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Objectively-Measured Physical Activity and Cognitive Functioning in Breast Cancer Survivors

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Abstract

Purpose—To explore the relationship between objectively measured physical activity and cognitive functioning in breast cancer survivors.

Methods—Participants were 136 postmenopausal breast cancer survivors. Cognitive functioning was assessed using a comprehensive computerized neuropsychological test. 7-day physical activity was assessed using hip-worn accelerometers. Linear regression models examined associations of minutes per day of physical activity at various intensities on individual cognitive functioning domains. The partially adjusted model controlled for primary confounders (model 1), and subsequent adjustments were made for chemotherapy history (model 2), and BMI (model 3). Interaction and stratified models examined BMI as an effect modifier.

Results—Moderate-to-vigorous physical activity (MVPA) was associated with Information Processing Speed. Specifically, ten minutes of MVPA was associated with a 1.35-point higher score (out of 100) on the Information Processing Speed domain in the partially adjusted model, and a 1.29-point higher score when chemotherapy was added to the model (both $p < .05$). There was a significant BMI x MVPA interaction ($p = .051$). In models stratified by BMI (< 25 vs. ≥ 25 kg/m²), the favorable association between MVPA and Information Processing Speed was stronger in the subsample of overweight and obese women ($p < .05$), but not statistically significant in the leaner subsample. Light-intensity physical activity was not significantly associated with any of the measured domains of cognitive function.

Conclusions—MVPA may have favorable effects on Information Processing Speed in breast cancer survivors, particularly among overweight or obese women.

Implications for Cancer Survivors—Interventions targeting increased physical activity may enhance aspects of cognitive function among breast cancer survivors.

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Keywords

exercise; cognitive function; oncology; information processing

INTRODUCTION

Over a quarter of a million women in America are survivors of invasive breast cancer, and this number is expected to exceed 3.2 million by 2022.[1] An estimated 20% to 30% of survivors live with symptoms of cognitive impairment in domains of memory, executive functioning, and information processing. Cognitive impairments noted among breast cancer survivors may be the result of exposures to chemotherapy and other breast cancer treatments (e.g., tamoxifen, aromatase inhibitors).[2, 3] A number of published studies have reported that these treatments (particularly chemotherapy) may influence cognitive function upwards of 5 years after treatment has been completed.[4–6] These cognitive impairments may have significant effects on work and quality of life, and are thought to contribute to feelings of fatigue, anxiety and depression.[7, 8] Although numerous studies have documented the incidence and prevalence of cognitive problems in breast cancer survivors, research on methods to prevent or reverse cognitive decline is sparse.[2]

An increasing body of evidence suggests that physical activity may have favorable effects on cognitive function.[9] The preponderance of evidence supporting associations between physical activity and cognition has come from studies in broad populations of older adults, and these findings may be relevant to breast cancer survivors.[9] For example, a Cochrane review found a protective effect of physical activity on cognitive functioning, indicating that regular physical activity can slow down or prevent functional decline associated with aging. [10] Results from a meta-analysis of randomized controlled trials of physical activity interventions indicate that aerobic physical activity may result in modest improvements in a subset of cognitive domains that are often attenuated in women who have received treatment for breast cancer. Specifically, physical activity interventions appear to positively influence domains of Attention and Information Processing Speed (g-factor = 0.15; 95% CI: 0.06–0.26), Executive Function (g-factor = 0.12; 95% CI: 0.02–0.23), and Memory (g-factor = 0.13; 95% CI: 0.02–0.24).[9] It is notable that obesity is related to this same constellation of cognitive domains that are often impaired in breast cancer survivors.[11–15] It is plausible that obesity and physical activity appear to influence the same cognitive domains because they are negatively correlated; however the relationships between obesity, physical activity, and cognitive functioning are not well defined.

Despite the increasing of knowledge about the effects of physical activity on cognitive function, several questions remain unanswered. For example, although there is evidence that activity intensity may influence the extent to which the physical activity exposure is related to cognition, [16] the specific dose and intensity of physical activity needed to influence cognition is not well established. Furthermore, the exercise prescription required to improve cognition in free-living adults remains unclear. Most intervention studies to have examined the impact of physical activity on cognition have used supervised physical activity interventions in highly controlled research settings. Findings from these studies may not be

transferrable to the general population of free-living adults due to the variability in adherence that occurs when individuals are counseled to perform unsupervised exercise in their free-living settings.[17] Thus from a practical perspective, we know little about how to design unsupervised (home-based) physical activity interventions that optimize the effects on cognition and neurological health. Finally, results from studies in healthy adults may not translate directly to other populations, such as breast cancer survivors. While there is considerable research examining the benefits of physical activity for reducing risk of recurrence, mortality, and improving quality of life, [18–20] the existing literature has not focused on the relationship between physical activity and cognitive functioning in cancer survivors. The few studies that have attempted to explore these questions in cancer survivors have found a positive relationship between physical activity and cognitive functioning; however, these studies have used subjective assessments of physical activity, which are prone to response biases.[21, 22]

The purpose of this study was to investigate the relationships between objectively measured physical activity and cognitive functioning, in a sample of free-living breast cancer survivors with a broad range of BMIs. We were particularly interested in examining these relationships in domains of memory, executive functioning, and information processing because these domains appear to be disproportionately compromised in breast cancer survivors.[2] We hypothesized that only higher-intensity activities will be associated with cognitive functioning variables, because higher intensities are likely to engage mechanism that may affect cognitive functioning (e.g., increased cerebral blood flow).[23] We also examined whether the association between physical activity and cognitive functioning varies by BMI, which is a modifiable risk factor for cognitive decline in other healthy and diseased populations.[14]

METHODS

Study design and sample

Participants were postmenopausal women from two complementary studies within the UCSD Transdisciplinary Research in Energetics and Cancer (TREC) center, which is a program project examining the role of insulin resistance and inflammation in breast cancer risk.[24] Ninety-six overweight and obese women (BMI ≥ 25 kg/m²) were recruited for the *Reach for Health Study*, a randomized trial examining the impact of metformin and a weight-loss counseling program on biomarkers associated with breast cancer prognosis. Data were collected for this study before enrollment in the weight-loss trial. An additional 40 lean women (BMI < 25 kg/m²) were recruited for the *Reach for Health Memory Study*, which was designed to enrich the sample of breast cancer survivors by enrolling a subsample of women with BMI's within the normal range. Recruitment of participants for the *Reach for Health* and *Reach for Health Memory* Studies were conducted simultaneously by means of flyers at community events, physician referral, and use of cancer patient registries.

Eligibility was assessed via a telephone interview. Eligible participants for this study were diagnosed with primary operable breast carcinoma (Stage I–III) within the past 5 years, were postmenopausal at the time of breast cancer diagnosis, and not scheduled for or currently

undergoing chemotherapy. Women were excluded if they had been diagnosed with any additional primary or recurrent invasive cancer within the last 10 years; or had serious medical conditions such as renal insufficiency, liver impairment, or congestive heart failure. Participants were also excluded if they were diabetic or were using hormone replacement therapy; had been diagnosed with a neurological condition; or were taking a medication that, in the investigators' judgment, would impact cognitive function.

Participants attended an in-person study visit where they completed a series of physical measures, study questionnaires, and a computerized test of cognitive functioning. In addition, participants were asked to wear an accelerometer positioned on their right hip for 7 days after their clinic visit. The UCSD institutional review board approved all study procedures and all participants signed informed consent.

Assessment of Physical Activity

Participants were asked to wear an ActiGraph GT3X+ accelerometer (ActiGraph, Pensacola, FL) during waking hours and to take it off for swimming or bathing. Participants were asked to wear these devices on days that were reflective of their typical behavior (e.g., not during vacations). The ActiGraph accelerometer is a small device (19g; 1.6cm × 3.3cm × 1.5cm) that measures acceleration ($\pm 6G$) on three axes at 30Hz. Participants received oral and written instructions on how to wear the device and received 2 phone calls from the study team reminding them to wear the device during the scheduled wear period. Accelerometers were returned by mail at the end of the 7-day wear period.

Data were downloaded from accelerometers using ActiLife v6.3.4 software and screened using wear-time validation guidelines outlined by Choi et al.[25] A trained member of the research team also individually reviewed each participant's accelerometer data for completeness. A complete wear period was defined as having 5 days with 600 minutes of wear time; or 3000 minutes (50 hours) across 4 days. A total of 4 participants had incomplete accelerometer data and were asked to re-wear the device for the number of missing days. All complete and valid data were processed in ActiLife using the low-frequency extension, and aggregated to 60-second epochs so published physical activity cut points could be applied.[26] Light-intensity physical activity (PA) was defined as 101 to 1,951 counts per minute, which is equivalent to 1.5 to 2.90 Metabolic Equivalents (METs). This classification of light PA covers a broad range of METs and possibly equally broad range of types of physical activities, so we also split Light PA into two categories (low light-intensity PA and high light-intensity PA) using cut points for older adults.[27] MVPA was defined as 1,952 or more counts per minute (3.30–7.00 METs). A threshold of 100 counts per minute defined sedentary activities. Time spent per-day in activities of defined intensities (sedentary, light PA, MVPA) was approximated by summing the minutes in a day where the counts met the criterion cut point for each intensity (e.g., 1,952 counts for MVPA). We averaged day-level approximations across measurement days for each participant to yield the average daily time spent in specific physical activity intensities. We used average daily time spent per day in MVPA as a continuous variable because it was normally distributed and used a 10-minute unit of analysis for ease of interpretation.

Assessment of Cognitive Functioning

Cognitive functioning was assessed at the clinic visit using the *NeuroTrax Comprehensive Testing Suite*, [28] which is a 45-minute computerized test designed to sample a range of cognitive domains. Previous validation studies have shown that NeuroTrax tests are comparable to traditional neuropsychological tests in their ability to differentiate cognitively healthy individuals from those with mild cognitive impairment is.[28] *NeuroTrax* tests are adaptive, such that the level of difficulty is based on performance of the individual being assessed. Scores for each of the individual cognitive domains were calculated by *NeuroTrax* and normalized for age and education level with a mean of 100 and a standard deviation of 15. Information Processing Speed was assessed low- and medium-load stages of Staged Information Processing Speed test; Memory was assessed using Verbal and Non verbal Memory Tests; and Executive Function was assessed by the Stroop Interference test, Go-NoGo Response Inhibition test, and the Catch Game [29]. Normalization for the current study was performed relative to a sample of 1124 adults (age:47.9 ±23.1 years; 56% female; education: 14.5±3.1 years) screened and determined to be cognitively healthy in controlled research studies using Mindstreams.[30] The individual domain scores (i.e., Information Processing Speed, Memory, Executive Function) were normally distributed and therefore used as continuous variables in this analysis. Higher scores on these domains represent better cognitive functioning.

Other assessments

Height and weight were measured at baseline clinic visits using standard protocols. Body Mass Index (BMI, kg/m²) was calculated and analyzed as a continuous variable in regression analyses. Medical records were reviewed to ascertain information related to breast cancer diagnosis and treatment. Variables assessed included date of diagnosis, disease stage, type of breast surgery, chemotherapy (any vs. no chemotherapy), and use of endocrine therapy.

Statistical Analyses

Participant descriptors (e.g., age, breast cancer characteristics) and physical activity variables were presented as mean (SDs) or n(%). Pearson Product Moment Partial Correlations examined associations of light PA and MVPA with the cognitive domains of Information Processing Speed, Memory, and Executive Function. Multivariable linear regression analyses modeled the associations of ten minutes spent in physical activity categories (light PA, MVPA) on cognitive domain scores. The models included adjustments for the primary confounding variables of total accelerometer wear-time and primary language spoken. We also included an adjustment for daily sedentary time, given the accruing evidence that specific types of sedentary behaviors such as daily computer use may influence cognitive abilities—particularly when cognition is assessed by computerized tests. [31–33] We did not adjust for participant age because cognitive domain scores (outcome measure) were normalized for participant age when data were processed. Subsequent adjustments were made for non-modifiable participant characteristics that previous studies have indicated are related to cognition, such as chemotherapy history (any vs. no chemotherapy) (model 2).[3, 34] We also adjusted for BMI (continuous variable) (model 3),

which is a modifiable lifestyle factor that may influence cognitive abilities.[35] Additional variables considered for adjustment were time since breast cancer diagnosis, type of breast cancer surgery, disease stage, use of endocrine therapy, and psychosocial status (Medical Outcomes Study Short Form-36 mental health subscale); however the addition of these variables to the base regression models did not meaningfully change the relationships between physical activity and cognitive domain scores. Given that only 6% of the study participants were not native English speakers, we conducted a sensitivity analysis to examine whether the effect sizes of the association of physical activity and cognitive scores were similar when non-native English speakers were excluded from the statistical models.

An interaction model was used to formally test whether the association between MVPA and cognitive domain scores varied by BMI. This interaction model included the base-model adjustments for language, accelerometer wear time, and sedentary time, the main effects of BMI and MVPA, and the BMI x MVPA interaction term. Subgroup analyses were used to explore the nature of the effect modification. Subsamples were grouped as normal weight ($\text{BMI} < 25 \text{ kg/m}^2$) vs. overweight/obese ($\geq 25 \text{ kg/m}^2$). Analyses were performed using SAS (version 9.3 Cary NC). All tests were two-sided and statistical significance was set at $p < .05$ for main effects, and $p < 0.1$ for interactions.

RESULTS

Of the 1157 women who were contacted about the study, 166 were eligible and 136 completed the clinic visit. The most frequent reasons for ineligibility were not being post-menopausal at diagnosis, and diagnosed more than 5 years ago. Accelerometer data were missing for one study participant, and the final analytic sample consisted of 135 women. As shown in Table 1, women in the study were a mean of 62.6 (SD=6.6) years old, had a mean BMI of 28.7 (SD=6.6) and were predominantly native English speakers (94%). Roughly half of the participants were diagnosed with Stage 1 cancer, 36% with Stage 2, and 15% with Stage 3 breast cancer. Half of the study participants received chemotherapy and 70% were taking endocrine therapy at the time of study assessment (i.e., aromatase inhibitor or Tamoxifen). On average, the interval between breast cancer diagnosis and study assessment was 2.1 years (SD=1.3) years.

Correlations among PA and cognitive domains are presented in Table 2. There was a significant positive association between MVPA and Information Processing Speed ($r=.20$ $p=.02$), but no meaningful associations between light physical activity and the other cognitive domains examined in this study. It is notable that the interpretation of the study's results did not change when Light PA was split into two categories (low light-intensity PA and high light-intensity PA) using cut points for older adults.[27]

Table 3 presents partial-, treatment-, and lifestyle-adjusted models of the associations of light physical activity and MVPA with cognitive scores on the Information Processing Speed domain. *To ease interpretation of the parameter estimates we have used a 10-minute unit of analysis for physical activity; therefore, the parameter estimates should be interpreted as a 1-point increase in the cognitive domain score per 10 minutes of daily physical activity (light physical activity or MVPA).* There were statistically significant

associations between MVPA and cognitive scores in the Information Processing Speed domain and no associations between light physical activity and any cognitive domain score. For example, 10 minutes of MVPA was associated with a 1.35-point higher score (out of 100) on the Information Processing Speed domain in the partially adjusted model (model 1; $p=.02$), and a 1.29-point higher score when chemotherapy was added to the multivariate model (model 2; $p=.04$). Subsequent adjustment for BMI weakened the statistical significance of the association (model 3) (β 1.22, $p=.07$). Effect sizes for the association of MVPA on Information Processing Speed was not meaningfully changed when non-English speakers were excluded from the models (1.30, $p=.02$ for the base model). This analysis found no statically significant associations between MVPA (or other activity intensities) and any other cognitive domains measured by the *NeuroTrax Comprehensive Testing Suite* (data not shown).

We also formally tested BMI as an effect modifier of the relationship between MVPA and Information Processing Speed and found that the BMI x MVPA interaction was statistically significant ($p<.1$). Hence we stratified the analysis by normal weight vs. overweight/obese, and examined the association between MVPA and Information Processing Speed within each stratum (Table 4). We observed that MVPA was significantly associated with Information Processing Speed in the subsample of overweight/obese women (β 1.83, $p=.02$ for BMI ≥ 25 kg/m²), but there was no association in the normal weight subsample. BMI was also not independently related to Information Processing Speed ($r=-.08$; $p=.35$). Interactions of MVPA with other significant predictors of cognitive function (i.e., chemotherapy history) did not approach statistical significance (data not shown).

DISCUSSION

There were no statistically significant associations between light intensity activity and cognition. However, we found a positive association between time spent in MVPA and the Information Processing Speed domain of cognitive functioning. Specifically, ten minutes per day of physical activity was associated with a 1.35-point higher score on the Information Processing Speed domain of cognitive functioning. Based on the linear trends in the models, these findings suggest that increasing activity to reach a goal of engaging in 60 minutes of MVPA most days of the week (current recommendations for weight loss) could have a clinically significant impact on Information Processing Speed (half-standard deviation higher score).[28] However, we had few participants who engaged in high levels of activity. Therefore we are not able to empirically demonstrate that the relationship between PA and Information Processing Speed remains linear at high levels of PA.

Although previous studies have observed positive associations between physical activity and a subset of cognitive domains including Attention, Executive Function, Memory, and Information Processing Speed;[9, 21] we only found statistically significant associations between physical activity and Information Processing Speed. The favorable associations between physical activity and Information Processing Speed observed in the current study are generally consistent with previous studies.[36–38] For example, data from prospective studies suggest that regular physical activity engagement in young adulthood (age 15–25 years) is associated with better information processing in older age.[38] However, it is

possible that our study's inability to detect associations between physical activity and domains of Memory and Executive Functioning was due to the narrow variability in scores measured for these cognitive domains in our study's sample. For example, the ranges of the Memory and Executive Functioning domains were 40.7 and 53.6 respectively, whereas the range of scores for the Information Processing Speed domain was roughly 30–40% broader.

Various studies have made strides to elucidate the mechanisms through which physical activity affects cognition. Brain-Derived Neurotrophic Factor (BDNF) is a likely mediator of the effect of physical activity on cognition, and plays a central role in various aspects of developmental and adult neuroplasticity, such as proliferation and differentiation, survival of neurons, neurogenesis, synaptic plasticity, and cognitive function.[39–41] In humans, physical activity interventions have demonstrated that peripheral BDNF concentrations are elevated significantly in response to both acute (single-bout of exercise) [42–44] and sustained exercise regimens.[45–47]

Higher intensity activities may increase cerebral blood flow and oxygen transport to the brain to a greater extent than lower intensity activities can, [23, 48–51] possibly explaining our finding that MVPA but not light activity was related to cognitive functioning. There is also evidence that the differential effects of various intensity activities on cognition are related to BDNF production. Specifically, the magnitude of increase in BDNF production in the hippocampus may be dependent on the physical activity intensity, such that activities need to reach a specific intensity threshold in order to meaningfully influence BDNF production.[52]

Several studies conducted in populations of breast cancer survivors using subjective measures of physical activity and found that higher levels of physical activity have beneficial effects on cognitive function. For example, Hartman and colleagues found that higher levels of self-reported physical activity were associated with better cognitive performance on a computerized neuropsychological test.[21] To our knowledge, studies exploring these relationships between physical activity and cognition using objective measures of physical activity have only been conducted in non-cancer populations. Results of these studies generally corroborate with our findings that only high intensity physical activities are associated with enhanced cognition performance. In a study of 229 older adults wearing accelerometers in free-living conditions, Kerr and colleagues found that higher-intensity physical activity had favorable effects on cognitive functioning assessed by the Trail Making Test (Parts A and B), a measure of executive functioning and processing speed. Specifically, MVPA was associated with a 14% greater performance on Trails B test ($p = .02$), and a 15% faster time to complete Trails A-B ($p = .03$) in fully-adjusted models; however lower-intensity activities (equivalent to light housework or gardening) were not associated with cognitive functioning.[53]

Obesity is a modifiable lifestyle factor that has been associated with higher rates of cognitive impairment in non-cancer populations, [14, 54] and has been associated with time spent in MVPA in interventions [55] and epidemiologic surveys.[56] In the current study, we identified BMI as an effect modifier of the relationship between MVPA and Information Processing, such that the relationship was stronger among heavier women. Specifically, the

beta coefficient corresponding to the association of MVPA and Information Processing Speed was roughly 3-fold higher than the same beta-coefficient in the full sample. Interestingly, BMI was not independently related to Information Processing Speed ($r=-.08$; $p=.35$). These findings suggest that heavier breast cancer survivors, who are at an elevated risk of cognitive impairment because of their body weight, may benefit from physical activity interventions for enhanced cognition. Alternatively, it is plausible that obese women recording the same accelerometer intensity were actually working at a higher metabolic rate than normal weight women because of their body weight. In such case, our accelerometer-based definition of MVPA reflects different levels of exertion in normal weight and obese adults. This alternative hypothesis is supported by data from various exercise physiology laboratories showing that the metabolic rate for walking (per kg of body mass) in obese adults is upwards of 33% greater than in normal weight adults.[57–59]

This study used cross-sectional data and therefore we are not able to establish whether the physical activity exposures preceded or resulted from the cognitive function outcome. Results of this study may also not be generalizable to younger, less educated and more ethnically and geographically diverse populations of cancer survivors. Further, our sample size was small and therefore prone to random sampling errors, and our statistical tests were vulnerable to type II errors. Therefore, it is important for future research to replicate and extend our findings to a larger sample of women for more generalizable results. We also used hip-worn accelerometers to measure physical activity, which may not capture upper body movements typical of resistance exercise that may be related to cognition [60] or physical activities that involve limited movement of the hips. Accelerometers may also underestimate intensities of physical activities such as walking at an incline or carrying heavy loads.[61] Another potential limitation of using accelerometers to assess physical activity is the possibility that the participants altered their behavior while wearing the devices. Although this phenomenon of participant reactivity to the devices has not been studied extensively, research suggests that risk of reactivity is relatively low.[62]

Strengths of this study include the use of an objective accelerometer-based measure of physical activity, which is thought to be less vulnerable to recall and response biases inherent in self-report measures of physical activity especially in an older and overweight population.[63] For example, self-reported physical activity measures can be problematic because they are prone to errors from recall (which may be a function of cognitive impairment) as well as over-reporting and “intensity biases”,[64] such as when an individuals’ perceived physical activity intensity is influenced his or her personal characteristics (e.g., age and BMI). These measurement errors associated with self-report tools may obscure the true relationships between routine engagement in physical activity and cognitive function outcomes. Furthermore, our study used a computerized neuropsychological test battery, which is more sensitive to detect small cognitive differences than other widely used tests such as the Mini-Mental State Examination.[65]

In conclusion, engagement in physical activity equivalent to intensity of brisk walking or jogging appears to be associated with enhanced information processing; however the association is modest and may be influenced by other lifestyle factors, such as weight status. In contrast, time spent engaging in light-intensity activities was not related to any of the

cognitive domains measured in this study. These data suggest that physical activity interventions specifically targeting MVPA may be able to enhance aspects of cognitive function among breast cancer survivors, particularly women who are overweight or obese. Additional insights from prospective and experimental studies examining the impact of MVPA on cognitive domains in normal and overweight/obese breast cancer survivors are needed to clarify these relationships.

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Table 1

Characteristics of Breast Cancer Survivors in a Study of Physical Activity and Cognition (n=135).

Characteristics mean (SD) unless otherwise noted	Total n=135
Age	62.6 (6.6)
Caucasian, non-Hispanic n(%)	107 (79.3)
Primary Language: English n(%)	127 (94.1)
Completed College n(%)	80 (59.2)
Body Mass Index (kg/m²)	28.7 (6.6)
Years Since Diagnosis	2.1 (1.3)
Cancer Stage	
1	67 (49.6)
2	48 (35.6)
3	20 (14.8)
Received Chemotherapy n(%)	65 (48.9)
Taking Endocrine Therapy n(%)	93 (69.9)
Average Min/Day Spent in Light PA^a	550.6 (201.6)
Average Min/Day Spent in MVPA^b	21.1 (18.3)
Average Min/Day Spent Sedentary	510.4 (83.7)
Average Min/Day Accelerometer Wear-Time	832.8 (63.2)
Information Processing Speed^c	105.1 (12.0)
Memory	104.8 (9.0)
Executive Function	102.6 (10.4)

^aPhysical activity.

^bModerate to vigorous intensity physical activity.

^cCognitive testing data was missing for the Information Processing domain for one study participant.

Table 2

Pearson Product Moment Partial^a Correlations of Physical Activity Intensities and Cognitive Domain Scores in a Sample of Breast Cancer Survivors (n=135).

	Light PA ^b	MVPA
Information Processing Speed	0.06	0.20*
Memory	−0.02	−0.01
Executive Function	−0.03	0.09

^aCorrelations adjusted for total accelerometer wear-time, sedentary time, and primary language spoken.

^bPhysical activity.

^bModerate to vigorous intensity physical activity.

*p<.05 (exact p-value=0.02).

Table 3

Multivariate Linear Regression Models Examining Associations of Ten Minutes of Physical Activity at Different Intensities and Information Processing Speed in a Sample of Breast Cancer Survivors (n=135^a).

	Ten minutes of Light PA^b	
	β 95% CI	p-value
Model 1: Partially-Adjusted ^d	−0.02 (−0.13–0.10)	0.80
Model 2: Treatment-Adjusted ^e	0.05 (−0.11–0.22)	0.52
Model 3: Lifestyle-Adjusted ^f	0.05 (−0.11–0.21)	0.54
	Ten minutes of MVPA^c	
	β 95% CI	p-value
Model 1: Partially-Adjusted ^d	1.35 (0.19–2.51)	0.02
Model 2: Treatment-Adjusted ^e	1.29 (0.07–2.51)	0.04
Model 3: Lifestyle-Adjusted ^f	1.23 (−0.08–2.53)	0.07

^a Cognitive testing data was missing for the Information Processing domain for one study participant.

^b Physical activity.

^c Moderate to vigorous intensity physical activity.

^d Partially-Adjusted Model: Adjusted for total accelerometer wear-time, sedentary time, and primary language spoken.

^e Treatment-Adjusted Model: Included Model 1 covariates as well as chemotherapy history (any vs. no chemotherapy).

^f Lifestyle-Adjusted Model: Included Model 2 covariates as well as BMI.

Table 4

Subsample Analyses of Associations of Ten Minutes of Moderate-to-Vigorous Intensity Physical Activity on Information Processing Speed. Separate Multivariate Linear Regression Models^a Were Analyzed for Each Subsample.

	N ^c	Ten minutes of MVPA ^b	
		β 95% CI	p-value
BMI <25 kg/m ²	40	0.62 (−1.16–2.39)	0.49
BMI ≥25 kg/m ²	94	1.83 (0.25–3.40)	0.02

^a Models adjusted for total accelerometer wear-time, sedentary time, and primary language spoken.

^b Moderate to vigorous intensity physical activity.

^c Cognitive testing data was missing for the Information Processing domain for one study participant.