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RESEARCH

Social-cognitive, demographic, clinical, and health-related correlates of physical activity and sedentary behaviour in newly diagnosed women with breast cancer

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Abstract

Purpose Identifying correlates of physical activity and sedentary behaviour allows for the identification of factors that may be targeted in future behaviour change interventions. This study sought to determine the social-cognitive, demographic, clinical, and health-related correlates of physical activity and sedentary behaviour in individuals recently diagnosed with breast cancer.

Methods Data were collected from 1381 participants within 90 days of diagnosis in the Alberta Moving Beyond Breast Cancer (AMBER) Cohort Study. Physical activity and sedentary behaviour were measured with ActiGraph GT3X+® and activPAL^{TM} devices, respectively, for seven consecutive days. Correlates were collected via a self-reported questionnaire, medical record extraction, or measured by staff.

Results Multivariable models were fitted for sedentary behaviour, light physical activity, and moderate-to-vigorous physical activity. Greater sedentary behaviour was associated with higher body fat percentage (BF%) (β=0.044; p<0.001) and being single (β=0.542; p<0.002). Lower light physical activity was associated with higher BF% (β=−0.044; p<0.001), higher body mass index (β=−0.039; p<0.001), greater disease barrier influence (β=−0.006; p<0.001), a HER2-positive diagnosis (β=−0.278; p=0.001), and being single (β=−0.385; p= 0.001). Lower moderate-to-vigorous physical activity was associated with higher BF% (β =−0.011; p=0.001), greater disease barrier influence (β=−0.002; p<0.001), and being of Asian (β=−0.189; p=0.002) or Indian/South American (β=−0.189; p=0.002) descent. Greater moderate-to-vigorous physical activity was associated with having greater intentions (β=0.049; p=0.033) and planning (β=0.026; p=0.015) towards physical activity.

Conclusion Tailoring interventions to increase physical activity for individuals recently diagnosed with breast cancer may improve long-term outcomes across the breast cancer continuum.

Keywords Breast cancer · Physical activity · Sedentary behaviour · ActiGraph · Pre-treatment

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Introduction

Physical activity has functional, fitness, and psychosocial benefits for those living with and beyond breast cancer [1]. The significance of physical activity engagement after a breast cancer diagnosis is evident when considering the number of individuals estimated to be diagnosed (~28,900 new cases in Canada) [2], combined with the reduced physical activity levels reported across the breast cancer continuum [3, 4]. Despite breast cancer being highly studied in exercise oncology and physical activity research, few studies have examined physical activity in individuals recently diagnosed with breast cancer (i.e. prior to initial treatment and/or surgery) [5]. Additionally, we have previously reported that greater physical activity after diagnosis was associated with less fatigue and better quality of life [6]. These findings of physical activity being associated with symptom severity [6], along with reports of reduced physical activity levels after a breast cancer diagnosis [3, 4], underscore the need to improve understanding of physical activity behaviour in newly diagnosed breast cancer patients.

Identifying correlates of physical activity and sedentary behaviour is important for understanding different factors that may be targeted in health behaviour change interventions to increase physical activity. Demographic, clinical, and health-related characteristics help to identify *who* may be susceptible to physical inactivity, allowing future interventions to focus on these sub-populations [7]. In addition, social-cognitive factors [8] may be used to tailor specific components of health behaviour change interventions to promote physical activity engagement. Within breast cancer specifically, lower physical activity history, older age, greater BMI, lower self-efficacy, lack of social support and planning, smoking, and disease stage have been associated with reduced physical activity engagement [7, 9, 10]. Greater symptom severity (i.e. anxiety, fatigue, pain) and greater BMI have also been linked to increased sedentary behaviour [11–13]. However, these associations have predominantly been identified either during or after completing breast cancer-related treatments.

The Alberta Moving Beyond Breast Cancer (AMBER) study is the first observational study to measure physical activity and sedentary behaviour objectively across the entirety of the breast cancer continuum (diagnosis through survivorship) [14]. Accordingly, the primary objective of this study was to identify correlates (social-cognitive, demographic, clinical characteristics, and health-related) of objectively measured physical activity and sedentary behaviour in a cohort of recently diagnosed breast cancer patients (after diagnosis and before or up to the start of treatment). This baseline analysis will fill a major gap in the current breast cancer and physical activity literature by identifying correlates at this timepoint, a first step in developing tailored interventions aimed at addressing physical inactivity early in the breast cancer continuum.

Methods

Participants and study design

The AMBER study's prospective cohort design, recruitment, methods, and full description of the baseline cohort have been previously described in detail [14, 15]. Briefly, participants eligible for the study were newly diagnosed with early-stage breast cancer (stage I–IIIc), had either not initiated neo-adjuvant therapy, or had not completed more than two cycles, were within 90 days of surgery and prior to adjuvant therapy, 18–80 years of age, were not pregnant at the time of recruitment, and were able to answer questionnaires in English. Those who had started adjuvant therapy (post-surgery) but had not completed more than two cycles of chemotherapy or ten fractions of radiation therapy were also eligible for the AMBER study. Eligible participants were recruited from Edmonton or Calgary, Alberta, Canada from July 2012 through July 2019. Study approval was obtained through the Health Research Ethics Board of Alberta: Cancer Committee (HREBA.CC-17-05076). Each participant provided a signed consent form prior to commencing study-related activities.

Measures

Physical activity and sedentary behaviour

Participants were provided an ActiGraph GT3X+® (ActiGraph, LLC, Pensacola, FL) to be worn on the right hip and a thigh-worn activPAL^{TM} (PAL Technologies, Glasgow, Scotland) accelerometer to wear for 7 days during their time out of bed (i.e. waking hours) for the day to measure objective light, moderate, and vigorous intensity physical activity as well as sedentary behaviour. Physical activity was estimated on the ActiGraph GT3X+® via the Soj3x prediction method (R Sojourn package version 1.1.0, Soj3x) which has been validated in comparison to direct observation in free-living adults [16]. Sedentary behaviour (i.e. sitting, lying) was estimated using activPAL^{TM} algorithms (PAL Software version 8), which has been validated in laboratory and free-living studies in adults [17]. Moderate and vigorous intensity physical activity hours per day were summed together, generating a moderate-to-vigorous intensity physical activity hours per day variable (MVPA). Both physical activity and sedentary behaviour were reported in hours per day (hours/day).

Self-reported physical activity and sedentary behaviour were collected as descriptive measures to provide additional context to the multivariable models. Self-reported physical activity was assessed with the *Past Year Total Physical Activity Questionnaire* [18]. This questionnaire measures time spent performing recreational household activities, occupational, and transportation activities within the past 12 months. Total non-sedentary activity was derived by summing the four domains. Recorded activity for each domain was reported in hours/week and converted to MET-hours/week using the Compendium of Physical Activities [19]. Self-reported sedentary behaviour was assessed with the *Sedentary Behaviour Questionnaire* (SBQ), which was adapted from the Australian Longitudinal Study on Women's Health [20]. The questionnaire captures time spent sitting during the following domains: during recreational time, while traveling, and while at work. Total time spent sitting is derived by summing the three domains. Recorded sitting time in each domain is reported in hours/day.

Social-cognitive measures

Social-cognitive measures of physical activity behaviour included self-administered questionnaires developed in accordance with the Theory of Planned Behaviour, all of which have been used previously by the research team and are reliable and valid in cancer populations [21]. Specific variables included perceived *attitude* towards physical activity (affective and instrumental, 6 items), *subjective norm* (injunctive and descriptive, 4 items), *perceived behavioural control/self-efficacy* (6 items) towards physical activity, in addition to *intentions* (3 items) and *planning* (5 items). Each variable ranged on a scale of 1–7, in which higher scores indicated more positive beliefs towards physical activity.

Self-reported barriers to physical activity were also assessed. Barriers included those related to *life* (9 items, range 9–63), *disease* (10 items, range: 10–70), and *motivation* (7 items, scale range: 7–49). Participants were asked about barrier influence and frequency for each respective category. These scores were then summed to generate a 'total' score (i.e. disease barrier frequency + disease barrier influence = disease barrier total). Each barrier ('life', 'disease', and 'motivation') ranged on a scale of 1–7, with higher scores being indicative of greater barrier influence for physical activity.

Demographic and clinical characteristics

A self-administered baseline health history questionnaire (BHQ) was used to collect demographic and health variables. Demographics included age, ethnicity, education, annual family income, employment, and marital status. Clinical characteristics were extracted from medical records and included tumour stage (I, II, or III), histology ('ductal carcinoma', 'ductal + lobular carcinoma', 'lobular carcinoma', 'other'), mastectomy status ('Yes' or 'No' to have had mastectomy), oestrogen receptor status (ER positive/negative), progesterone status (PR positive/negative), human epidermal growth factor receptor 2 status (HER2 positive/negative), neoadjuvant therapy status ('Yes' or 'No' to received), and menopausal status ('Pre' or 'Post').

Health-related outcomes

Self-reported health-related outcomes from the BHQ included items related to smoking status and alcohol drinking history. For the present analyses, variables included patient reporting of smoking status ('never smoked', 'past smoker', 'occasional smoker', or 'current smoker') and amount of alcohol consumed per day (g/day). Health-related outcomes related to body composition and anthropometry included waist-to-hip ratio, BMI ($kg*m^{-2}$), and BF%. Waist circumference was assessed with the National Institutes of Health (NIH) protocol and hip circumference was measured using the World Health Organization (WHO) procedure with a Gulick (Gilroy, CA) tape measure. Waist-to-hip ratio and BMI were both calculated via procedures outlined in the Canadian Physical Activity, Fitness & Lifestyle Approach [22]. A full body scan via dual x-ray absorptiometry (DXA) was used to assess BF%.

Statistical analysis

Descriptive statistics were used to summarize study sample baseline characteristics (demographic, clinical characteristics, health-related, social-cognitive, physical activity/sedentary behaviour) and were expressed as mean ± standard deviation (SD) or number (percent). Missing data checks were completed prior to conducting any statistical analyses and were handled via multivariate imputations through chained equations, which includes all correlated baseline variables in regression models [23, 24].

Unadjusted univariable models were used to identify significant independent associations of sedentary behaviour, light physical activity, and MVPA with social-cognitive, demographic, clinical, and health-related outcomes. Significant univariable outcomes were then fitted into multivariable linear regression models for sedentary behaviour, light physical activity, and MVPA. Each multivariable model was generated by starting with the strongest statistically significant independent association from the univariable model, identified by examining univariable model p values, followed by the remaining significantly associated variables from the univariable models added one at a time (i.e. forward selection).

Akaike information criterion (AIC) was calculated to identify the most appropriate physical activity and sedentary behaviour multivariable models. The AIC statistic balances both the fit and simplicity of the model (i.e. a model with a lower AIC value is considered to have a better 'goodness of fit' within the same dataset). AIC, compared to Bayesian information criterion, also performs well with smaller sample sizes. While ~1300 participants may be considered small in some fields, it is still sufficient to support reliable estimation of model parameters and evaluate model fit. AIC also allows for more flexibility in model selection, which is valuable when exploring a range of potential models to identify the best-fitting one. The variance inflation factor (VIF) was calculated for each predictor variable in the final multivariable models to account for multicollinearity. A VIF of 1 indicated 'no multicollinearity', 1-5 indicated 'moderate multicollinearity', and > 5 indicated 'high multicollinearity'. A VIF >5 warranted dropping the respective predictor variable from the multivariable model. All statistical analyses were performed in RStudio Version 4.0.0 (Boston, MA, USA).

Results

Sample characteristics

Of the1528 newly diagnosed early breast cancer patients recruited into the AMBER cohort study, there were 1381 participants with complete data on physical activity and sedentary behaviour (ActiGraph® and activPAL™), demographic and clinical characteristics, health-related outcomes, and social-cognitive factors. The average age at diagnosis was 55.4 years. Most participants were Caucasian (*n*=1209; 87.5%), married or living common-law (*n*=1040; 75.3%), post-menopausal (*n*=811; 58.7%), diagnosed with stage I or II breast cancer (*n*=1262; 89.4%), and had not received a mastectomy (*n*=823; 59.6%) (Table 1). All physical activity and sedentary behaviour results can be seen in Table 2. On average, participants wore the ActiGraph® and activPAL™ devices for 14.0 and 14.2 h/day, respectively. Wear time resulted in an average of 5.5 valid days/week for the ActiGraph® and 5.9 valid days/week for the activPAL™ (10 h of wear time per day = one valid day). Participants had an average of 1.0 h/day of MVPA and 8.9 h of sedentary behaviour.

Correlates of physical activity and sedentary behaviour

All unadjusted univariable model results can be seen in Table 3. AIC values and VIF values for chosen multivariable models can be seen in Supplemental Tables 1, 2, 3, 4, 5, and 6 (Supplemental File 1). Three separate multivariable

Table 1 Sociodemographic, clinical, health-related, and social cognitive variables at baseline in the AMBER cohort study (*n* = 1381)

Characteristic	*N* (%) or mean ± standard deviation
Age at diagnosis	55.4 ± 10.7
Ethnicity	
Caucasian	1209 (87.5)
Asian	95 (6.9)
Indian/South Asian	29 (2.1)
Black	9 (0.7)
Latino/Hispanic	18 (1.3)
First Nations/Indigenous/Metis	13 (0.9)
Other	8 (0.6)
Education	
High school or below	305 (22.1)
College	444 (32.2)
University	362 (26.2)
Graduate school	270 (19.5)
Annual family income	
< $50,000	216 (15.6)
$50,000–100,000	444 (32.2)
$100,000–150,000	325 (23.5)
> $150,000	396 (28.7)
Employment	
Works < 35 h/week	921 (66.7)
Works ≥ 35 h/week	460 (33.3)
Marital	
Married or common-in-law	1040 (75.3)
Separated or divorced or widowed	246 (17.8)
Single or never married	95 (6.9)
Clinical characteristics	
Breast cancer stage	
I	621 (43.0)
II	641 (46.4)
III	119 (8.6)
Histology	
Invasive ductal carcinoma	1164 (84.3)
Invasive ductal and lobular carcinoma mixed	55 (4.0)
Invasive lobular carcinoma	150 (10.9)
Other	12 (0.8)
Mastectomy	
No	823 (59.6)
Yes	558 (40.4)
ER positive	1222 (88.5)
PR positive	1059 (76.7)
HER2 positive	210 (15.2)
Received neoadjuvant therapy	104 (7.5)
Menopause status	
Pre	570 (41.3)
Post	811 (58.7)
Health-related	
Body mass index (kg*m−2)	27.5 ± 5.6

Table 1 (continued)

Characteristic	*N* (%) or mean ± standard deviation
Waist to hip ratio	0.9 ± 0.1
Percent body fat (BF%)	43.0 ± 7.2
Smoking	
Never smoker	792 (57.4)
Past smoker	500 (36.2)
Occasional smoker	11 (0.8)
Current smoker	78 (5.6)
Alcohol (g/day)	7.1 ± 16.4
Social cognitive	
Disease-related barriers *(10–70 scale)**	49.7 ± 22.3
Life-related barriers *(9–63 scale)**	41.3 ± 19.3
Motivation-related barriers *(7–49 scale)**	41.4 ± 19.1
Affective attitude *(1–7 scale)***	5.4 ± 1.1
Instrumental attitude *(1–7 scale)***	6.4 ± 0.8
Injunctive subjective norm *(1–7 scale)***	6.4 ± 0.8
Descriptive subjective norm *(1–7 scale)***	4.3 ± 1.2
Perceived behavioural control *(1–7 scale)***	5.8 ± 1.1
Self-efficacy *(1–7 scale)***	5.7 ± 1.2
Intentions *(1–7 scale)***	5.9 ± 1.1
Planning *(1–7 scale)***	4.5 ± 1.8

*Higher scores are indicative of greater barrier influence for physical activity

**Higher scores are indicative of more positive beliefs towards physical activity

models for sedentary behaviour, light physical activity, and MVPA are presented below.

Sedentary behaviour

In the multivariable model (Table 4), greater sedentary behaviour was associated with higher BF% ($\beta = 0.044$; $p < 0.001$) and being single or never married ($\beta = 0.542$; $p = 0.002$). No other factors were associated with fewer hours of daily sedentary behaviour. The amount of variance in sedentary behaviour explained by the model was 4% (adjusted R-square = 0.04).

Light physical activity

Lower light intensity physical activity was associated (Table 5) with higher BF% ($\beta = -0.044$; $p < 0.001$), higher BMI ($\beta = -0.039$; $p < 0.001$), greater disease ($\beta = -0.006$; $p < 0.001$) and life ($\beta = 0.008$; $p < 0.001$) barrier influences ($\beta = 0.008$; $p < 0.01$), having a diagnosis that was stage 3 ($\beta = -0.261$; $p = 0.023$) or HER2 positive ($\beta = -0.278$; $p = 0.001$), and being single or never married ($\beta = -0.385$; $p = 0.001$). The amount of variance in light intensity physical activity explained by the model was 21% (adjusted R-square = 0.21).

Table 2 Physical activity and sedentary behaviour at baseline in the AMBER cohort study ($n = 1381$)

Variable	Mean ± standard deviation
Objective physical activity (ActiGraph®)	
Valid days	5.5 ± 1.4
Weartime (h/day)	14.0 ± 1.4
Light-intensity physical activity (h/day)	4.4 ± 1.2
Moderate intensity physical activity (h/day)	0.9 ± 0.5
Vigorous intensity physical activity (h/day)	0.2 ± 0.2
MVPA (h/day)	1.1 ± 0.7
Self-report physical activity (PYTPAQ — 'Time spent performing…')	
Recreational activity (h/week)	6.6 (5.6)
Recreational activity (MET-h/week)	29.0 (27.1)
Occupational activity (h/week)	12.4 (12.6)
Occupational activity (MET-h/week)	41.0 (44.1)
Household activity (h/week)	21.7 (13.3)
Household activity (MET-h/week)	60.3 (40.4)
Total activity (h/week)	40.7 (18.3)
Total activity (MET-h/week)	130.3 (63.4)
Objective sedentary behaviour (activPAL™)	
Valid days	5.9 ± 1.5
Weartime (h/day)	14.2 ± 1.2
Sedentary behaviour (h/day)	8.9 ± 1.6
Self-report sedentary behaviour (SBQ — 'Time spent sitting during…')	
Recreational time (h/day)	6.0 (2.7)
Occupational time (h/day)	2.1 (2.3)
Travel time (h/day)	1.3 (1.0)
Total sitting time (h/day)	9.3 (3.5)

MVPA, moderate-to-vigorous physical activity; *PYTPAQ*, Past Year Total Physical Activity Questionnaire; *SBQ*, Sedentary Behaviour Questionnaire

Moderate-to-vigorous intensity physical activity (MVPA)

Lower MVPA was associated (Table 6) with higher BF% ($\beta = -0.011$; $p = 0.001$), greater disease ($\beta = -0.002$; $p < 0.001$) and life-related barrier influence ($\beta = -0.002$; $p < 0.01$), having a HER2-positive diagnosis ($\beta = -0.097$; $p = 0.02$), and being of Asian ($\beta = -0.189$; $p = 0.002$) or Indian/South American descent ($\beta = -0.323$; $p = 0.002$). Greater MVPA was associated with positive intentions for physical activity ($\beta = 0.049$; $p = 0.03$), planning for physical activity ($\beta = 0.026$; $p = 0.015$), and having an annual income > \$150,000 ($\beta = 0.128$; $p = 0.007$). The amount of variance in MVPA explained by the model was 10% (adjusted R-square = 0.10).

Table 3 Unadjusted univariable models of sedentary behaviour and physical activity in the AMBER baseline population

Variable	Sedentary behaviour		Light-intensity physical activity		MVPA	
	Estimate (SE)	*p value*	Estimate (SE)	*p value*	Estimate (SE)	*p value*
Sociodemographic						
Age	0.002 (0.004)	0.64	−0.002 (0.003)	0.57	0.002 (0.001)	0.18
Ethnicity (Caucasian is referent)						
Asian	−0.167 (0.174)	0.41	0.432 (0.131)	0.04*	−0.190 (0.106)	<0.01*
Indian/South Asian	−0.291 (0.307)		−0.172 (0.231)		−0.359 (0.106)	
Black	0.297 (0.547)		−0.117 (0.412)		−0.189 (0.189)	
Latino/Hispanic	−0.545 (0.388)		−0.011 (0.292)		−0.201 (0.134)	
First Nations/Indigenous/Metis	−0.135 (0.456)		−0.008 (0.343)		−0.070 (0.158)	
Other	0.814 (0.580		−0.406 (0.436)		−0.378 (0.200)	
Education ('high school' is referent)						
College	−0.256 (0.121)	0.10	0.034 (0.092)	0.34	−0.017 (0.042)	0.03*
University	−0.185 (0.127)		0.114 (0.096)		0.061 (0.044)	
Graduate school	−0.313 (0.136)		0.163 (0.103)		0.099 (0.047)	
Employment ('< 35' is referent)						
Works ≥ 35 h/week	0.108 (0.093)	0.26	−0.048 (0.070)	0.50	−0.018 (0.033)	0.59
Marital status ('married or common-law' is referent)						
Separated or divorced or widowed	0.246 (0.116)	<0.01*	−0.070 (0.087)	0.01*	−0.0001 (0.040)	0.88
Single or never married	0.518 (0.175)		−0.408 (0.132)		−0.031 (0.061)	
Income (< $50k is referent)						
$50,000–100,000	−0.147 (0.136)	0.15	0.172 (0.102)	0.06	0.087 (0.047)	<0.01*
$100,000–150,000	−0.244 (0.143)		0.280 (0.108)		0.107 (0.050)	
> $150,000	−0.304 (0.138)		0.224 (0.104)		0.225 (0.048)	
Clinical characteristics						
Cancer stage ('stage 1' is referent)						
Stage 2	0.184 (0.092)	0.06	−0.189 (0.069)	<0.01*	−0.049 (0.032)	0.15
Stage 3	0.315 (0.163)		−0.426 (0.123)		−0.092 (0.057)	
ER status ('negative' is referent)						
Positive	0.000 (0.138)	0.93	0.137 (0.104)	0.19	−0.013 (0.048)	0.79
PR status ('negative' is referent)						
Positive	−0.169 (0.104)	0.09	−0.175 (0.104)	0.12	0.023 (0.036)	0.52
HER2 status ('negative' is referent)						
Positive	0.268 (0.122)	0.03*	−0.322 (0.092)	<0.01*	−0.100 (0.043)	0.02*
Histology ('ductal carcinoma' is referent)						
Ductal and lobular carcinoma	0.121 (0.226)	0.30	0.025 (0.170)	0.13	0.039 (0.078)	0.15
Lobular carcinoma	−0.227 (0.142)		0.246 (0.107)		0.111 (0.049)	
Other	−0.524 (0.456)		−0.170 (0.358)		0.070 (0.165)	
Mastectomy status ('no' is referent)						
Yes	−0.076 (0.090)	0.42	0.063 (0.068)	0.35	−0.018 (0.031)	0.57
Neoadjuvant status ('no' is referent)						
Yes	0.145 (0.167)	0.39	−0.336 (0.125)	0.01*	0.008 (0.058)	0.89
Menopause Status ('pre' is referent)						
Post	0.070 (0.089)	0.44	−0.106 (0.067)	0.12	0.024 (0.031)	0.44
Health-related						
Smoking status ('never' is referent)						
Past smoker	−0.080 (0.093)	0.12	0.077 (0.070)	0.43	−0.009 (0.032)	0.22
Occasional smoker	−0.598 (0.496)		−0.045 (0.374)		0.227 (0.173)	
Current smoker	0.339 (0.194)		−0.150 (0.146)		−0.108 (0.068)	
Alcohol (g/day)	−0.002 (0.003)	0.41	0.002 (0.002)	0.40	−0.0004 (0.002)	0.18

Table 3 (continued)

Variable	Sedentary behaviour		Light-intensity physical activity		MVPA	
	Estimate (SE)	*p value*	Estimate (SE)	*p value*	Estimate (SE)	*p value*
BMI	0.038 (0.008)	<0.01*	−0.090 (0.005)	<0.01*	−0.014 (0.003)	<0.01*
Percent body fat	0.040 (0.006)	<0.01*	−0.072 (0.004)	<0.01*	−0.015 (0.002)	<0.01*
Waist to hip ratio	1.598 (0.661)	0.01*	−3.555 (0.491)	<0.01*	−0.619 (0.230)	0.01*
Social cognitive						
Disease-related barriers	0.002 (0.002)	0.36	−0.010 (0.001)	<0.01*	−0.003 (0.001)	<0.01*
Life-related barriers	0.004 (0.002)	0.08	−0.004 (0.002)	0.022*	−0.003 (0.001)	0.0003*
Motivation-related barriers	0.009 (0.002)	<0.01*	−0.012 (0.002)	<0.01*	−0.005 (0.001)	<0.01*
Affective attitude	−0.154 (0.040)	<0.01*	0.179 (0.030)	<0.01*	0.098 (0.014)	<0.01*
Instrumental attitude	−0.197 (0.058)	<0.01*	0.209 (0.043)	<0.01*	0.125 (0.020)	<0.01*
Injunctive subjective norm	−0.104 (0.036)	0.92	0.019 (0.028)	<0.01*	0.054 (0.013)	<0.01*
Descriptive subjective norm	−0.007 (0.054)	<0.01*	0.057 (0.041)	0.49	0.068 (0.019)	<0.01*
Perceived behavioural control	−0.094 (0.041)	0.02*	0.069 (0.031)	0.03*	0.059 (0.014)	<0.01*
Self-efficacy	−0.114 (0.036)	<0.01*	0.129 (0.027)	<0.01*	0.077 (0.012)	<0.01*
Intentions	−0.163 (0.042)	<0.01*	0.195 (0.031)	<0.01*	0.127 (0.014)	<0.01*
Planning	−0.090 (0.024)	<0.01*	0.087 (0.018)	<0.01*	0.067 (0.008)	<0.01*

*Significant at the $p<0.05$ level

MVPA, moderate-vigorous physical activity

Table 4 Correlates of sedentary behaviour (hours/day) in the AMBER cohort study

Variable	Estimate (SE)	*p* value
Percent body fat	0.044 (0.010)	***< 0.01***
BMI	−0.014 (0.013)	0.27
Motivation barriers	0.001 (0.002)	0.54
Affective attitude	−0.018 (0.052)	0.73
Intentions	−0.003 (0.063)	0.96
Planning	−0.023 (0.031)	0.45
Instrumental attitude	−0.058 (0.043)	0.44
Self-efficacy	−0.030 (0.043)	0.49
Marital status ('married or common law' is referent)		
Separated or divorced or widowed	0.213 (0.114)	0.07
Single or never married.	0.542 (0.175)	***< 0.01***

SE, standard error

Bold/italic print denotes significant *p* value ($p < 0.05$)

Model: $p < 0.0001$

Adjusted R-square = 0.04

Table 5 Correlates of light-intensity physical activity (hours/day) in the AMBER cohort study

Variable	Estimate (SE)	*p* value
Percent body fat	−0.044 (0.007)	***< 0.01***
Body mass index	−0.039 (0.009)	***< 0.01***
Waist to hip ratio	0.090 (0.496)	0.86
Motivation barriers	−0.004 (0.002)	0.08
Disease barriers	−0.006 (0.002)	***< 0.01***
Intentions	0.050 (0.043)	0.25
Affective attitude	−0.008 (0.036)	0.81
Instrumental attitude	0.035 (0.052)	0.50
Self-efficacy	−0.013 (0.031)	0.68
Planning	0.012 (0.021)	0.55
HER2 positive	−0.278 (0.084)	***< 0.01***
Stage ('stage 1' is referent)		
Stage 2	−0.123 (0.063)	0.05
Stage 3	−0.261 (0.115)	***0.02***
Marital status ('married or common law' is referent)		
Separated or divorced or widowed	−0.039 (0.119)	0.62
Single or never married	−0.385 (0.119)	***< 0.01***
Received neoadjuvant therapy	−0.123 (0.118)	0.30
Life barriers	0.008 (0.002)	***< 0.01***

SE, standard error

Bold/italic print denotes significant *p* value ($p < 0.05$)

Model: $p < 0.0001$

Adjusted R-square = 0.21

Discussion

The current study sought to identify social-cognitive, demographic, clinical, and health-related correlates of objectively assessed physical activity and sedentary

Table 6 Correlates of MVPA (hours/day) in the AMBER cohort study

Variable	Estimate (SE)	*p* value
Intentions	0.046 (0.217)	***0.03***
Planning	0.026 (0.011)	***0.02***
Affective attitude	0.017 (0.018)	0.33
Percent body fat	−0.011 (0.003)	***< 0.01***
Motivation barriers	−0.002 (0.001)	0.10
Instrumental attitude	0.007 (0.026)	0.80
Self-efficacy	0.010 (0.020)	0.63
Disease barriers	−0.002 (0.001)	***0.02***
BMI	0.002 (0.004)	0.53
Income (< $50,000 is referent)		
$50,000–100,000	0.058 (0.045)	0.20
$100,000–150,000	0.061 (0.049)	0.21
> $150,000	0.128 (0.048)	***0.01***
Descriptive subjective norm	0.019 (0.014)	0.18
Perceived behavioural control	−0.002 (0.021)	0.92
Ethnicity ('Caucasian' is referent)		
Asian	−0.189 (0.061)	***< 0.01***
Indian/South American	−0.323 (0.103)	***< 0.01***
Black	−0.159 (0.183)	0.39
Latino/Hispanic	−0.104 (0.129)	0.42
First Nations/Indigenous/Metis	−0.054 (0.152)	0.72
Other	−0.270 (0.193)	0.76
Injunctive subjective norm	−0.014 (0.022)	0.52
Life barriers	−0.002 (0.001)	***0.01***
Waist to hip ratio	0.272 (0.250)	0.278
HER2 positive	−0.097 (0.041)	***0.02***

SE, standard error

Bold/italic print denotes significant *p* value ($p < 0.05$)

Model: $p < 0.0001$

Adjusted R-square = 0.10

behaviour in a sample of recently diagnosed breast cancer patients. Higher BF% was the only outcome associated with both physical activity (i.e. reduced light and MVPA) and sedentary behaviour (i.e. increased sedentary behaviour), while having positive intentions and planning towards physical activity were both associated with greater MVPA in those recently diagnosed with breast cancer. Being 'single or never married' was associated with two outcomes, less light physical activity and greater sedentary behaviour.

Correlates of sedentary behaviour

Findings from previous literature are mixed regarding associations of sedentary behaviour in cancer populations [11, 25]. For example, D'Silva et al. reported that being overweight/obese was associated with increased sedentary behaviour in a sample of individuals with lung cancer [25], which aligns with our findings of greater BF% being associated with greater sedentary behaviour in individuals with breast cancer. To our knowledge, only two other studies have provided evidence on associations of sedentary behaviour in a breast cancer samples, reporting associations of increased sedentary behaviour with greater symptom severity (i.e. pain, fatigue, anxiety) [11, 12]. Recently, isotemporal substitution interventions have been used with cancer populations, which includes reallocating sedentary behaviour with more active behaviours (i.e. light or MVPA). Welch et al. recently reported on the success of this approach in which 30 min of sedentary time was reallocated to 30 min of MVPA in a sample of breast cancer survivors, resulting in increased overall physical activity and improved quality of life [26]. It is worth noting that our results showed the greatest amount of self-reported sedentary behaviour took place during recreational and leisure time (e.g. while watching television). Our findings suggest that these interventions may consider targeting recreational and leisure time activities that substitute physical activity for sedentary behaviour in recently diagnosed individuals with breast cancer who may be overweight/obese and/or identify as 'single or never married'.

Correlates of light physical activity

Clinically, a HER2- positive diagnosis was associated with less light physical activity. Most work to date has focused on *pre-diagnosis* physical activity levels as a risk factor for more biologically aggressive breast cancer tumours [27]. Our findings indicate that more biologically aggressive tumours are also associated with reduced physical activity, specifically of light intensity, in recently diagnosed individuals with breast cancer. Our findings of greater BF% and BMI being associated with reduced light physical activity support previous literature as well, and show these relationships also exist prior to starting breast cancer treatments, not just within survivorship [7, 13]. Based on previous work that suggests a relationship between decreased physical activity, higher body composition at diagnosis, and an increased risk of breast cancer recurrence [28, 29], these findings emphasize the importance of promoting physical activity amongst overweight and obese individuals early in the breast cancer continuum.

Additionally, being 'single or never married' was associated with reduced light physical activity. Although not a direct measure of social support, this finding may indicate the importance of social support for physical activity engagement. Previous research has reported on positive health benefits and high adherence rates to exercise for individuals with prostate cancer when participating with someone else

[30]. Finally, greater influence of disease-related barriers was the only social-cognitive factor associated with reduced light physical activity. This finding was not surprising since disease-related side effects, such as cancer-related fatigue, have been shown to contribute to reduced physical activity in individuals living with breast cancer [31]. Since increased light physical activity has been associated with less fatigue in cancer populations [32], this finding provides rationale for providing education on disease barrier-management techniques, such as managing fatigue with exercise, at diagnosis.

Correlates of moderate to vigorous physical activity

Additional sub-populations associated with reduced physical activity were identified in our MVPA model. Being of Asian or Indian/South American descent, as well as those in a lower socioeconomic status bracket (<$50,000), were associated with lower MVPA. These objective physical activity associations are similar to prior literature that indicates those diagnosed with breast cancer who identify with an ethnic minority group or report a lower socioeconomic annual income self-report lower physical activity [33, 34]. Social cognitive correlates of MVPA included a greater influence of disease- and life-related barriers with less MVPA. Perceived barriers, such as not having time to exercise due to other responsibilities (e.g. work-related), have been previously reported in breast cancer samples receiving adjuvant therapy [35], and contribute to the reduction in MVPA engagement. Our results are consistent with this previous work and again promote the use of education on barrier management techniques in future physical activity interventions to reduce the likelihood of decreased physical activity across the breast cancer continuum.

The additional social cognitive associations identified in our analysis suggest that having both the intention and plan to be physically active may be necessary to achieve recommended MVPA levels in individuals recently diagnosed with breast cancer. While this finding supports previous literature in other cancer populations that utilized self-reported physical activity methods [36–39], they are in contrast to earlier work supporting additional correlates including self-efficacy, perceived behavioural control, attitude, and subjective norm, all of which can influence exercise intentions [37, 38]. Furthermore, given the limited variance explained across all multivariable models (sedentary behaviour = 4%; light physical activity = 21%; MVPA = 10%) at this single timepoint, considering other potential correlates such as environmental factors that are beyond the individual (e.g. availability and accessibility of exercise facilities and resources) will be important to assess.

This research may be best conducted by using a social ecological model approach [40], which would allow for identification of associations amongst policy, the physical environment, the interpersonal environment, and physical activity behaviour within recently diagnosed breast cancer samples. Provided that self-reported physical activity and sedentary behaviour in our sample showed that individuals recently diagnosed with breast cancer spent the least amount of time being active and the greatest amount of time being sedentary within the domain of recreational and leisure activities, focusing on this domain may be an approach to optimize changing physical activity levels.

Taken together, our study's findings provide valuable information pertaining to correlates of physical activity behaviour after a recent breast cancer diagnosis. Higher BF% was strongly associated with both physical activity and sedentary behaviour. This finding alone clearly identifies a breast cancer sub-population that should be targeted prior to starting treatment for future exercise and physical activity interventions. Targeting individuals with a recent breast cancer diagnoses and greater BF% could be a focus for future prehabilitation interventions to improve both long- and short- term outcomes via tailored total body exercise (aerobic + resistance training), nutritional, and behaviour change support [5, 41]. Provided the well-established body composition benefits of exercise in breast cancer populations [1], doing so may not only improve BF%, but also positively impact physical function and fatigue [42], both of which can influence overall quality of life.

While this study adds to our understanding of potential correlates of both objectively measured physical activity and sedentary behaviour at an understudied timepoint, limitations must be considered in the interpretation and impact of these findings. First, our analyses may be prone to type I error and should be interpreted as such. However, these analyses were primarily hypothesis generating given the exploratory nature of our study. Additionally, this was a cross-sectional analysis; thus, causal relationships cannot be determined from our statistical analyses. For example, although we did observe strong relationships with higher BF% and reduced physical activity at both light and moderate/vigorous intensities as well as sedentary behaviour, we are unable to determine if higher BF% causes decreased physical activity or increased sedentary behaviour, and vice versa. The AMBER cohort study will examine these relationships across time in future analyses [14]. Second, our sample was particularly active (MVPA = 1.1 h/day), which contrasts with previous studies exploring physical activity levels in those living with breast cancer [43] and may impact the generalizability of the observed relationships in our analyses with other studies. However, it is important to note that our analysis focused on the period prior to treatment, an understudied timepoint, and provides context into which factors may contribute to physical activity and sedentary behaviour across the continuum. Lastly, our sample was also predominantly comprised of those of Caucasian descent (87.5%). As such, the generalizability of our results to all individuals recently diagnosed with breast cancer across all ethnicities may be limited in scope, and findings related to ethnic descent should be interpreted cautiously given the relatively smaller sample size.

Conclusion

Our findings showed that higher BF% was associated with increased sedentary behaviour, reduced light physical activity, and reduced MVPA in individuals recently diagnosed with breast cancer. Our study also identified other sub-populations within the breast cancer sample that were associated with decreased physical activity, including HER2-positive diagnoses, ethnic minorities, single or never married, and lower socioeconomic status. Social-cognitive factors related to greater levels of MVPA included having stronger intentions and planning towards physical activity. Future research should aim to identify additional correlates of physical activity and sedentary behaviour in recently diagnosed breast cancer patients, including factors beyond the individual at community, environmental, and policy levels.

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Author contributions Chad W. Wagoner and S. Nicole Culos-Reed contributed to material preparation, formal analysis, and main text writing. S. Nicole Culos-Reed, Christine M. Friedenreich, Jeff K. Vallance, Margaret L. McNeely, and Kerry S. Courneya contributed to study conceptualization. S. Nicole Culos-Reed, Christine M. Friedenreich, Jeff K. Vallance, Margaret L. McNeely, Kerry S. Courneya, and Charles E. Matthews contributed to the methodology. Qinggang Wang, Leanne Dickau, and Andria Morielli contributed to project administration and data curation. All authors reviewed and edited the submitted manuscript.

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Data availability Data can be made available upon reasonable request.

Declarations

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Health Research Ethics Board of Alberta: Cancer Committee (HREBA.CC-17-05076).

Consent to participate Informed consent was obtained from all participants included in the study.

Competing interests The authors declare no competing interests.

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