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Predictive ability of the theory of planned behavior on physical activity in newly diagnosed women with breast cancer: a prospective cohort study

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Abstract

Purpose Few studies assess how well the Theory of Planned Behavior (TPB) predicts physical activity over time after a breast cancer diagnosis. This study evaluated TPB's prediction, measured at diagnosis, on women's physical activity 1 year later.

Methods The Alberta Moving Beyond Breast Cancer (AMBER) study follows women recently diagnosed with breast cancer ($n = 1528$; average age 55.4). Participants completed questionnaires on TPB variables about recreational activity shortly after diagnosis. At 1 year, actiGraph GT3X+® devices measured light and moderate-vigorous activity, and self-reported activity over the past year was assessed with the Past Year Total Physical Activity Questionnaire. Structural equation models evaluated TPB variables' ability to predict physical activity after 1 year.

Results At diagnosis, positive attitudes ($\beta = 0.51$; $p < 0.001$) and greater perceived behavioral control ($\beta = 0.16$; $p < 0.001$) were associated with greater intentions for physical activity derived from device-measured ($R^2 = 0.51$, $p < 0.001$) and self-reported questionnaire ($R^2 = 0.54$, $p < 0.001$). The TPB at diagnosis was associated with greater device-measured MVPA at 1 year ($\beta = 0.13$; $p < 0.01$). The TPB was not associated with device-measured light-intensity physical activity ($\beta = 0.07$; $p = 0.08$) or self-reported recreational physical activity ($\beta = 0.08$; $p = 0.07$).

Conclusion The variance explained by the TPB for physical activity at 1 year after breast cancer diagnosis was minimal. These findings highlight the need to identify additional factors influencing intentions and long-term activity.

Implications for Cancer Survivors Incorporating behavior change strategies that influence attitudes toward physical activity may positively impact intentions at diagnosis. To ensure long-term activity among breast cancer survivors, supportive care should include interventions addressing factors beyond initial intentions.

Keywords Theory of Planned Behavior · Physical activity · Breast cancer · Structural equation modeling · Intention-behavior gap

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Introduction

Physical activity has many benefits for women diagnosed with breast cancer, including improved physical fitness, physical function, psychosocial well-being, health-related quality of life, and alleviated treatment-related side effects [1]. Meeting the minimum physical activity guidelines before a breast cancer diagnosis and after breast cancer treatment is also associated with reduced recurrence and mortality [2–4]. Despite these benefits, barriers such as reduced self-efficacy and social support [5, 6], the severity of treatment-related side effects [7, 8], and unawareness of or access to supportive physical activity resources (i.e., education or services) [7] may contribute to the low physical activity participation that is observed across breast cancer survivorship [9, 10].

The Theory of Planned Behavior (TPB) suggests that an individual's intention is the immediate determinant of physical activity and mediates the influence of the individual's attitude, subjective norm, and perceived behavioral control [11]. Previous studies have linked these TPB determinants—attitude (i.e., positive or negative evaluation of a behavior), subjective norm (i.e., perceived social pressure to perform a behavior), perceived behavioral control (i.e., perceived difficulty in performing a behavior), planning, and intentions—to physical activity behavior among various cancer populations [12–17]. However, many of these studies have been cross-sectional [12–14, 16, 17] or focused on associations between physical activity and the TPB in the post-treatment phase of cancer survivorship [13–15, 17]. As a result, evidence is lacking regarding intentions for physical activity at breast cancer diagnosis and how these intentions may influence future physical activity behavior. To date, TPB testing has helped identify potential associations, though there remains a limited understanding of the TPB's predictive ability for physical activity.

Thus, it is unclear how well the TPB predicts physical activity behavior over time for women newly diagnosed with breast cancer. Given its longitudinal design, the Alberta Moving Beyond Breast Cancer (AMBER) study provides an excellent opportunity to examine prospective associations that will provide a better understanding of the TPB's ability to predict physical activity behavior. Leveraging these methodological strengths, this study aimed to assess the predictive ability of TPB determinants measured near diagnosis on device-measured (i.e., accelerometry) and self-reported physical activity behavior 1 year after a breast cancer diagnosis.

Methods

Participants and study design

The AMBER study design and baseline cohort have previously been described [18, 19]. Briefly, this was a prospective cohort study in which newly diagnosed women with stage I-IIIc breast cancer who were 18–80 years of age, were not pregnant, had either not initiated neo-adjuvant therapy, or had not completed more than two cycles, were within 90 days of surgery and before adjuvant treatment, and were able to answer questionnaires in English were eligible. Eligible participants were recruited from Edmonton and Calgary, Alberta, Canada, from July 2012 through July 2019. The study was approved by the Health Research Ethics Board of Alberta: Cancer Committee (HREBA.CC-17–05076). Participants provided signed consent before starting study-related activities.

Demographic and clinical characteristics

A self-administered baseline health history questionnaire (BHQ) was used to collect sociodemographic and clinical characteristics. Sociodemographic variables included age, ethnicity, education, annual income, employment, and marital status. Clinical characteristics included tumor stage (I, II, or III), histology ("ductal carcinoma," "ductal + lobular carcinoma," "lobular carcinoma," "other"), mastectomy status ("Yes" or "No" to having had a mastectomy), treatment type, estrogen receptor status (ER-positive/negative), progesterone status (PR positive/negative), human epidermal growth factor receptor two status (HER2 positive/negative), neoadjuvant therapy status ("Yes" or "No" to received), and menopausal status ("Pre" or "Post").

Theory of Planned Behavior determinants

All items were measured on 1–7 Likert scales, and item scores were summed and averaged. Lower scores reflect less positive attitudes, subjective norms, perceived behavioral control, and intentions towards physical activity participation.

Attitude

Affective attitude was assessed by measuring participants' enjoyment, fun, and pleasure levels when participating in leisure physical activity. Participants were asked to respond to the following prompt: "For me, participating in regular physical activity for the next six months would be: enjoyable, fun, and pleasurable," with greater scores representing positive affective attitudes. Similarly, *instrumental attitude* was assessed using the same prompt and measured if participants felt participating in physical activity was beneficial, useful, and important, with greater scores representing positive instrumental attitudes.

Subjective norm

Descriptive norm for physical activity participation was assessed with the following: [1] "I think that during the next six months, those who are important to me will themselves be… [answer ranging from extremely inactive to extremely active]"; [2] "I think that during the next six months, most people who are important to me will themselves participate in physical activity [answer ranging from strongly disagree to strongly agree]"; and [3] "I think that during the next six months, the amount of physical activity that most people who are important to me do will be… [answer ranging from extremely low to extremely high]". Similarly, *injunctive norms* were assessed using a similar prompt to measure if participants felt they participated in physical activity and if those important to them would approve, be supportive, and be encouraging.

Perceived behavioral control

Perceived behavioral control was assessed by asking the following: [1] "If you were really motivated, how controllable would it be for you to participate in regular physical activity during the next six months [answer ranging from extremely uncontrollable to extremely controllable]"; and [2] "If you were really motivated, do you feel that you would have complete control over whether you participated in regular physical activity during the next six months [answer ranging from extremely untrue to extremely true]."

Intentions

Intention was assessed with the following: [1] "I strongly intend to participate in regular physical activity during the next six months [answer ranging from extremely untrue to extremely true]"; [2] "How motivated are you to participate in regular physical activity during the next six months [answer ranging from extremely unmotivated to extremely motivated]"; and [3] "How committed are you to participating in regular physical activity during the next six months [answer ranging from extremely uncommitted to extremely committed]".

Planning

Planning was assessed with the following five statements: [1] "I have made plans concerning WHEN I am going to engage in regular physical activity over the next six months"; [2] "I have made plans concerning WHERE I am going to engage in regular physical activity over the next six months"; [3] "I have made plans concerning WHAT kind of regular physical activity I am going to engage in over the next six months"; [4] "I have made plans concerning HOW I am going to get to a place to engage in regular physical activity over the next six months"; and [5] "I have made plans concerning WHO I am going to be physically active with over the next six months". Greater scores represented more detailed planning.

Physical activity

ActiGraph GT3X+® (ActiGraph, LLC, Pensacola, FL) devices were provided to participants and were worn on the right hip for seven consecutive days during their time out of bed (i.e., waking hours) to assess device-measured light, moderate, and vigorous-intensity physical activity at baseline and 1 year after study enrollment. The total hours of moderate and vigorous-intensity physical activity per day were combined, resulting in a variable for moderate-to-vigorous intensity physical activity hours per day. The Soj3x prediction method (R Sojourn package version 1.1.0, Soj3x) was used to derive light, moderate, and vigorous physical activity data from the ActiGraph GT3X+® device, which has been validated in free-living adults [20]. Physical activity at each intensity level was reported as hours per day. Only participants with an average weekly wear time of $\geq$ 4 days/week were included (10 h of wear time = one valid day). Self-report physical activity was assessed using the Past Year Total Physical Activity Questionnaire [21]. The questionnaire assesses total physical activity, including recreational, occupational, household, and transit activities, within the past 12 months. Self-reported physical activity was reported in hours per week and converted to MET-hours per week using the Compendium of Physical Activities [22].

Statistical analysis

All data were analyzed using RStudio Version 4.3.0 (Boston, MA, USA). Descriptive statistics were used to summarize the study sample's baseline characteristics (demographics, clinical characteristics, and physical activity), which were expressed as mean $\pm$ standard deviation (SD) or as a number (percent).

Structural equation modeling was conducted using the *Lavaan* package to test the predictive ability of the Theory of Planned Behavior (with and without the inclusion of planning) at baseline on physical activity 1 year after diagnosis. Missing data checks were completed before conducting any analyses. Missing data were addressed with multivariate imputations through chained equations [23, 24]. Attitudes, subjective norm, and perceived behavioral control were considered latent variables, intentions and planning were considered mediating variables, and physical activity (derived from both the ActiGraph® and the Past Year Total Physical Activity Questionnaire, separately) was considered an observed variable. Univariate and multivariate normality assumptions were assessed via the Shapiro-Wilk Univariate and the Mardia Multivariate normality tests, respectively. A maximum likelihood estimation with a Satorra-Bentler scaled test statistic was used as the model estimation method. This estimation method was chosen because it corrects for violations of the multivariate normality assumption. Multiple tests assessed model fit, including the chi-square statistic (sensitive to large sample sizes), the root mean square error of approximation, comparative fit indexes, and the root mean square residual error. Results from each model fit test were examined to determine if the specified model was plausible. Coefficients and R^2 values were derived from the structural model.

Structural equation models were created for light-intensity and moderate-vigorous-intensity physical activity (MVPA; hours/week) derived from the ActiGraph®. Structural equation models were also created for self-reporting recreational physical activity (hours/week). The decision was made not to generate structural equation models for household, occupational, and transit physical activity given the nature in which TPB questions were framed (i.e., TPB questions were worded to focus on leisure and recreational physical activity in the next 6 months). All structural equation models were adjusted for light-intensity physical activity (MVPA model only), MVPA (light-intensity physical activity model only), body mass index (BMI), age, education, comorbidities, disease stage, surgery type, location (Calgary or Edmonton), and smoking status. Covariates were selected based on previously established demographic and health-related factors related to physical activity participation, as well as previously published analyses from the AMBER dataset [12, 25–27].

Results

Sample characteristics

A total of 1528 newly diagnosed early breast cancer patients were enrolled in the AMBER cohort study at baseline, whose characteristics have been previously reported [19]. Briefly, the average age at diagnosis was 56 ± 11 years. The baseline cohort was also 87% white, with over half being post-menopausal (59%) and diagnosed with Stage II or Stage III breast cancer (55%). In the present study, 1069 participants (70% of baseline sample) had fully completed baseline TPB questionnaires *and* valid device-measured physical activity (i.e., ≥ 4 valid wear-time days) at 1 year. Additionally, 1269 participants (83% of baseline sample) had fully completed baseline TPB questionnaires *and* fully completed self-reported physical activity questionnaires at 1 year. All physical activity descriptives at 1 year can be seen in Table 1. On average, participants wore the ActiGraph® devices for 14.5 h/day. Wear time resulted in an average of 6.1 valid days/week.

Device-measured light intensity physical activity

Positive attitudes ($\beta = 0.51$; $p < 0.001$) and greater perceived behavioral control ($\beta = 0.16$; $p < 0.001$) were associated with greater intentions ($R^2 = 0.51$) to do light-intensity physical activity, while subjective norm ($\beta = 0.15$; $p = 0.06$) was not associated. Intentions ($\beta = 0.07$; $p = 0.08$), perceived behavioral control ($\beta = -0.04$; $p = 0.30$), and planning ($\beta = -0.04$; $p = 0.21$) at diagnosis were not associated with light-intensity physical activity at 1 year. The model accounted for ~ 21% ($R^2 = 0.21$) of the variance in light-intensity physical activity at 1 year (Fig. 1), which was not explained by the TPB but rather

Table 1 Device-based and self-reported physical activity at 1-year in the AMBER Cohort Study, 2013–2020

Variable	Mean (SD)
ActiGraph® Physical Activity (n = 1085)	
Valid days	6.1 (1.0)
Weartime (hours/day)	14.5 (1.3)
Light-intensity physical activity (hours/day)	4.7 (1.3)
Moderate intensity physical activity (hours/day)	1.0 (0.5)
Vigorous intensity physical activity (hours/day)	0.2 (0.2)
Moderate-Vigorous physical activity (hours/day)	1.1 (0.6)
Self-Report Physical Activity (PYTPAQ, n = 1261)	
Recreational Activity (hours/week)	6.3 (5.3)
Recreational Activity (MET-hours/week)	27.4 (23.9)
Occupational Activity (hours/week)	15.0 (16.1)
Occupational Activity (MET-hours/week)	34.4 (39.8)
Household Activity (hours/week)	19.9 (11.6)
Household Activity (MET-hours/week)	54.7 (34.5)
Transit Activity (hours/week)	0.2 (0.6)
Transit Activity (MET-hours/week)	0.7 (2.2)
Total Activity (hours/week)	41.4 (18.6)
Total Activity (MET-hours/week)	117.1 (55.3)

SD standard deviation, *PYTPAQ* Past Year Total Physical Activity Questionnaire

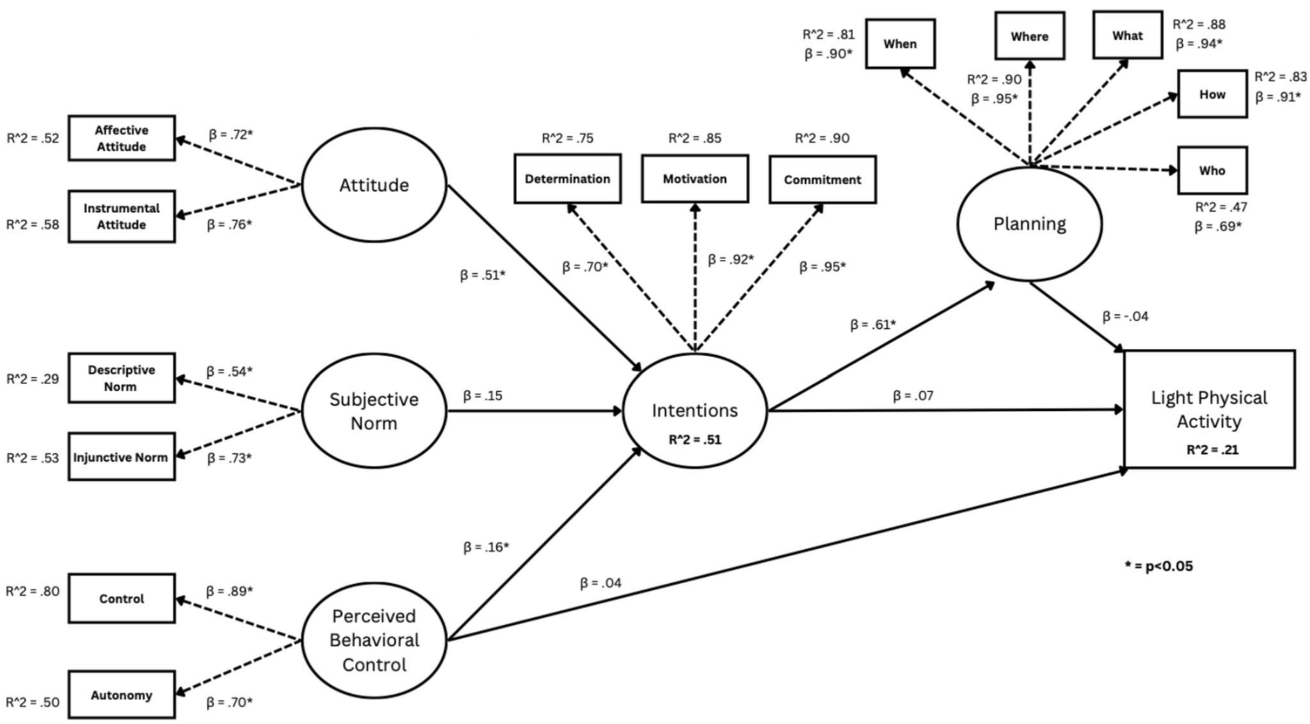

Fig. 1 Structural equation model path diagram for light-intensity physical activity

by significant associations between covariates and light-intensity physical activity, including BMI ($\beta = -0.39$; $p < 0.001$), MVPA ($\beta = 0.12$; $p < 0.001$), and location ($\beta = 0.08$; $p < 0.01$).

Device-measured moderate-vigorous intensity physical activity (MVPA)

Positive attitudes ($\beta = 0.51$; $p < 0.001$) and greater perceived behavioral control ($\beta = 0.16$; $p < 0.001$) were associated with greater intentions ($R^2 = 0.51$) to engage in MVPA, while subjective norm ($\beta = 0.15$; $p = 0.06$) was not associated. Greater intentions ($\beta = 0.13$; $p < 0.01$) for MVPA at diagnosis were associated with greater MVPA at 1 year, while perceived behavioral control ($\beta = 0.04$; $p = 0.35$) and planning ($\beta = 0.02$; $p = 0.63$) at diagnosis were not associated with MVPA at 1 year. The TPB at diagnosis accounted for ~ 6% ($R^2 = 0.06$) of the variance in MVPA at 1 year (Fig. 2).

Recreational physical activity (self-report)

Positive attitudes ($\beta = 0.57$; $p < 0.001$) and greater perceived behavioral control ($\beta = 0.18$; $p < 0.001$) were associated with greater intentions ($R^2 = 0.54$) to engage in recreational physical activity, while subjective norm ($\beta = 0.08$; $p = 0.21$) was not associated with intentions to do recreational physical activity at diagnosis. Greater planning ($\beta = 0.19$; $p < 0.001$) to do recreational physical activity at diagnosis was associated with greater recreational physical activity at 1 year, while intentions ($\beta = 0.08$; $p = 0.07$) and perceived behavioral control ($\beta = 0.04$; $p = 0.27$) at diagnosis were not associated with recreational physical activity at 1 year. The TPB at diagnosis accounted for ~ 8% ($R^2 = 0.08$) of the variance in recreational physical activity at 1 year (Fig. 3).

Discussion

Findings from the present study indicate that positive attitudes and perceived behavioral control are associated with greater intentions to engage in physical activity shortly after diagnosis across intensity and measurement, while subjective norms are not. Interestingly, no TPB constructs shortly after diagnosis were associated with light-intensity physical activity 1 year later. Physical activity intentions at diagnosis were associated with MVPA, explaining 6% of the variance, and planning at diagnosis was associated with self-reported recreational physical activity, explaining 8% of the variance, 1 year later. Many studies have reported on the potential utility of the TPB for supporting physical activity behavior and exercise intervention design across different cancer populations [13, 15–17, 28, 29]. Findings in this study suggest that while attitudes and perceived behavioral control positively impact intentions to be physically active at diagnosis, collectively, the TPB constructs assessed shortly after diagnosis

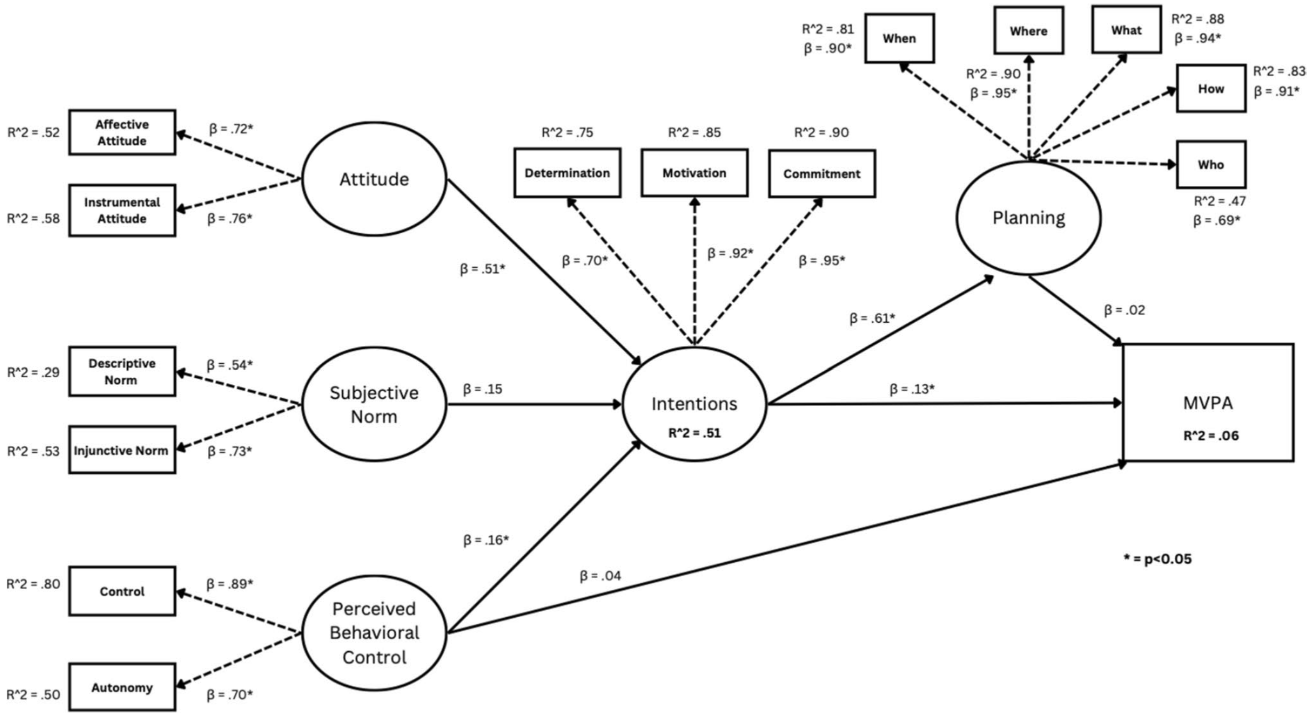

Fig. 2 Structural equation model path diagram for moderate–vigorous physical activity

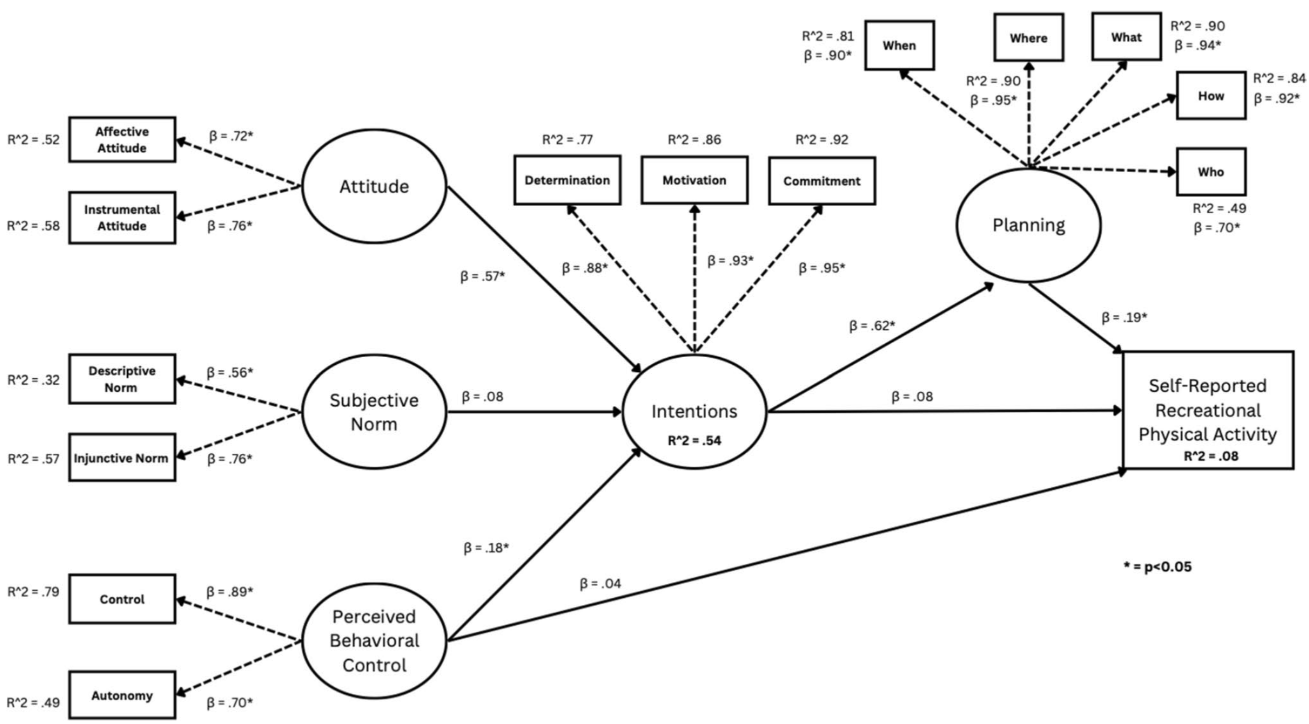

Fig. 3 Structural equation model path diagram for self-reported recreational physical activity

are not strong predictors of physical activity behavior 1 year later. There is a need to continue to understand the influence of additional factors on intentions to best support physical activity behavior after a breast cancer diagnosis, such as the impact of treatment.

The TPB posits that perceived behavioral control and intentions directly impact behavior (e.g., physical activity). Trinh et al. [13] reported the direct effects of perceived behavioral control and intentions on self-reported leisure MVPA in a cohort of kidney cancer survivors. Similarly, Min et al. [17] identified a significant direct impact of both perceived behavioral control and intentions with self-report leisure MVPA among a cohort of breast cancer survivors. Our findings do not support perceived behavioral control directly predicting physical activity within the TPB, as it was not associated with light-intensity physical activity, MVPA, or self-reported recreational physical activity 1 year after diagnosis. However, previous research has been cross-sectional rather than longitudinal [13, 17]. Thus, perceived behavioral control may be directly related to physical activity when measurements occur during the same time period after treatment (i.e., cross-sectional studies). However, this association was not evident in our study 1 year after a breast diagnosis, in which participants are likely to undergo surgery, receive neoadjuvant/adjuvant therapies, and, as a result, experience more perceived barriers to physical activity [30]. This result suggests that while women with breast cancer may have the confidence to engage in physical activity at diagnosis, other factors, such as cancer-specific barriers [31] that arise after a diagnosis, may result in changes in their behavior that differ from what they intended to do at baseline [32].

Although there were no associations between physical activity and perceived behavioral control, this study showed that intentions for physical activity at breast cancer diagnosis were associated with MVPA at 1 year, as measured over 7 days by accelerometer. This finding supports the notion that intentions play a role in engaging in MVPA, although the explained variance was small (6%). Furthermore, intentions were not associated with device-measured light intensity or self-reported recreational physical activity, which is inconsistent with prior research [13, 15–17]. In addition to the longitudinal design of the AMBER study [18], which differs from most previous cross-sectional analyses of the TPB, the present study's timeline includes the impact of cancer-related therapies that elicit side effects, potentially altering intentions and perceived behavioral control towards physical activity [33]. This possibility is supported by Caru et al. [34], who reported a decline in physical activity intentions 6–8 weeks after a cancer diagnosis and treatment initiation. Although the study focused on pediatric populations, it illustrates how intentions may fluctuate following a cancer diagnosis, which might help explain the lack of association observed in the present study. Future research should assess the impact of cancer treatments on intentions and perceived behavioral control over time. Capturing changes in intentions and perceived behavioral control may better represent the changing physical activity needs of women diagnosed with breast cancer and aid in predicting future behavior after diagnosis.

The intention-behavior gap presents a dilemma in the TPB, as it typically negatively impacts the translation of high intentions into actual physical activity [35, 36]. Previous studies suggest extending the TPB to include additional variables (i.e., planning, demographics) rather than discarding the theory [37, 38]. We attempted to address this gap in the literature by including planning as a mediating variable between intentions and physical activity across structural equation models. Results showed that planning positively mediated the relationship between intentions and self-reported recreational physical activity over the next year, but not device-measured light-intensity physical activity or MVPA measured over 7 days at 1 year. This finding has possible implications for including behavior change techniques within a physical activity intervention design, such as action planning, which has been associated with greater physical activity in women diagnosed with breast cancer [12]. Though informative, this mediating effect should be interpreted carefully, as the TPB's predictive ability remained limited, further underscoring the need to identify other factors that may explain long-term physical activity behavior after a breast cancer diagnosis. Additionally, the timing of assessing the TPB variables should be considered. Assessing at or close to diagnosis may reflect intentions that are soon changed with the reality of treatment impacts [34]. Consideration for assessing intentions after treatment may be a more realistic predictor of future behavior.

Attitudes and perceived behavioral control collectively explained a significant proportion of the variance in intentions at baseline across light-intensity physical activity, MVPA, and self-reported recreational physical activity. This finding is consistent with previous studies across various cancer types, including breast [17], kidney [13], bladder [15], and advanced (metastatic) cancers [16], underscoring the importance of these TPB determinants in shaping an individual's intentions for physical activity across intensity levels and domains. An additional finding across all structural equation models was that attitudes had a consistently strong influence on intentions. This finding suggests that promoting positive beliefs and experiences (i.e., instrumental and affective attitudes) about physical activity at diagnosis may be impactful in fostering positive intentions for future physical activity behavior in women newly diagnosed with breast cancer. However, as our findings suggest, higher intentions do not significantly predict future physical activity behavior. Therefore, future work may focus on understanding how external variables during this period may modify the relationship between baseline intentions and physical activity 1 year after diagnosis.

Limitations should be considered to better contextualize the findings of the present study. Objective and subjective measures of physical activity were used to assess behavior at different time points in our longitudinal design. The Actigraph® measures of total physical activity were obtained over 7 days, approximately 1 year after diagnosis. In contrast, the self-report measures of recreational physical activity, although measured 1 year after diagnosis, asked about the past 12 months. As a result, differences may exist between self-reported and objectively measured physical activity, as these measures capture physical activity over different periods, limiting their direct comparison. Additionally, the Actigraph® measured total physical activity across three intensities, and it is not possible to discern the distribution of physical activity across different domains with this device (e.g., recreational, occupational, household, and transit). Although self-reported physical activity across various domains was obtained, which could help address this limitation, the TPB measures specifically prompted participants to concentrate on recreational physical activity. Consequently, structural equation models were not constructed for different physical activity domains, limiting generalizability. Future studies may address these limitations by adapting TPB questions to encompass a broader range of physical activity domains, as well as utilizing the EPiCC framework [39] to assess the TPB in relation to various treatment combinations, thereby providing a more comprehensive understanding of physical activity behavior and its determinants across breast cancer survivorship.

Conclusion

The TPB showed a small but significant association with accelerometer-measured moderate-to-vigorous physical activity (MVPA), but not with light physical activity or self-reported recreational physical activity. TPB determinants (i.e., attitudes and perceived behavioral control) collectively predicted intentions, with attitudes being the strongest predictor. These findings indicate that while attitudes and perceived behavioral control predict intentions at diagnosis, additional factors may predict long-term physical activity behavior. Consideration of strategies to increase confidence and positive experiences with physical activity may be important to impact one's intentions, such as the behavior change techniques of action planning and self-monitoring. Assessing changes in intentions to be physically active across the breast cancer continuum may also inform the design of future interventions to promote physical activity. Further identification of cancer-related (i.e., treatment impact) and other external factors may further inform how to tailor interventions to support long-term physical activity behavior after a breast cancer diagnosis.

Author Contribution 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 and obtained the research funding. 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 and Leanne Dickau contributed to project administration, data curation, and data analysis. All authors reviewed and edited the submitted manuscript.

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Data availability De-identified data from this study are not available in a public archive. De-identified data from this study will be made available (as allowable according to institutional IRB standards) by emailing the corresponding author.

Declarations

Ethics approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent The Health Research Ethics Board of Alberta: Cancer Committee (HREBA.CC-17-05076) granted approval. Informed consent was obtained from all participants included in the study.

Conflict of interest The authors declare no competing interests.

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