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ORIGINAL ARTICLE

Determinants of changes in physical activity from pre-diagnosis to post-diagnosis in a cohort of prostate cancer survivors

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Abstract

Purpose Physical activity (PA) has been shown to improve quality of life and survival in cancer survivors; however, a cancer diagnosis may change PA patterns. We examine determinants of changes in meeting the PA guidelines (150 min/week of moderate aerobic PA) before and after a prostate cancer diagnosis.

Methods Eight hundred and thirty prostate cancer survivors who participated in a population-based case–control study between 1997 and 2000 in Alberta, Canada, enrolled in a prospective cohort study. Past year activity levels were self-reported at diagnosis (pre-diagnosis measure) and again 2 years post-diagnosis. Determinants were collected by questionnaires and medical chart abstractions. Four PA patterns were created: non-exercisers (fail to meet guidelines pre-diagnosis and post-diagnosis), adopters (fail to meet guidelines pre-diagnosis, meet guidelines post-diagnosis), maintainers (meet guidelines pre-diagnosis and post-diagnosis) and relapsers (meet guidelines pre-diagnosis, fail to meet guidelines post-diagnosis).

Results Multinomial logistic regression analyses identified that being a non-exerciser compared to maintainer was associated with being employed, rural location, high PSA, smoking status, not attending support groups and less than average physical quality of life (QoL). Being a relapser compared to maintainer was associated with rural location and lack of friend support. Finally, being a non-exerciser compared to adopter was associated with urinary incontinence, smoking status and less than average physical and mental QoL.

Conclusions Demographic, health and lifestyle variables are associated with changes in meeting PA guidelines from pre-diagnosis to post-diagnosis in prostate cancer survivors. Programming should be aimed at offering interventions to help inactive survivors adopt PA and active survivors to maintain PA.

Keywords Exercise determinants · Physical activity · Guidelines · Prostate cancer · Correlates

Background

Globally, prostate cancer is the second most commonly diagnosed and prevalent cancer among men and is the most frequently diagnosed cancer in high-income countries with survival rates improving due to advances in treatment and detection [1]. Considering high survival rates, research has focused on ways to mitigate both the short-term and long-term burdens that occur with a diagnosis of prostate cancer. Physical activity, especially moderate-vigorous recreational physical activity, has been shown to improve overall health and cancer outcomes, such as reduced prostate cancer specific mortality through improved cardiovascular fitness and alterations in various signaling pathways [2–5]. Physical activity guidelines currently suggest that the general population perform at least 150 min of moderate aerobic physical activity per week (equivalent to 75 min of vigorous aerobic physical activity) and muscle-strengthening activities two or more days per week [6] and guidelines produced specifically for cancer survivors mirror these recommendations [7].

Despite consistent physical activity recommendations for healthy populations and populations of cancer survivors and building evidence of the benefits related to quality of life and

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survival after cancer, recent evidence suggests that the majority of cancer survivors, including prostate cancer survivors, are failing to meet physical activity guidelines [8]. Understanding the determinants that influence participation in physical activity is important to enhance health promotion strategies.

While some studies investigate cross-sectional correlates related to meeting physical activity guidelines either before or after a diagnosis of prostate cancer [9, 10], there is no evidence yet regarding the patterns of physical activity changes from pre-diagnosis to post-diagnosis. Further, a diagnosis of cancer can often change lifestyle habits [11], thus investigating the long-term patterns of physical activity are warranted to understand the association fully. The aim of this study was to examine the demographic, medical, lifestyle and quality of life (QoL) related factors associated with changes in physical activity after a prostate cancer diagnosis. We examined the four possible patterns of meeting physical activity guidelines from pre- to post-diagnosis (non-exercisers, adopters, maintainers and relapsers) and report on the six possible comparisons of such patterns as they have not previously been investigated in prostate cancer survivors.

After completing a comprehensive literature search on factors associated with physical activity levels and physical activity participation in cancer survivors, we hypothesized that patterns related to maintaining or adopting physical activity after prostate cancer diagnosis would be associated with characteristics such as younger age, higher education and the availability of social support, while patterns related to relapsing or remaining inactive would be associated with higher body mass index, more comorbidities and active smoking status [12–14].

Methods

Study sample

The study participants were 830 men diagnosed with histologically confirmed, clinically significant stage II–IV invasive prostate cancer who were enrolled in a population-based case–control study between 1997 and 2000 in Alberta, Canada [15] and then were re-consented to participate in a prospective cohort study in 2000 [3]. Eligibility criteria included being English speaking, under 80 years of age and no prior cancer diagnosis except non-melanoma skin cancers. Cases were identified through the population-based Alberta Cancer Registry that has over 95% case ascertainment [16]. Ethics approval for this cohort follow-up study was obtained from the Alberta Cancer Research Ethics Board and the Conjoint Health Research Ethics Board at the University of Calgary.

Data collection

Baseline interviews on lifetime physical activity occurred in person with trained interviewers within 6 months of diagnosis (average 4.3 months (standard deviation 1.3)). The *Lifetime Total Physical Activity Questionnaire* (LTPAQ) captures three types of physical activity (occupational, household and recreational), as well as the frequency, intensity and duration of activity from childhood through to diagnosis. The LTPAQ has been previously tested for reliability and used in many research settings worldwide [17]. This questionnaire was re-administered via interview 2 years post-diagnosis (follow-up) to capture activity done since diagnosis.

At the baseline interviews conducted as part of the case–control study [15], participants also reported their demographic characteristics (including marital status, education and ethnicity), health and screening history, family history of cancer, adult weight and height, lifetime alcohol consumption and lifetime smoking habits. At follow-up, quality of life was assessed using the SF-36 questionnaire component summary scores for physical and mental health, which has been tested for reliability and validity in cancer survivors [18]. Anthropometric measurements were directly assessed at this time by the trained interviewers using standardized methods. Medical chart reviews were completed by trained Health Record Technicians from the Alberta Cancer Registry to abstract data on cancer stage, all treatments (i.e. surgery, radiotherapy, chemotherapy, hormone therapy) received during follow-up and all clinical outcomes including any progressions, recurrences, new primaries and comorbidities that occurred. Determinants investigated were any variable that had either been cited in previous literature related to physical activity participation or that seemed plausible to affect physical activity participation.

Recommended physical activity guidelines for cancer survivors [7, 19] are in agreement with the 2018 Physical Activity Guidelines for Americans [6], recommending either 75 min of vigorous aerobic exercise per week or 150 min of moderate aerobic exercise per week (or any equivalent combination of moderate and vigorous activity). Though information on several domains of physical activity was collected in this study, recreational physical activity is most commonly investigated from previous literature [9] and for consistency will be the domain investigated in the present study. Recreational physical activity can also be most easily targeted and improved through lifestyle changes. Using the Compendium of Physical Activities [20, 21], recreational physical activity completed by the participants at each time point was coded into metabolic equivalents (METs). Time spent participating in activities between 3 and 6 METs were categorized as moderate physical activity and added to time spent participating in vigorous physical activity (activities > 6 METs) multiplied by two to match guidelines for moderate-

vigorous [6]. This calculation created a single measure of moderate-vigorous recreational physical activity (MVPA). Time spent in MVPA was then dichotomized into either (a) meeting physical activity guidelines (≥ 150 min/week) or (b) failing to meet physical activity guidelines (0–149 min/week).

Physical activity levels for the time period 1 year prior to prostate cancer diagnosis were used for the analyses of the pre-diagnosis level to best capture physical activity habits as they occurred before diagnosis, while physical activity reported in the time period from diagnosis to 2 years post-diagnosis was used as the post-diagnosis level. Participants were grouped into one of four possible patterns of meeting physical activity guidelines from pre-diagnosis to post-diagnosis: (1) non-exercisers (fail to meet guidelines pre-diagnosis and post-diagnosis), (2) adopters (fail to meet guidelines pre-diagnosis, meet guidelines post-diagnosis), (3) maintainers (meet guidelines pre-diagnosis and post-diagnosis) and (4) relapsers (meet guidelines at pre-diagnosis, fail to meet at post-diagnosis) [22].

Statistical analysis

Following the analytical approaches used by Song et al. [23] and Crawford et al. [13], chi-square tests (χ^2) were performed to analyse the dichotomous determinants across the four patterns of meeting physical activity guidelines from 1 year pre-diagnosis to 2 years post-diagnosis. Demographic determinants were grouped as follows: age at diagnosis (< 65 vs. ≥ 65), education (did not complete university/college vs. completed university/college), employment at baseline (no vs. yes), marital status (not married vs. married/common-law), ethnicity (other vs. Caucasian) and location of residence (urban vs. rural). Medical determinants were grouped as body mass index at diagnosis (normal (< 25 kg/m^2) vs. overweight/obese (> 25 kg/m^2)), tumour stage (II vs. III/IV), Gleason grade (< 7 vs. ≥ 7), PSA (0–10 vs. > 10), family history of prostate cancer (no vs. yes), Charlson comorbidity score [24] at follow-up (0–1 vs. ≥ 2), hormone therapy (no vs. yes), prostatectomy (no vs. yes), cancer progression at follow-up (none vs. progression), cancer recurrence at follow-up (none vs. cancer recurrence) and urinary incontinence (no vs. yes). Lifestyle determinants were grouped as follows: smoking status at baseline (non-smoker vs. smoker), made any sustained lifestyle changes (i.e. diet, exercise, spiritual/religious, work habits, acupuncture, herbal/homeopathy) since diagnosis (did not change lifestyle vs. changed lifestyle), friend support through cancer experience (no friend support vs. friend support reported), spousal/partner or family support through cancer experience (no spouse/family support vs. spouse/family support reported) and attending support group to help through cancer experience (did not attend a support group or counselling vs. attended support group or counselling). Finally, quality of life, as measured by the SF-36 summary scores for physical and mental health, was categorized as being greater than average or less than average relative to the US general population [25].

Determinants with a bivariate chi-square statistic meeting the threshold of $p < 0.10$ were carried forward and entered into a multivariate multinomial logistic regression model. Age at diagnosis was included in all models as a covariate given the importance of age as a determinant of physical activity levels [26] while all other variables were entered into initial models and removed sequentially if they were not statistically significant at the level of $p < 0.10$. Separate analyses were conducted to investigate independent determinants of each pattern of meeting physical activity guidelines vs. maintainers and vs. each other. Multicollinearity was assessed using variance inflation factors and was found to be acceptable. Generalized Hosmer–Lemeshow goodness of fit tests for multinomial logistic regression [27] were performed to ensure fit of our multivariate models ($p > 0.05$). All analyses were conducted using Stata (version 14; StataCorp LP, College Station, TX, USA). Statistical significance for the multinomial logistic regression model was set at $p < 0.05$.

Results

In the year prior to prostate cancer diagnosis, 296 of the 830 prostate cancer survivors in this cohort (35.7%) had levels of recreational physical activity that met the recommended guidelines (169.8 ± 263.8 min/week), while 378 (45.5%) of these cohort members achieved recreational physical activity guidelines 2 years post-diagnosis (215.9 ± 266.4 min/week) resulting in a statistically significant difference in physical activity attained from pre- to post-diagnosis ($p < 0.001$).

The univariate chi-square analyses of the demographic, medical, lifestyle and quality of life related determinants across the four patterns of meeting physical activity guidelines from pre-diagnosis to follow-up post-diagnosis were examined initially (Table 1).

Multivariate multinomial logistic regression analysis was used to examine the identified determinants ($p < 0.10$) of patterns for non-exercisers, adopters and relapsers vs. maintainers (Table 2) and the other patterns compared to each other (Table 3). Prostate cancer survivors were more likely to be non-exercisers compared to maintainers if they were employed at baseline (OR = 2.00; 1.32–3.04), lived in rural settings (OR = 2.36; 1.58–3.54), had higher PSA levels at diagnosis (OR = 1.52; 1.05–2.22), were smokers at baseline (OR = 2.76; 1.49–5.13) or had a less than average physical QoL component summary score (OR = 2.34; 1.54–3.55). Prostate cancer survivors were less likely to be non-exercisers compared to maintainers if they reported attending support groups or counselling (OR = 0.48; 0.29–0.79). Individuals were more likely to be relapsers compared to maintainers if they lived in rural settings (OR = 1.92; 1.09–

Table 1 Demographic, medical and lifestyle correlates of patterns of meeting physical activity guidelines from past-year pre-diagnosis to follow-up in prostate cancer survivors ($n = 830$)

	Non-exercisers, *n* (%)	Adopter, *n* (%)	Maintainers, *n* (%)	Relapsers, *n* (%)	*p* (χ^2)
Determinant					
Demographic					
Overall	370 (44.6%)	164 (19.8%)	214 (25.8%)	82 (9.9%)	
Age at diagnosis					0.778
< 65 ($n = 283$)	129 (45.6%)	57 (20.1%)	67 (23.7%)	30 (10.6%)	
≥ 65 ($n = 547$)	241 (44.1%)	107 (19.6%)	147 (26.9%)	52 (9.5%)	
Education					*0.001*
Did not complete university/college ($n = 515$)	251 (48.7%)	100 (19.4%)	109 (21.2%)	55 (10.7%)	
University/college ($n = 315$)	119 (37.8%)	64 (20.3%)	105 (33.3%)	27 (8.6%)	
Employed at baseline					*0.058*
No ($n = 375$)	153 (40.8%)	71 (18.9%)	113 (30.1%)	38 (10.1%)	
Yes ($n = 455$)	217 (47.7%)	93 (20.4%)	101 (22.2%)	44 (9.7%)	
Marital status					*0.094*
Other ($n = 131$)	70 (53.4%)	18 (13.7%)	33 (25.2%)	10 (7.6%)	
Married/common-law ($n = 699$)	300 (45.9%)	146 (20.9%)	181 (25.9%)	72 (10.3%)	
Ethnicity					*0.037*
Other ($n = 41$)	22 (53.7%)	6 (14.6%)	5 (12.2%)	8 (19.5%)	
Caucasian ($n = 789$)	348 (44.1%)	158 (20.0%)	209 (26.5%)	74 (9.4%)	
Location					*< 0.001*
Urban ($n = 488$)	181 (37.1%)	101 (20.7%)	161 (33.0%)	45 (9.2%)	
Rural ($n = 342$)	189 (55.3%)	63 (18.4%)	53 (15.5%)	37 (10.8%)	
Medical					
Body mass index at baseline					0.873
Normal ($n = 174$)	75 (43.1%)	34 (19.5%)	49 (28.2%)	16 (9.2%)	
Overweight/obese ($n = 656$)	295 (45.0%)	130 (19.8%)	165 (25.2%)	66 (10.1%)	
Tumour stage					0.522
II ($n = 642$)	282 (43.9%)	128 (19.9%)	172 (26.8%)	60 (9.4%)	
III/IV ($n = 188$)	88 (46.8%)	36 (19.2%)	42 (22.3%)	22 (11.7%)	
Gleason grade					0.255
< 7 ($n = 317$)	152 (48.0%)	63 (19.9%)	70 (22.1%)	32 (10.1%)	
≥ 7 ($n = 513$)	218 (42.5%)	101 (19.7%)	144 (28.1%)	50 (9.8%)	
PSA at diagnosis					*0.009*
0–10 ($n = 380$)	147 (38.7%)	82 (21.6%)	114 (30.0%)	37 (9.7%)	
> 10 ($n = 450$)	223 (49.6%)	82 (18.2%)	100 (22.2%)	45 (10.0%)	
Family history of prostate cancer					0.279
No ($n = 662$)	300 (45.3%)	124 (18.7%)	176 (26.6%)	62 (9.4%)	
Yes ($n = 168$)	70 (41.7%)	40 (23.8%)	38 (22.6%)	20 (11.9%)	
Charlson comorbidity score at follow-up					0.155
0–1 ($n = 289$)	122 (42.2%)	54 (18.7%)	88 (30.5%)	25 (8.7%)	
2+ ($n = 541$)	248 (45.8%)	110 (20.3%)	126 (23.3%)	57 (10.5%)	
Hormone therapy					0.498
No ($n = 271$)	117 (43.2%)	58 (21.4%)	65 (24.0%)	31 (11.4%)	
Yes ($n = 527$)	236 (44.8%)	103 (19.5%)	142 (26.9%)	46 (8.7%)	
Prostatectomy					0.130
No ($n = 585$)	276 (47.2%)	109 (18.6%)	146 (25.0%)	54 (9.2%)	
Yes ($n = 245$)	94 (38.4%)	55 (22.5%)	68 (27.8%)	28 (11.4%)	
Cancer progression at follow-up					0.287
None ($n = 713$)	309 (43.3%)	146 (20.5%)	185 (26.0%)	73 (10.2%)	
Progression ($n = 117$)	61 (52.1%)	18 (15.4%)	29 (24.8%)	9 (7.7%)	

Table 1 (continued)

	Non-exercisers, *n* (%)	Adopter, *n* (%)	Maintainers, *n* (%)	Relapsers, *n* (%)	*p* (χ^2)
Cancer recurrence at follow-up					0.470
None (*n* = 578)	263 (45.5%)	115 (19.9%)	149 (25.8%)	51 (8.8%)	
Cancer recurrence (*n* = 252)	107 (42.5%)	49 (19.4%)	65 (25.8%)	31 (12.3%)	
Urinary incontinence					*0.095*
No (*n* = 436)	182 (41.7%)	97 (22.3%)	119 (27.3%)	38 (8.7%)	
Yes (*n* = 385)	182 (47.3%)	66 (17.1%)	93 (24.2%)	44 (11.4%)	
Lifestyle					
Smoking status baseline					*< 0.001*
Non-smoker (*n* = 714)	292 (40.9%)	145 (20.3%)	199 (27.9%)	78 (10.9%)	
Smoker (*n* = 116)	78 (67.2%)	19 (16.4%)	15 (12.9%)	4 (3.45%)	
Lifestyle change					0.666
Did not change lifestyle (*n* = 458)	199 (43.5%)	94 (20.5%)	123 (26.9%)	42 (9.2%)	
Changed lifestyle (*n* = 372)	171 (46.0%)	70 (18.8%)	91 (24.5%)	40 (10.8%)	
Friend support					*0.011*
No friend support (*n* = 393)	188 (47.8%)	67 (17.1%)	90 (22.9%)	48 (12.2%)	
Friend support reported (*n* = 437)	182 (41.7%)	97 (22.2%)	124 (28.4%)	34 (7.8%)	
Family support					0.213
No spouse/family support (*n* = 68)	26 (38.2%)	10 (14.7%)	24 (35.3%)	8 (11.8%)	
Spouse/family support reported (*n* = 762)	344 (45.1%)	154 (20.2%)	190 (24.9%)	74 (9.7%)	
Support group					*< 0.001*
Did not attend support group or counselling (*n* = 703)	332 (47.2%)	140 (19.9%)	159 (22.6%)	72 (10.2%)	
Attended support group or counselling (*n* = 127)	38 (29.9%)	24 (18.9%)	55 (43.3%)	10 (7.9%)	
Quality of life					
Physical QoL component summary score					*< 0.001*
Greater than average physical QoL (*n* = 247)	75 (30.4%)	61 (24.7%)	87 (35.2%)	24 (9.7%)	
Less than average physical QoL (*n* = 570)	284 (49.8%)	103 (18.1%)	126 (22.1%)	57 (10.0%)	
Mental QoL component summary score					*0.018*
Greater than average mental QoL (*n* = 532)	218 (41.0%)	120 (22.6%)	146 (27.4%)	48 (9.0%)	
Less than average mental QoL (*n* = 285)	141 (49.5%)	44 (15.4%)	67 (23.5%)	33 (11.6%)	

p (χ^2) chi-square

p<0.10

3.38), while participants were less likely to be relapsers compared to maintainers if they reported having friend support (OR = 0.56; 0.33–0.96) (Table 2).

Prostate cancer survivors were more likely to be non-exercisers compared to adopters if they reported experiencing urinary incontinence (OR = 1.51; 1.02–2.23), were a smoker at baseline (OR = 1.88; 1.07–3.30), had a less than average physical (OR = 2.00; 1.29–3.10) or mental (OR = 1.60; 1.05–2.43) QoL component summary scores. Survivors were more likely to be adopters compared to relapsers if they reported having friend support (OR = 1.97; 1.14–3.42) (Table 3).

Discussion

We examined the demographic, medical, lifestyle and quality of life related variables associated with various patterns of physical activity change from pre-diagnosis to post-diagnosis in prostate cancer survivors. To our knowledge, this investigation is the only study that has reported determinants associated with four patterns of physical activity behaviour related to meeting recreational physical activity guidelines across a diagnosis of cancer from pre- to post-diagnosis. In preliminary analyses, there was an approximately 10% increase in the number of men meeting physical activity guidelines from 1 year pre-diagnosis to 2 years post-diagnosis (35.7% compared to 45.5%), suggesting that some men positively changed their health behaviours following a diagnosis of cancer. Further, these changes may be clinically significant in terms of improved survival based on previous findings [3]. A diagnosis of cancer provides a teachable moment available for health interventions to promote positive change and implement long-term support programs [28]. Though there is a paucity of literature suggesting that older cancer survivors

Table 2 Multivariable adjusted multinomial logistic regression of the correlates of patterns of meeting physical activity guidelines from past-year pre-diagnosis to follow-up for being a non-exerciser, adopter or relapser vs. maintainer in prostate cancer survivors ($n = 817$)

	Non-exercisers vs. maintainers		Adopters vs. maintainers		Relapsers vs. maintainers	
Determinant	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Demographic						
Education						
University/college vs. other	0.68 (0.47–1.01)	0.054	0.74 (0.48–1.14)	0.167	0.60 (0.34–1.06)	0.079
Employment at baseline						
Yes vs. no	2.00 (1.32–3.04)	*0.001*	1.56 (0.97–2.48)	0.064	1.13 (0.62–2.08)	0.687
Marital status at baseline						
Yes vs. no	1.00 (0.60–1.64)	0.998	1.65 (0.88–3.09)	0.120	1.50 (0.68–3.30)	0.312
Ethnicity						
Caucasian vs. other	0.41 (0.14–1.20)	0.104	0.59 (0.17–2.03)	0.405	0.30 (0.09–1.03)	0.056
Location						
Rural vs. urban	2.36 (1.58–3.54)	*<0.001*	1.62 (1.02–2.57)	*0.040*	1.92 (1.09–3.38)	*0.024*
Medical						
PSA						
> 10 vs. ≤ 10	1.52 (1.05–2.22)	*0.027*	1.10 (0.72–1.68)	0.662	1.29 (0.75–2.20)	0.358
Urinary incontinence						
Yes vs. no	1.32 (0.91–1.92)	0.149	0.87 (0.57–1.34)	0.535	1.48 (0.87–2.53)	0.150
Lifestyle						
Smoking status at baseline						
Smoker vs. non-smoker	2.76 (1.49–5.13)	*0.001*	1.47 (0.71–3.04)	0.303	0.50 (0.16–1.57)	0.233
Friend support						
Friend support vs. none	0.77 (0.53–1.13)	0.183	1.11 (0.72–1.70)	0.644	0.56 (0.33–0.96)	*0.036*
Support group						
Attended support group or counselling vs. not	0.48 (0.29–0.79)	*0.004*	0.54 (0.31–0.94)	*0.028*	0.56 (0.26–1.21)	0.140
Quality of life						
Physical QoL component summary score						
Less than average vs. greater than average	2.34 (1.54–3.55)	*< 0.001*	1.17 (0.74–1.84)	0.505	1.68 (0.93–3.06)	0.088
Mental QoL component summary score						
Less than average vs. greater than average	1.22 (0.83–1.81)	0.312	0.77 (0.48–1.22)	0.260	1.34 (0.77–2.32)	0.302

Adjusted for age at diagnosis (continuous), education (less than high school, high school, trade, other non-university, university), employment at baseline (yes vs. no), location (urban vs. rural), PSA levels at diagnosis (< 4, 4–10, 10–20, > 20), smoking status at baseline (current smoker, former smoker, never smoker), friend support (friend support reported vs. not), attending a support group (attended vs. not) and physical quality of life component summary score (continuous). $n = 817$, with exception to urinary incontinence where $n = 814$ due to missing values

$p<0.05$

commonly make positive lifestyle changes throughout their cancer experience, Hackshaw-McGeagh et al. [11] found weak evidence to suggest that prostate cancer patients had an overall increase in physical activity from pre-diagnosis to 9 months post-diagnosis, further supporting the applicability of implementing and facilitating health interventions and support to this population of survivors.

Several determinants were continually associated with positive patterns of physical activity behaviour (i.e. adopters or maintainers) compared to negative patterns of physical activity behaviours (i.e. non-exercisers or relapsers). Active smoking status was often associated with higher odds of following negative patterns of physical activity behaviour across the cancer experience. Effect sizes ranged from near a two-time increase in odds of adhering to negative physical activity behaviours to increases of three-times the odds. Active smoking is a behaviour that is often found co-occurring with other negative health behaviours such as alcohol consumption and physical inactivity, and this result is corroborated by other studies investigating correlates of physical activity in cancer survivors [29, 30]. Action directed at providing strategies to improve smoking cessation in cancer patients has recently become a priority for many governing bodies [31], and this support may translate into improved physical activity promotion given the connection between the two health behaviours. The majority of the present study participants (86%) were

Table 3 Multivariable adjusted multinomial logistic regression of the correlates of patterns of meeting physical activity guidelines from past-year pre-diagnosis to follow-up for various patterns vs. each other in prostate cancer survivors ($n = 817$)

	Non-exercisers vs. adopters		Non-exercisers vs. relapsers		Adopters vs. relapsers	
Determinant	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Demographic						
Education						
University/college vs. other	0.93 (0.62–1.40)	0.729	1.14 (0.66–1.95)	0.635	1.22 (0.68–2.20)	0.498
Employment at baseline						
Yes vs. no	1.29 (0.84–1.99)	0.251	1.77 (1.00–3.12)	*0.048*	1.37 (0.74–2.56)	0.317
Marital status at baseline						
Yes vs. no	0.60 (0.34–1.07)	0.084	0.66 (0.32–1.37)	0.268	1.10 (0.47–2.54)	0.828
Ethnicity						
Caucasian vs. other	0.70 (0.26–1.84)	0.465	1.37 (0.54–3.49)	0.508	1.97 (0.62–6.28)	0.251
Location						
Rural vs. urban	1.46 (0.98–2.17)	0.063	1.23 (0.74–2.05)	0.418	0.85 (0.48–1.49)	0.561
Medical						
PSA						
> 10 vs. ≤ 10	1.39 (0.94–2.04)	0.097	1.18 (0.72–1.95)	0.506	0.85 (0.49–1.48)	0.574
Urinary incontinence						
Yes vs. no	1.51 (1.02–2.23)	*0.039*	0.89 (0.54–1.46)	0.642	0.59 (0.34–1.02)	0.060
Lifestyle						
Smoking status at baseline						
Smoker vs. non-smoker	1.88 (1.07–3.30)	*0.027*	5.57 (1.95–15.86)	*0.001*	2.96 (0.96–9.14)	0.059
Friend support						
Friend support vs. none	0.70 (0.48–1.03)	0.072	1.38 (0.84–2.28)	0.205	1.97 (1.14–3.42)	*0.016*
Support group						
Attended support group or counselling vs. not	0.88 (0.49–1.57)	0.667	0.85 (0.39–1.83)	0.672	0.96 (0.42–2.18)	0.924
Quality of life						
Physical QoL component summary score						
Less than average vs. greater than average	2.00 (1.29–3.10)	*0.002*	1.39 (0.78–2.47)	0.262	0.69 (0.38–1.28)	0.243
Mental QoL component summary score						
Less than average vs. greater than average	1.60 (1.05–2.43)	*0.028*	0.92 (0.55–1.51)	0.730	0.57 (0.32–1.02)	0.057

Adjusted for age at diagnosis (continuous), education (less than high school, high school, trade, other non-university, university), employment at baseline (yes vs. no), location (urban vs. rural), PSA levels at diagnosis (< 4, 4–10, 10–20, > 20), smoking status at baseline (current smoker, former smoker, never smoker), friend support (friend support reported vs. not), attending a support group (attended vs. not) and physical quality of life component summary score (continuous). $n = 817$, with exception to urinary incontinence where $n = 814$ due to missing values

$p<0.05$

non-smokers at baseline, leaving relatively small sample sizes of active smokers in each of the four patterns of physical activity behaviour. Given the homogeneous smoking behaviours of the these prostate cancer survivors, there was some imprecision in the estimates related to the impact that active smoking status has on adhering to these patterns of physical activity behaviour; hence, more research is needed to understand the true effect.

Social support was captured through variables such as marital status, family support, friend support and attending support groups or counselling. Interestingly, reporting friend support and attending support groups or counselling was more consistently associated with positive physical activity behaviours compared to family support and marital status. Having family support was not statistically significantly different across patterns of physical activity behaviours and therefore not analysed further in the multinomial models. Marital status, on the other hand, was included in the multinomial models but was not then found to be a statistically significant determinant of either positive or negative patterns of physical activity behaviour. These results suggest that a network of support extending beyond the familial unit to facilitate healthful behaviours may be important [14, 32].

Interestingly, some determinants previously found to be associated with negative patterns of physical activity behaviour such as older age, increased body mass index, lower

education and higher levels of comorbid conditions [10, 13, 33] were not associated with physical activity in our sample. There was no statistical difference in the proportion of men who adhered to the four patterns of physical activity behaviour based on age, body mass index or comorbidities. Hence, these factors were not investigated further as significant determinants of physical activity patterns suggesting that they may not be as influential for achieving current recommended guidelines of physical activity in prostate cancer survivors as previously expected. Additionally, from our literature search, it appears that studies citing body mass index as a factor associated with physical activity levels were primarily restricted to female cancer survivors [12, 33, 34]. Thus, body mass index may be a gender-specific determinant of physical activity more applicable in female populations. There was a difference in the proportion of men who adhered to the patterns of physical activity behaviour by education level; however, when carried forward to multinomial models, education was not found to be statistically significant determinant.

Less than average scores on the physical quality of life component were found to be statistically significantly associated with being a non-exerciser compared to being maintainer or adopter, while less than average scores on the mental quality of life component was only associated with being a non-exerciser compared to adopter. Poor physical quality of life was more strongly associated with being a non-exerciser than poor mental quality of life. Given the cross-sectional assessments that were made during follow-up, it is difficult to determine if the poor quality of life scores contribute to the lack of achieving physical activity guidelines, or conversely, if the failure to achieve such guidelines is contributing to poor quality of life. Previous studies investigating correlates of physical activity in cancer survivors have seen similar results with higher quality of life associated with higher physical activity levels [35, 36], though these studies also have the same limitation with interpreting causality.

Living in a rural location was consistently associated with an increased likelihood of being non-exercisers, adopters and relapsers compared to maintainers. This finding has been cited as a barrier in qualitative studies [37] but has not been quantified in analytic studies. A near doubled increase in odds suggests that living in remote and rural locations may be a substantial barrier for individuals to reach and maintain physical activity guidelines. Although living in rural locations has not been previously found in the literature to be a significant determinant of physical activity behaviours, lack of facilities (which includes lack of access to equipment and lack of appropriate facilities) has been cited as a barrier to physical activity for cancer survivors in numerous descriptive studies [33, 38, 39] and has also been associated with decreased physical activity in several analytic studies [29, 40]. We found that participants who live in rural areas experienced barriers of being physically active likely because of lack of facilities available to them. Future research studies could consider investigating both place of residence and availability of recreational facilities as important determinants of activity. Further, this finding may support the need for future studies to target rural populations to improve access to resources for this population.

This study consists of a large, well-defined study population that includes detailed and repeated measurements of health behaviours at pre-diagnosis and post-diagnosis time points collected from high-quality data sources such as validated and standardized questionnaires. Given the number of determinants assessed, variables were dichotomized to preserve sample size and enhance interpretability of estimates. Use of objective measures of physical activity such as accelerometers in the future may reduce potential recall error found from self-reported data, though objective measures are rarely used to describe long-term physical activity behaviours such as those used in our study (past year and past 2 years). The sample of men in this study was fairly homogenous since they were primarily Caucasian, well-educated men who enrolled in the cohort. Although ethnicity and education were rarely found to be statistically significant determinants of patterns of physical activity behaviour, the lack of heterogeneity may limit generalizability to other sample populations. Further, determinants may differ in current settings compared to the timing of our data collection given that the field of exercise oncology has garnered more recognition in recent years and that clinicians now may recommend physical activity as a means to mitigate side effects of treatment.

It has been found that physical activity level can decline while on active treatment, followed by an increase post-treatment [41]; however, our study did not collect data on time on active treatment so we are not able to investigate the shorter term changes in physical activity behaviour immediately following diagnosis. Additionally, our study did not include prostate cancer patients diagnosed with early stage 1 cancers. This population group would be interesting to investigate since this stage of cancer is often not life threatening, resulting in long survival times with increased opportunity to implement health behaviour changes to reduce risk of mortality from other causes.

Conclusion

In summary, we observed changes in physical activity levels, with nearly 10% more prostate cancer survivors attaining guidelines of recreational moderate-vigorous physical activity after diagnosis compared to pre-diagnosis. Nevertheless, 9.9% of previously active men became inactive after their diagnosis and 44.6% of previously inactive men remained inactive after their diagnosis, suggesting substantial opportunities for interventions. Several modifiable and non-modifiable determinants were identified that were either facilitators or barriers to positive patterns of physical activity behaviours. To elicit

positive behaviour habits in prostate cancer survivors post-diagnosis, attention should be focused on ways to mitigate barriers or implement programming to concurrently reduce the effects of detrimental determinants while also promoting physical activity.

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Author's contributions K.S. C., S.E. M. and C.M. F. were involved in study conception and design. K.S.C., C.M. F. and C.R. S. acquired the data. C.R. S. completed statistical analyses and drafting of the manuscript. All authors critically revised the manuscript for intellectual content, approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest

Ethics approval and consent to participate The study protocol was approved by the Health Research Ethics Board of Alberta—Cancer Committee and the Conjoint Health Research Ethics Board at the University of Calgary. Informed consent was provided by all participants prior to study participation. 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.

List of abbreviations *LTPAQ*, the Lifetime Total Physical Activity Questionnaire; *MET*, metabolic equivalent of task; *MVPA*, moderate vigorous physical activity; *OR*, odds ratio; *PSA*, prostate-specific antigen; *QoL*, quality of life

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