacy, depression, fatigue, and disability status on the 8th day. At this point, the accelerometer and battery of questionnaires were returned via mail, and checked for missing data upon receipt. Telephone calls were made to collect missing data. Six months later, similar procedures were carried out to collect the longitudinal data. Participants were paid \$20 for completion of both baseline and follow-up assessments.

Measures

Health Status: Health status was assessed by the Patient Determined Disease Steps (PDDS) scale (47). The PDDS is a self-report questionnaire that contains a single item assessing self-reported disability using an 8-level ordinal scale with a score of 0 indicating the individual has mild to no symptoms and 8 indicating the individual is bedridden. Scores from the PDDS are linearly and strongly related with physician-administered Expanded Disability Status Scale scores [$r = .93$; (47)].

Physical Activity: We used an Actigraph accelerometer (Model #7164 version, Health One Technology, Fort Walton Beach, FL) to objectively measure physical activity in the MS sample. The ActiGraph monitor was pre-programmed for start time and data collection interval. Data were retrieved for analysis via a PC interface and software provided with the unit. In this study, the epoch was 1 minute, and the accelerometers were worn during the waking hours, except while showering, bathing, and swimming, for a 7-day period. The participants recorded the time the accelerometer was worn on a log, and this was verified by inspection of the minute-by-minute accelerometer data. The minute-by-minute counts were summed across all 7 days and then averaged to provide a physical activity measure reflecting average total movement counts per day with higher scores representing more physical activity. Previous research has demonstrated the Actigraph accelerometer to be a reliable and valid measure of physical activity in persons with MS (48).

Self-Efficacy: Self-efficacy for physical activity was measured by the Exercise Self-Efficacy Scale [EXSE; (49)] which assesses beliefs in capabilities to engage in 20+ minutes of moderate physical activity 3 times per week, in one month increments, across the next six months. Item scores ranged from 1 (no confidence at all) to 10 (completely confident) and all values were aggregated and divided by total number of items resulting in total scores ranging from 1 to 10. Internal consistency for the EXSE was excellent ($\alpha = .99$).

Depression: Depression was assessed by the depression scale of the Hospital Anxiety and Depression scale [HADS; (50)]. The 7-item depression scale assesses the frequency of a specific feeling over the past week on a 4 point likert scale from 0 (“not at all”) to 3 (“most of

the time”). Some example items from this scale include; “I feel cheerful” and “I still enjoy the things I used to enjoy.” Positively-worded items were reverse scored and then all individual item scores were summed to achieve a total depression score ranging from 0 to 21 with higher scores indicating greater levels of depression. This scale has previously been used in studies of MS patients (51) and has established psychometric properties. Coefficient alpha for the anxiety depression components of the HADS was .82.

Fatigue: We used the Fatigue Severity Scale [FSS; (52)] to assess fatigue. The FSS is a 9-item scale that assesses the severity of fatigue symptoms. Participants are asked to indicate how appropriate they feel each statement applied to them during the past week on a scale from 1 to 7 with higher scores indicating agreement. Total scores range from 1 to 7 and are calculated by aggregating all items and dividing by the number of items with higher scores indicating greater fatigue severity. Some example items include “My motivation is lower when I am fatigued” and “Fatigue is among my three most disabling symptoms.” It has good psychometric properties (52) and, in the present study, excellent internal consistency ($\alpha = .93$)

Data Analysis—As with the BCS sample, correlational analyses initially examined associations among model constructs. Because we were examining relationships across time in the MS sample, we conducted a panel analysis within a covariance modeling framework with the full-information maximum likelihood (FIML) estimator in Mplus 5.2 (42). Panel analysis is a useful analytic technique for testing theoretical relationships among constructs across time (53). Panel models are able to determine initial baseline associations among hypothesized constructs and also relationships between changes in those same constructs over time independent of the baseline relationship and other variables in the model. In this sample, we had missing data for the primary model constructs as follows: self-efficacy 0.3% ($n = 1$) at baseline and 5.5% ($n = 16$) at follow-up; depression and fatigue 0.3% ($n = 1$) and 5.8% ($n = 17$); and accelerometer 4.5% ($n = 13$) and 9.2% ($n = 27$). Standard model fit indices, as previously described, were used to examine the adequacy of model fit.

Model Testing—The model tested examined the hypothesized effects in a longitudinal panel model whereby we tested the overall fit of the baseline model and the relationships among changes in the hypothesized constructs simultaneously. Additionally, we calculated stability coefficients for the primary model constructs. These coefficients represent correlations between the same variables (e.g., fatigue at baseline and 6 months) measured across time while controlling for the influence of other variables in the model. Overall, the stability coefficients were acceptable for physical activity ($\beta = .74$), self-efficacy ($\beta = .72$), depression ($\beta = .75$), and fatigue ($\beta = .69$). For the sake of clarity, these paths are not shown in the figures.

The hypothesized model was also tested when controlling for any possible effects of demographics (i.e., age, education, employment, income), time since diagnosis, disease type, and disability status.

Results

Participant characteristics

The MS sample (M age = 48.0 ± 10.3) was primarily Caucasian (94%), married (68%), employed (53%), and highly educated (28% had some college education and 57.7% were college graduates), with a median annual household income of greater than \$40,000 (67.7%). The sample was composed of 246 individuals with relapsing-remitting MS, 12 with primary progressive MS, and 34 were diagnosed with secondary progressive MS. The mean values for the primary model constructs at both time points are shown in Table 3. The sample could be classified as moderately active given that Ng and Kent-Braun (54) have reported mean values

of ~125,000 counts per day in persons with MS. However, our sample were still considerably less active than healthy adults without MS. Values for the PDSS score suggest that this sample were in the first stage of MS whereby disease activity and course were manageable via medication and rehabilitation therapy.

Correlations among Model Constructs—Table 4 details the correlations among physical activity, self-efficacy, depression, and fatigue for the MS sample.

Panel Model of Physical Activity to Fatigue Relationships—The hypothesized panel model provided a reasonable fit to the data ($\chi^2 = 54.22$, $df = 16$, $p < .001$; SRMR = 0.08, CFI = 0.97) and all paths were significant and in the expected direction. However, an examination of the modification indices suggested the model could be improved by allowing a direct path between physical activity and fatigue at both time points. Thus, we allowed this path and re-ran the model. This proved to be an excellent fit to the data ($\chi^2 = 29.86$, $df = 14$, $p < .005$; SRMR = 0.05, CFI = 0.99) and a significantly better fitting model than the originally hypothesized model ($\chi^2_{diff} = 14.36$, $df = 2$, $p < .01$). The standardized path coefficients for this model are shown in parentheses in Figure 3 and the model accounted for 36% of the variation in fatigue at baseline and 68.4% of the variation in changes in fatigue over time. Table 2 details the parameter estimates, standard errors, and p-values for the total effects and indirect effects at baseline and follow-up in the MS sample.

Effects of Covariates on Hypothesized Relationships—We next tested the previous model while statistically controlling for the covariates described earlier. This model was also an excellent fit to the data ($\chi^2 = 25.86$, $df = 18$, $p = .10$; SRMR = 0.01, CFI = .99). With one exception, the magnitude and direction of the hypothesized relationships were unaffected by the inclusion of the covariates in the model. The previously significant baseline path between physical activity and fatigue was nonsignificant in this model (see Figure 3). The full model accounted for 42.8% of the variance in fatigue at baseline and 71% of the change in fatigue at follow-up. All standardized parameter estimates of hypothesized model constructs after controlling for covariates are shown in Figure 3. Health status (i.e., PDDS) was significantly associated with physical activity ($\beta = -.19$, $p < .001$), self-efficacy ($\beta = -.20$, $p < .001$), depression ($\beta = .20$, $p < .001$), and fatigue ($\beta = .17$, $p < .001$) at baseline and with changes in physical activity ($\beta = -.13$, $p < .001$) and fatigue ($\beta = .06$, $p < .05$) at follow-up. Additionally, female participants reported greater increases in depression at follow-up ($\beta = -.21$, $p < .01$). No other covariates were significantly related to model constructs.

Discussion

The present study examined the potential psychosocial pathways from physical activity to disease-related fatigue in a cross-sectional sample of BCS and a longitudinal sample of individuals with MS. Using secondary analysis of two existing data sets (36,37) and the addition of new measures, we hypothesized an underlying theoretical model in which physical activity, a known correlate of fatigue, was expected to influence fatigue indirectly through self-efficacy and depression. This model proved a good fit to the data, all hypothesized pathways were statistically significant, and remained so after controlling for demographic, medical, and health status variables. As hypothesized, the relationship between physical activity and fatigue was indirect and mediated by self-efficacy and depression. Self-efficacy had both an indirect effect on fatigue through depression, as well as a direct effect.

We believe these findings to be important from several perspectives. First, disease-related fatigue is a particularly debilitating symptom frequently reported by cancer survivors and individuals with MS, has important implications for carrying out one's normal day to day activities, and compromises quality of life (3,55). Although there is a considerable literature

examining physical activity effects on fatigue in breast cancer survivors (17,18) and in MS (19) the potential correlates that might explain this relationship have not been systematically examined. In the present study, we have taken the social cognitive theory perspective that self-efficacy may be one of the more proximal factors in the physical activity to fatigue pathway. Indeed, Gielissen et al. (56) have reported that, in a sample of long term stem cell transplant survivors, self-efficacy for control over cancer complaints was a consistent, independent predictor of fatigue severity, whereas medical factors were not. Similarly, Trojan et al. (15) found arthritis self-efficacy to be moderately to strongly associated with general, physical, and mental fatigue in individuals with multiple sclerosis but that physical activity was only associated with physical fatigue. The present findings suggest that self-efficacy plays an important role in the physical activity and fatigue relationship having a direct effect on fatigue independent of the consistently reported depression and fatigue relationship. Additionally, our reanalysis of the data deleting somatic items that may have overlapped with fatigue items did not unduly affect model relationships.

Our confidence in the utility of the hypothesized model was further bolstered by support for the hypothesized relationships being evidenced at baseline in the MS sample and then among changes in the model constructs across time. Of particular importance was our ability to replicate and validate the cross-sectional model longitudinally in a sample using different measures of the key constructs, and an objective measure of physical activity. This latter strength may be responsible for the one key difference between the two sets of findings, namely the direct, as well as indirect, effect of physical activity on fatigue in the MS sample. Initially, this difference was present both in the baseline model and the longitudinal change model. However, the baseline association between physical activity and fatigue was rendered nonsignificant when controlling for the covariates. Thus, there is some suggestion that using more objective measures of physical activity may provide a more complete picture of the physical activity and fatigue relationship. Subsequent studies are urged to replicate these findings and to further pursue the nature of this direct relationship.

We note that testing the proposed model in BCS and MS is important for a number of reasons. First, in both cases, the disease states result in increased levels of depressive symptoms and fatigue following diagnosis. From a theoretical perspective, there is good evidence to suggest that both physical activity and self-efficacy are associated with reductions in fatigue and depressive symptoms. In this regard, a particular strength of model development and testing is the examination of parameters across different groups, thereby establishing generalizability and robustness of predictions, i.e., further theory development.

The direct and indirect effects of self-efficacy on fatigue in both samples and across time are of particular importance, as self-efficacy is a modifiable construct. This would suggest that, in the context of organized physical activity programs designed for disease populations, strategies can be implemented to target the primary sources of efficacy information with a view to enhancing perceptions of capabilities and reducing levels of depression and fatigue associated with disease states such as breast cancer and MS. Targeting mastery experiences, providing appropriate social modeling experiences, increasing support and levels of social persuasion, as well as teaching participants to appropriately interpret physiological and affective stimuli are examples that might be embedded into physical activity programs to meet the goal of efficacy enhancement. It should also be noted that we used two different types of exercise self-efficacy in these studies. Although it is likely they overlap considerably, they may also make independent contributions to the relationships. Additionally, other measures of self-efficacy (e.g., coping efficacy) may also have independent roles to play in the model. Further determination of this is warranted.

It is of further importance to note that the hypothesized model associations were not unduly affected when demographic and medical and health status factors were statistically controlled. However, the association of demographic and medical status factors with key model constructs is informative. For example, in the BCS sample, older women and those currently on treatments were less efficacious and reported higher levels of fatigue. Such information is potentially useful for those in clinical and applied settings with regard to appropriately modifying physical activity prescriptions for these survivors. As might be expected, having more comorbidities and having had a more recent diagnosis were associated with being less physically active. Whether such associations are driven by being physically unable to be active or perceiving physical activity as harmful has yet to be determined. In the MS sample, health status, as measured by the PDDS, was associated with all model constructs at baseline and with changes in fatigue and physical activity at follow-up. Although this association did not differentially influence model fit or strength of associations, it clearly underscores that health status is an important correlate of the hypothesized model constructs and should be further considered in studies examining the physical activity and fatigue relationship.

One of the primary strengths of the present study is the adoption of a strong theoretical perspective, social cognitive theory (29,30) to better clarify the potential pathways from physical activity to fatigue in individuals with chronic disease. As previously noted, presenting evidence to suggest self-efficacy may be one of the first steps in this process is important due to its potential for modification and its status as a very proximal outcome of physical activity. Our initial cross-sectional model of BCS reflects a secondary analysis of a previously published data set in which fatigue was shown to be a potential source of efficacy information (36). There is some theoretical precedent for taking the current approach given that efficacy expectations and their informational sources quite often work in a reciprocally determining manner (30). Our ability to test this model in a longitudinal manner using a different sample, different measures of key constructs and an objective measure of physical activity is further testimony to the potential of such a model to explain the relationship between physical activity and fatigue. Further testing and extension of the proposed model is called for to determine: a) whether the hypothesized longitudinal relationships can be replicated in similar populations and in populations with other chronic diseases and b) whether physical activity interventions can effectively produce reductions in fatigue through increases in self-efficacy and reductions in depression.

It is critical to understand that we are not advocating that the only pathways from physical activity to fatigue are through psychosocial constructs or that the model tested herein is the only possible model of this relationship. Clearly, fatigue is a complex and multifaceted state that is influenced by numerous factors. For example, a number of physiological parameters have been associated with increased fatigue in cancer survivors. These include, but are not limited to, elevated cortisol levels (57), inflammatory markers such as C-reactive proteins [CRP; (58)], and reductions in activated T-cell levels (59). Interestingly, Bandura (30) has suggested that perceived efficacy may act as a modulator of stress and depression effects on immune function and illness progression. For example, in an experiment designed to examine self-efficacy effects on immune function in severe phobics, Wiedenfeld et al. (60) were able to demonstrate that enhancing coping efficacy reduced stress which, in turn, lead to improved immunocompetence. Studies examining the potential links between physical activity, self-efficacy, physiological parameters and fatigue are necessary to further enhance our understanding of the complex biopsychosocial basis of fatigue.

In addition, there may be some debate as to whether fatigue should precede depression in this model rather than the position we have adopted. It is clearly the case that both constructs have complex etiologies and are multiply determined. Indeed, the relationship between fatigue and depression is typically quite robust and often inflated due to use of depression measures that

contain fatigue-related items. In the present study, the relationship remained significant even after removing such items (Study 1) and using a measure which does not include such items (Study 2). Clearly, the two constructs are not orthogonal and share common variance. Further, evidence to support our position is provided by findings from a comparative outcomes trial in which the treatment of depression had the concomitant effect of reducing fatigue (2). However, although treating depression almost always reduces fatigue, the opposite is not consistently demonstrated (61) suggesting fatigue may be an outcome of depression and not the opposite.

We further note that although we have made theoretical arguments regarding the direction of variable relationships in our model, we are certainly not advocating causality. It is wholly possible that the relationships could be reversed, a perspective that would be in line with the reciprocally determining nature of social cognitive theory (25). Thus, it is equally plausible that interventions to reduce fatigue may have the added benefit of enhancing physical activity involvement.

In conclusion, our results offer preliminary cross-sectional and longitudinal support for at least one psychosocial pathway from physical activity to fatigue in two populations with chronic disease: breast cancer survivors and individuals with MS. The advantage of such a model is that the primary “active agent” in this relationship is self-efficacy, a modifiable factor. From a prevention perspective, it might be argued that disease-related fatigue can potentially be reduced by promoting physical activity participation for populations such as BCS and those with MS. However, it appears this relationship may be dependent on the provision of physical activity environments which cultivate a strong sense of self-efficacy by providing performance feedback and social modeling and persuasion (30).

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Abbreviations

MS	Multiple Sclerosis
BCS	Breast Cancer Survivors
BMI	Body Mass Index
CES-D	Center for Epidemiologic Studies Depression Scale
FACT-F	Functional Assessment of Cancer Therapy-Fatigue
FIML	Full information maximum likelihood
CFI	Comparative Fit Index
SRMR	Standardized root mean square residual
PDDS	Patient Determined Disease Steps
EXSE	Exercise Self-efficacy Scale; Hospital Anxiety and Depression Scale
FSS	Fatigue Severity Scale
CRP	C-reactive proteins
PA	Physical activity
SE	self-efficacy
Dep	Depressive mood

Figure 1. Relationships among physical activity, self-efficacy, depression, and fatigue in breast cancer survivors. Note: All path coefficients standardized and values in parentheses reflect a model tested without somatic items in the CES-D.

Figure 2.
Best fitting model in breast cancer survivors showing standardized path coefficients after controlling for demographic, medical, and health status factors.

Panel A

Panel B

Figure 3.

Panel model showing relationships among physical activity, self-efficacy, depression, and fatigue in individuals with multiple sclerosis. Note: Panel A shows baseline relationships and Panel B reflects associations among changes in these constructs at six months. All values are standardized and values in parentheses reflect associations after controlling for demographic, medical, and health status factors.

Table 1
Correlations among physical activity, self-efficacy, depression, and fatigue in breast cancer survivors (BCS)

Variable	1	2	3	4
1. Physical activity	–			
2. Exercise self-efficacy	.36	–		
3 Depression	-.18	-.37	–	
4. Fatigue	-.18	-.48	.62	–

Note. All correlations above are statistically significant ($p < .05$). Some of these correlations have previously been reported in Rogers et al (36).

Table 2
Total and indirect effects parameter estimates for structural models

Breast Cancer Sample			
	<i>Parameter Estimate</i>	<i>Standard Error</i>	<i>p-value</i>
Total Effects	-.17	.04	< .001
Indirect Effects			
PA – SE – Dep – Fatigue	-.04	.01	.002
PA – SE – Fatigue	-.13	.03	<.001
SE – Dep –Fatigue	-.12	.03	<.001
Multiple Sclerosis Sample			
<u>Baseline</u>			
Total Effects	-.28	.05	< .001
Indirect Effects			
PA – SE – Dep – Fatigue	-.03	.01	.001
PA – SE – Fatigue	-.07	.02	<.001
SE – Dep –Fatigue	-.12	.03	<.001
<u>Follow-Up</u>			
Total Effects	-.17	.04	< .001
Indirect Effects			
PA – SE – Dep – Fatigue	-.00	.001	.12
PA – SE – Fatigue	-.02	.007	.03
SE – Dep –Fatigue	-.01	.006	.06

Note: PA = Physical activity; SE = Self-efficacy; Dep = Depressive mood

Table 3
Mean values for physical activity, self-efficacy, depression, and fatigue in multiple sclerosis (MS) at baseline and follow-up

Baseline	M	SD
Physical Activity	220006	121252
Self-Efficacy	7.21	3.29
Depression	6.05	4.12
Fatigue	4.97	1.44
Follow-Up		
Physical Activity	206834	104781
Self-Efficacy	6.67	3.47
Depression	6.29	4.27
Fatigue	4.89	1.50

Mean values for physical activity, depression, and fatigue have previously been reported in Motl & McAuley (62)

Table 4
Correlations among physical activity, self-efficacy, depression, and fatigue in MS sample

	1.	2.	3.	4.	5.	6.	7.	8.
1. Physical Activity (Baseline)	-							
2. Self-Efficacy (Baseline)	.30	-						
3. Depression (Baseline)	-.19	-.30	-					
4. Fatigue (Baseline)	-.32	-.49	.50	-				
5. Physical Activity (6 Months)	.74	.25	-.18	-.35	-			
6. Self-Efficacy (6 months)	.27	.74	-.29	-.41	.28	-		
7. Depression (6 Months)	-.12	-.27	.78	.44	-.18	-.31	-	
8. Fatigue (6 Months)	-.30	-.41	.50	.81	-.41	-.48	.49	-

Note : All correlations are significant at $p \leq .05$