

**Physical activity and sedentary behavior in breast- and colon- cancer survivors
relative to non-cancer controls**

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ABSTRACT

OBJECTIVE: To assess differences in accelerometer-assessed moderate to vigorous intensity physical activity (MVPA), light intensity physical activity, and sedentary time between cancer survivors and age- and sex-matched controls.

PATIENTS AND METHODS: Breast cancer survivors (n= 245) from the ACCEL-Breast Study (2013), and colon cancer survivors (n=163) from the ACCEL-Colon Study (2012-2013), were matched 1:1 by sex and five-year age category with non-cancer controls from the AusDiab accelerometer sub-study (2011-2012). Multivariable conditional logistic regression models tested the odds of case/control status per hour per day of MVPA, light activity and sedentary time. Results conversely indicate the odds of an additional hour per day of activity for cases (cancer survivors) versus controls.

RESULTS: Breast cancer survivors had significantly greater odds than controls of one hour per day more MVPA (OR=3.41, 95% CI: 1.79-6.49) and greater odds of accruing one hour per day additional sedentary time in prolonged (≥ 20 min) bouts (OR=1.16, 95% CI: 1.00-1.33). Colon cancer survivors had significantly higher odds (relative to controls) of performing one hour per day more MVPA (OR=2.12, 95% CI: 1.00-4.52) and MVPA in ≥ 10 minute bouts (OR=4.10, 95%CI: 1.10-15.10); and, significantly lower odds of one hour per day more light activity (OR=0.83, 95% CI: 0.69-0.99).

CONCLUSION: Contrary to findings from previous research (based on self-reported physical activity), cancer survivors engaged in more MVPA than non-cancer controls. Cancer survivors also engaged in more sedentary time, but less light physical activity. These findings highlight the importance of considering the full activity spectrum in the context of cancer control.

Physical activity is associated with improved survival in adults diagnosed with colorectal¹⁻³ and breast cancer.^{2,4,5} There is also evidence that physical activity enhances quality of life and improves physical functioning in colorectal cancer⁶⁻⁸ and breast cancer survivors.^{9,10}

Sedentary behaviour has recently been suggested as another risk factor for poorer survival and quality of life outcomes in cancer survivors.¹¹ Sedentary behaviour refers to any waking activity characterized by an energy expenditure ≤ 1.5 metabolic equivalents and a sitting or reclining posture.¹² Physical inactivity and sedentary behaviour both contribute to chronic diseases such as type 2 diabetes and cardiovascular disease; as comorbid conditions, these contribute significantly to the burden of ill health and premature death associated with cancer survivorship.¹³

Despite the benefits of an active lifestyle for adults diagnosed with cancer, evidence suggests that breast and colon cancer survivors participate in less physical activity,^{14,15} and breast cancer survivors engage in more sedentary behaviour¹⁶ than individuals without cancer. However, nearly all research to date that has examined physical activity and sedentary behaviour of cancer survivors has utilised self-report. There is often poor agreement between self-reported estimates and objectively assessed physical activity. For example, the Godin Leisure-Time Exercise Questionnaire administered to colon cancer survivors showed fair correlation ($\rho = 0.51$), but poor agreement (ICC = 0.33, 95% CI: 0.18-0.46) with moderate to vigorous physical activity (MVPA) derived from accelerometer data.¹⁷

Accelerometers provide detailed information on the frequency, intensity and duration of physical activities and sedentary time.^{18,19} Three studies have compared the

accelerometer-assessed physical activity and sedentary behaviour of breast cancer survivors to healthy controls.²⁰⁻²² These studies concur that cancer survivors engage in greater amounts of sedentary time, and lesser amounts of light physical activity than non-cancer controls. There is less agreement between the studies regarding MVPA, with one study showing that breast cancer survivors perform more MVPA,²² one study showing less MVPA,²⁰ and another showing no difference compared with controls.²¹ No studies to date have used objective activity monitoring to compare the physical activity or sedentary behaviour of colon cancer survivors with that of non-cancer controls.

The objective of this study was to determine whether breast and colon cancer survivors are more or less likely than age- and sex-matched non-cancer controls to engage in accelerometer-assessed MVPA, light-intensity physical activity and sedentary time. This information will help to clarify our understanding of activity profiles in these clinical populations, and help identify appropriate areas for intervention.

PATIENTS AND METHODS

Study population

Data for these case-control analyses were drawn from three cross-sectional studies: ACCEL-breast,²³ ACCEL-colon²⁴ and the AusDiab accelerometer sub-study.²⁵ All studies obtained ethics approval and written informed consent from their participants. Additionally, ethics approval was obtained for this secondary data analysis from Human Research Ethics Committees at the Western Australia (WA) Department of Health and The Department of Medical Education at The University of Melbourne.

ACCEL-Breast

The ACCEL-Breast study was conducted in WA in 2013. Six hundred women, who had previously taken part in a case-control study of breast cancer conducted between 2009 and 2011, were invited to take part. Of these, 552 were eligible based on the requirements of: being aged 18 to 80 years at the time of diagnosis, being one to three years post-diagnosis, and residing in WA at the time of diagnosis. Potential participants who had a subsequent diagnosis of cancer, a recurrence of their original breast cancer or were currently undertaking chemotherapy or radiotherapy, were excluded. Of the eligible group, 340 agreed to take part in the study, and 274 went on to complete the study in 2013. Ethics approval was obtained from Human Research Ethics Committees at the WA Department of Health and The University of WA.

ACCEL-colon

The ACCEL-colon study was conducted in Alberta (Canada) and WA between 2012 and 2013. Nine hundred and twenty seven eligible colon cancer survivors recruited through the Alberta Cancer Registry and WA Cancer Registry were invited to take part in the study. Eligibility was based on being between the ages of 18 and 80; having histologically confirmed stage I to III diagnosis of a first, primary colon cancer; having completed cancer treatment; speaking English; being able to provide written informed consent; and being able to wear an accelerometer for seven consecutive days. Participants were excluded if they were currently undergoing any adjuvant treatment. Of the eligible group, 197 agreed to take part, and 181 went on to complete the study. Three participants had stage IV disease and were excluded for a final sample of 178. There

were no significant differences in the accelerometer-derived variables between Canadian and Australian participants.²⁴ Ethics approval was obtained from the Alberta Health Services (Alberta Cancer Research Ethics Committee), Athabasca University, WA Department of Health and The University of WA.

AusDiab substudy

A total of 1,014 eligible participants from the 2011/2012 wave of the Australian Diabetes, Obesity and Lifestyle (AusDiab) Study were invited to participate in an accelerometer substudy. Participants who were ambulatory, not already known to be pregnant and aged ≥ 35 years were deemed eligible. Of this eligible group, 782 agreed to take part and 741 went on to complete the study. Ethics approval was obtained from The Alfred Hospital Humans Ethics Committee and the Ethics Committee of the International Diabetes Institute.

Accelerometry measures

Each study used the Actigraph GT3X+ tri-axial accelerometer (Actigraph, LLC, Pensacola, FL), with near identical protocols and data reduction procedures. Participants were asked to wear the devices on an elasticised belt on the hip for seven consecutive days, during all waking hours (unless doing water-based activities). Activity counts (vertical) were categorised as per commonly used activity count cutpoints: sedentary (<100 counts per minute [cpm]), light-intensity (100 - 1951 cpm), moderate-intensity (1952 - 5724 cpm), or vigorous-intensity physical activity (≥ 5725 cpm), using data recorded at 30 Hz.²⁶ Prolonged bouts of sedentary time were defined as 20

consecutive minutes or more. Prolonged MVPA was calculated as time in strict 'bouts' of ten consecutive minutes or more with no allowance for an interruption.

To be considered valid, days of data collection required at least 10 hours of wear time and no excessive counts (>20,000 counts per minute; cpm) registered. The raw accelerometer data were processed in 60 second epochs and the time spent in each activity level was averaged over the number of valid days. A validated, non-wear algorithm was used to determine non-wear time.²⁷ The same data processing procedures and data reduction algorithms were used across all three studies.

Participants were also instructed to complete a physical activity diary to supplement the accelerometer data. Both studies used checks against the diary as quality control for the potential errors in the classifications of the non-wear algorithm.

Statistical analysis and sample size

All analyses were conducted using Stata version 12 (Statacorp, College Station, TX, USA). Significance was set at $p < 0.05$, two-tailed. Breast and colon cancer cases were matched 1:1 by sex and five-year age groups to participants from the AusDiab accelerometer substudy.

Participants who provided at least one valid day of monitor data and who had complete data for outcome variables and covariates were included in the final analytic sample. Participants were dropped from the analytic sample if they were missing data for age, sex or covariates in the final models (education level, smoking status, body mass index [BMI]).

Descriptive statistics were employed to characterise the study populations: means and standard deviations²⁸ described normally distributed continuous variables; medians and minimum, maximum were used for skewed continuous variables; and, counts and percentages were used for categorical variables. Conditional logistic regression models examined the odds of case/control status (for breast cancer survivors and colon cancer survivors separately) per hour per day of MVPA, MVPA in 10-minute bouts, light activity, sedentary time and sedentary time in 20-minute bouts. Through modelling case/control status as the outcome, the odds ratios also can be taken to indicate the odds of an additional hour per day of these activities for cases versus controls. Logistic regression models initially considered confounding from a number of socio-demographic factors (employment status, partner status, household income, educational attainment, smoking status, BMI). Variables were removed from the multivariable model using a backward stepwise procedure that considered both the effect on the odds ratio (factor retained if its removal changed OR>10%) and the p-value (removed if p<0.2). Following this procedure, final models for each activity type were adjusted for wear time, BMI, smoking status and education level.

We then tested for interactions between physical activity and BMI (categorised by median split), and between physical activity and time since diagnosis (categorised by median split).

RESULTS

In total there were 245 matched pairs with complete data for the breast cancer survivor-control comparison, and 163 matched pairs with complete data for the colon

cancer survivor-control comparison. The characteristics of participants in this study are described in Table 1. The mean age of participants for the breast cancer survivor-control analyses was 60 (ranging from 36 to 85). Participants included in the colon cancer survivor-control analyses had a mean age of 64.3 (ranging from 30 to 85), and 45% were female. Differences between cancer survivors and their controls were observed by smoking status (there were fewer cancer survivors in the 'never smoker' category) and education attainment (there were fewer university graduates amongst cancer survivors).

--- Insert Table 1 about here ---

Case-control comparisons

In multivariate models (Table 2), breast cancer survivors had significantly greater odds than controls of one hour per day more MVPA (OR=3.41, 95% CI: 1.79-6.49), and the ORs for one hour per day more MVPA in 10-minute bouts were elevated although the difference was not statistically significant (OR=2.49, 95%CI: 0.93-6.64). Breast cancer survivors had lower odds of engaging in one hour per day more light physical activity (OR=0.87 95% CI: 0.75-1.01), and higher odds of an additional hour of sedentary time that had been accrued in bouts of at least 20 minutes (OR=1.16, 95% CI: 1.00-1.33) than controls.

Colon cancer survivors also had significantly greater odds than controls of one hour per day more MVPA (OR=2.12, 95% CI: 1.00-4.52) and MVPA accrued in 10-minute bouts (OR=4.10, 95%CI: 1.10-15.10). Colon cancer survivors also had

significantly lower odds than controls of one hour per day more light intensity physical activity (OR=0.83, 95% CI: 0.67-0.97). The odds in relation to accumulating one hour per day more sedentary time, or sedentary time accrued in 20-minute bouts, were somewhat elevated, but not significant (Table 2).

--- Insert Table 2 about here ---

A sensitivity analysis using log-transformed MVPA was conducted and results obtained using transformed and untransformed data were unchanged. We have presented the results based on untransformed MVPA models, for ease of interpretation.

We also examined potential interactions between activity type and BMI, and activity type and time since diagnosis. These analyses showed no significant interaction between BMI (median split) or time since diagnosis (median split) with any of MVPA, MVPA 10 minute bouts, light activity, sedentary time and sedentary time in 20 minute bouts (results not shown).

DISCUSSION

These case-control analyses pooled data from three cross-sectional studies (ACCEL-Breast, ACCEL-Colon and the AusDiab accelerometer substudy) to assess differences between breast and colon cancer survivors and controls in time spent in different intensities of activity. Both breast and colon cancer survivors were more likely to engage in MVPA (including MVPA accrued in bouts of ten minutes or more for colon

cancer) than non-cancer controls, which is contrary to most evidence (largely based on self-report) that has accumulated to date.

We also found that both breast and colon cancer survivors had greater odds of engaging in additional sedentary behavior (including sedentary time accrued in bouts of 20 minutes or more) than non-cancer controls, and lower odds of engaging in an additional hour per day of light physical activity. This aligns with findings from a previous study on cancer survivors, that reported higher volumes of sedentary time¹⁶ and less physical activity¹⁴ compared to the general population.

The higher MVPA in breast cancer survivors, compared to matched non-cancer controls, is contrary to findings from Dallal *et al.*,²⁰ who conducted a case-control study of breast cancer cases and controls, and used accelerometers to assess the physical activity of participants. This study found that breast cancer cases had greater odds of being in the lowest quartile of MVPA compared to their age-matched controls, but higher odds of being in the highest quartile of sedentary behavior (consistent with our findings). Substantial differences in study methodologies may explain the different findings with regards to MVPA. Many of the breast cancer survivors in the Dallal *et al.* study were undergoing treatment (chemotherapy or surgery) at the time their accelerometer data were collected, whereas participants in the ACCEL-Breast study were not undergoing active treatment (with the exception of endocrine therapy). Further, the accelerometer cut-point employed to characterise MVPA was lower in the Dallal *et al.* study (760 cpm), which would have generated higher estimates of MVPA relative to our estimates (based on 1952 cpm). Our study does concur with a more recent study by Phillips *et al.*,²² who found that breast cancer survivors, compared to

matched controls, participated in more MVPA, less light physical activity and more sedentary time than their matched controls.

Our study presents the first comparison of objectively-assessed physical activity and sedentary time between colon cancer survivors and matched controls. Previous studies comparing the self-reported physical activity of colon or colorectal cancer survivors to matched controls have found contrasting results. Hawkes *et al.*¹⁴ found that colorectal cancer survivors (up to three years post-diagnosis) were significantly more likely to be inactive (reporting no physical activity) or insufficiently active (reporting less than 150 minutes of physical activity per week) in relation to matched controls. In another study, James *et al.* compared physical activity levels of colon cancer survivors and age-, sex- and ethnicity- matched non-cancer controls, and found similar levels of self-reported MVPA between survivors and controls.²⁹

Our findings suggest that cancer survivors may be more physically active than similarly aged adults without cancer. This could potentially be explained by greater motivation following diagnosis to engage in healthy behaviors, as suggested by the “teachable moment” hypothesis.²¹ This hypothesis postulates that the period immediately following primary treatment is a phase when cancer survivors are highly receptive to behavior modification interventions. To further investigate this hypothesis, the impact of clinician advice (whether than be from a general practitioner or oncologist) on activity levels during this time at select time points is worth exploring further.

Our finding that cancer survivors also had greater odds of extra sedentary behavior than their matched controls is concerning, given recent studies linking sedentary behavior with mortality in colorectal cancer survivors. Campbell *et al.* found

that sedentary behavior reported prior to diagnosis was associated with higher all-cause mortality (RR <3 vs ≥6 h/day=1.36, 95% CI: 1.10, 1.68), whilst sedentary behavior reported after diagnosis was associated with higher all-cause (RR=1.27, 95% CI: 0.99, 1.64) and colorectal cancer specific mortality (RR=1.62, 95% CI: 1.07, 2.44).¹³ Similar findings were noted by Arem *et al.*, who found a 21% increase in colorectal cancer-specific mortality for pre-diagnosis sedentary behavior (self-reported TV viewing time) and a 73% increase associated with the highest category of post-diagnosis sedentary behavior.³⁰

It is possible that the higher odds of sedentary behavior noted in both breast and colon cancer survivors reflect a compensation mechanism. If cancer survivors purposefully engage in additional MVPA in an attempt to improve their health, they might also increase their sedentary behavior either due to fatigue or because they perceive it has been 'earned'. Whilst the absolute difference between cases and controls (matched by 5-year age group) in MVPA was a small difference of approximately 7 minutes per day, this is equivalent to three-quarters of an hour per week, which is a reasonable difference considering the overall low levels of MVPA. More research is needed to better understand the reasons for these differences between cancer survivors and age-matched controls.

Strengths and limitations

This was a secondary analysis using data from existing studies. Our accelerometer processing (in terms of the duration of accelerometer-assessed physical activity and sedentary time) resulted in data that would be comparable between our

cases and controls, but not between our studies and other cancer survivor studies. We were limited to the number of similarly aged controls available in the AusDiab accelerometer substudy, and as such not all cancer cases could be matched to a control. Finally, missing data also reduced the number of matched pairs included in the final model and analysis.

While the objective assessment incorporated into our study provides many benefits over self-report, there are some limitations specific to the use of accelerometers that must be considered. Accelerometers offer an accurate measure of physical activity and are not subject to the reporting bias or recall problems associated with self-report methods. However, some misclassification of MPVA, light physical activity and sedentary time still occurs. Hip acceleration data does not capture accurate workloads pertaining to certain activities such as stationary biking, swimming, weight training or data relative to body positioning (e.g. sitting, standing, lying down). Misclassification could be differential if the types of activities undertaken differ between cancer survivors and controls.

Conclusion

The current study suggests that breast and colon cancer survivors have greater odds of performing one hour per day more MVPA than age- and sex-matched non-cancer controls. Cancer survivors also had greater odds of accruing additional sedentary time. The differing results between self-report and accelerometry suggest that self-reported physical activity may be subject to differential exposure misclassification bias (different for cancer survivors and adults without cancer). Thus, we suggest that physical activity (and sedentary behavior) validation data from cancer survivor and non-

cancer specific populations be considered and quantitative bias analysis performed for future studies examining physical activity, sedentary behavior and health outcomes in cancer survivors.

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Table 1. Descriptive characteristics of breast (n = 245) and colon (n=163) cancer survivors, and their age- and sex-matched AusDiab controls

	Breast case-control		Colon case-control	
	Breast cancer survivors (n = 245)	AusDiab controls (n=245)	Colon cancer survivors (n=163)	AusDiab controls (n=163)
Smoking Status (%)				
Never smoked	58.8	71.8	45.4	69.3
Former smoker	35.9	24.1	49.1	26.4
Currently smoker	5.3	4.1	5.5	4.3
BMI (kg/m ²)	26.8 (5.57)	27.2 (5.71)	27.2	27.5 (4.09)
Income (%)				
<\$40,000	30.7	30.0	33.5	32.5
\$40,000-80,000	28.1	28.7	34.8	32.5
>\$80,000	41.2	41.3	31.7	35.1
Education (%)				
High school	37.6	40.0	13.5	33.7
Trade/technical	34.7	22.5	65.0	27.0
University	27.8	37.6	21.5	39.3
Partner status (%)				
Partnered	77.1	73.4	79.1	79.1
Not partnered	22.9	26.6	20.9	20.9
Time since diagnosis (months)				
Median, 25 th 75 th percentile	35.4	-	18.9,	-
	31.5, 38.8		15.0 21.7	
Treatment ^a (%)				
Surgery only	20.9	-	54.6	-
Surgery + Adjuvant	79.1	-	45.4	-

Comorbidities ^b (%)				
None	72.2	-	39.9	-
Hypertension or hypercholesterolaemia only	16.7	-	36.8	-
Angina, heart attack or diabetes	9.0	-	23.3	-
MVPA (min/day)	26.2	20.6	23.7	20.6
Median, 25th 75th percentile	15.0, 42.4	10.8, 34.3	9.1, 43.4	10.7, 40.3
MVPA 10 min bouts (min/day)	3.8	2.4	1.4	1.6
Median, 25th 75th percentile	0, 14.9	0, 12.0	0, 14.3	0, 11.4
Light physical activity (hr/day)	5.7 (1.3)	6.0 (1.8)	5.2 (1.7)	5.7 (1.4)
Sedentary time (hr/day)	8.22 (2.1)	8.34 (2.3)	8.80 (1.6)	8.81 (1.5)
Sedentary 20 min bouts (hr/day)	3.15 (1.9)	3.0 (1.9)	3.8 (1.9)	3.6 (1.4)
Wear time (mins/day)	867.6 (69.9)	886.9 (77.7)	868.6 (74.1)	899.6 (76.7)

Data are means ²⁸ except where indicated.

^a Data missing for one breast cancer survivor.

^b Insufficient data available for AusDiab participants.

Table 2. Odds ratios for accelerometer-assessed physical activity and sedentary time, for breast cancer survivors and colon cancer survivors relative to non-cancer controls

	Breast case-control		Colon case-control	
	OR	95% CI	OR	95% CI
MVPA (h/day)	3.41	1.79 – 6.49	2.12	1.00 – 4.52
MVPA time in 10 min bouts (h/day)	2.49	0.93 – 6.64	4.10	1.10 – 15.10
Light physical activity (h/day)	0.87	0.75 – 1.01	0.83	0.69 – 0.99
Sedentary time (h/day)	1.05	0.92 – 1.21	1.14	0.96 – 1.36
Sedentary time in 20 min bouts (h/day)	1.16	1.00 – 1.33	1.11	0.95 – 1.29

Each model adjusted for: accelerometer wear-time, smoking status, education level and BMI. ORs represent odds of case/control status per hour per day of different activity intensities; results conversely indicate the odds of an additional hour per day of activity for cases versus controls.