Do cancer survivors develop healthier lifestyle behaviors than the cancer-free population in the PLCO study?

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Abstract

Background Current studies report mixed results in health status and health behaviors after a diagnosis of cancer. The aim of our study is to investigate potential differences in lifestyle factors among cancer survivors and cancer-free individuals in a prospective cohort study conducted in the United States.

Methods Using data from the Prostate, Lung, Colorectal and Ovarian (PLCO) Trial, 10,133 cancer survivors were identified and compared to 81,992 participants without cancer to evaluate differences in body mass index (BMI), smoking, NSAID use, and physical activity.

Results Cancer survivors, compared to the cancer-free, were significantly less likely to engage in physical activity (odds ratio (OR) = 0.82, 95% CI = 0.77–0.88). Compared to those who were obese at baseline, cancer survivors were more likely to be at normal BMI at follow-up compared to the cancer-free (OR = 1.90, 95% CI = 1.42–2.54). Cancer survivors were less likely to report regular aspirin use as compared to the cancer-free population (OR = 0.86, 95 % CI = 0.82–0.92). Of the current smokers, cancer survivors were more likely to be former smokers at follow-up compared to the cancer-free (OR = 1.50, 95% CI = 1.30–1.74).

Conclusion Upon stratification by baseline health markers, cancer survivors practice healthier lifestyle habits such as smoking cessation and maintenance of a healthy weight. However, cancer survivors are less likely to be physically active as compared to cancer-free individuals, regardless of baseline practices.

Implications for cancer survivors For cancer survivors who reported poor health status and behaviors at baseline, a cancer diagnosis may encourage the practice of healthier lifestyle behaviors.

Keywords Tobacco · BMI · Physical activity · NSAID · Aspirin

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Introduction

Cancer survivors—with survival defined from the point of diagnosis through the end of that person's life [1]—account for nearly 14.5 million people in the United States today [2]. By 2024, there will be a projected 19 million cancer survivors [3]. Between 2004 and 2010, 68% of those diagnosed with cancer survived at least 5 years past diagnosis [2], a major improvement from the 5-year survival from 1975 to 1977 of 49% [2]. As medical advances in cancer diagnosis and treatment occur, along with the aging of the population, the number of cancer survivors will continue to grow [4].

Cancer survivors typically have poorer health after diagnosis and treatment when compared to the general population [5]. Cancer survivors have risk of recurrence of the primary cancer and an increased risk of second primary cancer, as well as a greater risk for comorbid chronic conditions and premature mortality related to cancer and/or consequences of

treatment [6–9]. Genetic predisposition, lifestyle factors and the effects of cancer treatment all contribute to the elevated risk of these adverse medical and health conditions [10]. As those diagnosed with cancer are living longer and are more prone to develop chronic disease, survivorship care and the identification of public health strategies to promote optimal health are becoming increasingly important [11]; thus, identifying ways to reduce secondary health problems of cancer survivors is becoming of great interest among researchers and clinicians.

Recommendations for healthy behaviors, such as meeting physical activity and nutritional guidelines, do not differ greatly between cancer survivors and those without cancer [4, 12]. However, with the adoption of these types of healthy behaviors—such as meeting physical activity and nutritional recommendations—cancer survivors may experience protection against cancer recurrence and other health problems [13, 14]. A national cross-sectional survey of cancer survivors showed that those who met a greater number of lifestyle behavior recommendations, including 5-a-day fruit and vegetable consumption and physical activity guidelines, had better health-related quality of life (HRQoL) [15]. A Cochrane review indicated that HRQoL measures for cancer survivors were improved with interventions promoting physical activity [16]. Conversely, obesity and failure to engage in behaviors that meet healthy lifestyle guidelines have been negatively associated with HRQoL measures in cancer survivors [17].

Tertiary prevention through lifestyle behavior changes—increasing physical activity, reducing alcohol intake, smoking cessation, improving diet and using preventive pharmaceuticals such as NSAIDs—can play a critical part in reducing the adverse sequelae from cancer and the associated treatment [18]. Current smoking post-diagnosis in colorectal cancer survivors has been associated with higher colorectal cancer-specific mortality and higher all-cause mortality [19]. In a meta-analysis of 22 prospective cohort studies, breast cancer survivors who were physically active post-diagnosis had a reduced risk of recurrence, new primary cancers and progression of the initial cancer [20]. Among breast and colorectal cancer survivors, the regular use of aspirin has been associated with decreased risk for recurrence and death due to cancer [21, 22].

Studies of cancer survivors demonstrate mixed results for lifestyle behaviors compared to those never diagnosed with cancer. A US population-based case control study of breast, prostate, and colorectal cancer based on the Behavioral Risk Factor Surveillance System (BRFSS) reported that breast cancer survivors exhibited lower rates of current smoking and were more likely to meet the daily fruit and vegetable recommendations when compared to non-cancer controls [23]. However, when compared to the cancer-free, cancer survivors from the Health Information National Trends Survey (HINTS) in the United States showed no statistically significant difference in the proportion of current smokers in a study evaluating tobacco use, fruit and vegetable intake, physical activity, and body mass index (BMI) [5]. Breast cancer survivors in the Danish Diet, Cancer and Health Cohort exhibited no reduction in BMI, and no reduced consumption of alcohol or tobacco compared to cancer-free women [24]. Cancer survivors in a UK population-based study were less likely to engage in physical activity and more likely to be sedentary, compared to cancer-free controls [25].

As the previous research has produced mixed results on health behaviors by cancer survivors, the aim of our study is to investigate potential differences in key lifestyle factors (e.g., physical activity, smoking status, NSAID/aspirin use), among cancer survivors and cancer-free individuals in a large prospective cohort study conducted in the United States. We hypothesized that cancer survivors will report lower activity levels, higher BMI, higher rates of smoking cessation, and less NSAID use as compared to the cancer-free. We also investigated lifestyle factors between short-term (<5 years) and long-term (≥5 years) survivors, as few studies have comprehensively assessed whether differences exist in health behaviors by time since diagnosis.

Methods

Participants and data collection

Health behaviors of cancer survivors were compared to those of the cancer-free in the Prostate, Lung, Colorectal and Ovarian (PLCO) Cancer Screening Trial. The PLCO Cancer Screening Trial was implemented in the United States to evaluate the effect of screening for these cancers on cancer-related mortality [26]. Between November 1993 and July 2001, 154,897 men and women between the ages of 55 and 74 were randomized into either an intervention arm or a control arm of the PLCO trial. The trial was conducted at ten centers across the United States (located in Alabama, Colorado, Hawaii, Michigan, Minnesota, Missouri, Pennsylvania, Utah, Washington, D.C., and Wisconsin). Individuals in both arms of the trial continued their routine health care. Participants in the intervention arm received additional screening exams for prostate, lung, colorectal, and ovarian cancer. A self-administered baseline questionnaire was completed at entry by all participants. The follow-up questionnaire was provided to participants between 2006 and 2008, with an average of 10 years between randomization and follow-up completion. Informed consent was obtained in written form from all research participants. Each study center obtained ethical approval for human subject research.

The data used in this study include information from randomization through December 31, 2009. Of the 154,897 participants enrolled in the study, 97,406 completed both baseline and follow-up questionnaires and had no cancer diagnosis

prior to study enrollment. Those identified as having no confirmed cancer diagnosis at follow-up were designated the cancer-free group. Cancer survivors were identified as having a confirmed cancer diagnosis between enrollment and follow-up and must have had a confirmed cancer behavior of "malignant, primary site." Those diagnosed with cancer during the study, but after the completion of the follow-up questionnaire, were excluded from the study because the aim of this study is to assess behaviors after cancer diagnosis (4389). Of the 11,528 PLCO participants who had completed a baseline questionnaire and had a cancer diagnosis, 11,025 participants completed the supplemental questionnaire. Lastly, those diagnosed with "in situ" cancers or "uncertain or borderline" cancers, 892 individuals, were omitted for this analysis. We analyzed data for 81,992 cancer-free individuals and 10,133 cancer survivors (Fig. 1). The cancer diagnoses by site were as follows: 4275 prostate, 1720 breast, 858 colon, 731 hematopoietic, 412 lung, 396 bladder, 384 melanoma, 363

endometrial, 232 renal, 163 head and neck, 119 ovarian, 90 thyroid, 89 upper gastrointestinal, 42 pancreatic, 12 biliary, 9 glioma, 8 liver cancers, and 258 from other sites (Fig. 1). If cancer survivors were diagnosed with more than one cancer, they were grouped according to first cancer diagnosis.

Although the intervention arm was screened for prostate, lung, colorectal, and ovarian cancers, in both arms, the incidence rate of cancer was similar. Of the 10,133 cancer survivors, 5343 were from the intervention arm and 4790 were from the control arm. For specific cancer site, the number of controls vs interventions were as follows: 2346 vs 1929 for prostate cancer, 231 vs 181 for lung cancer, 379 vs 479 for colorectal cancer, 73 vs 46 for ovarian cancer, 24 vs 18 for pancreatic cancer, 220 vs 164 for melanoma, 176 vs 193 for bladder cancer, 867 vs 853 for breast cancer, 381 vs 350 for hematopoietic cancers, 4 vs 4 for liver cancer, 48 vs 41 for upper gastrointestinal cancers, 5 vs 7 for biliary cancers, and 142 vs 116 for other cancer sites.

Fig. 1 PLCO Enrollment flow diagram
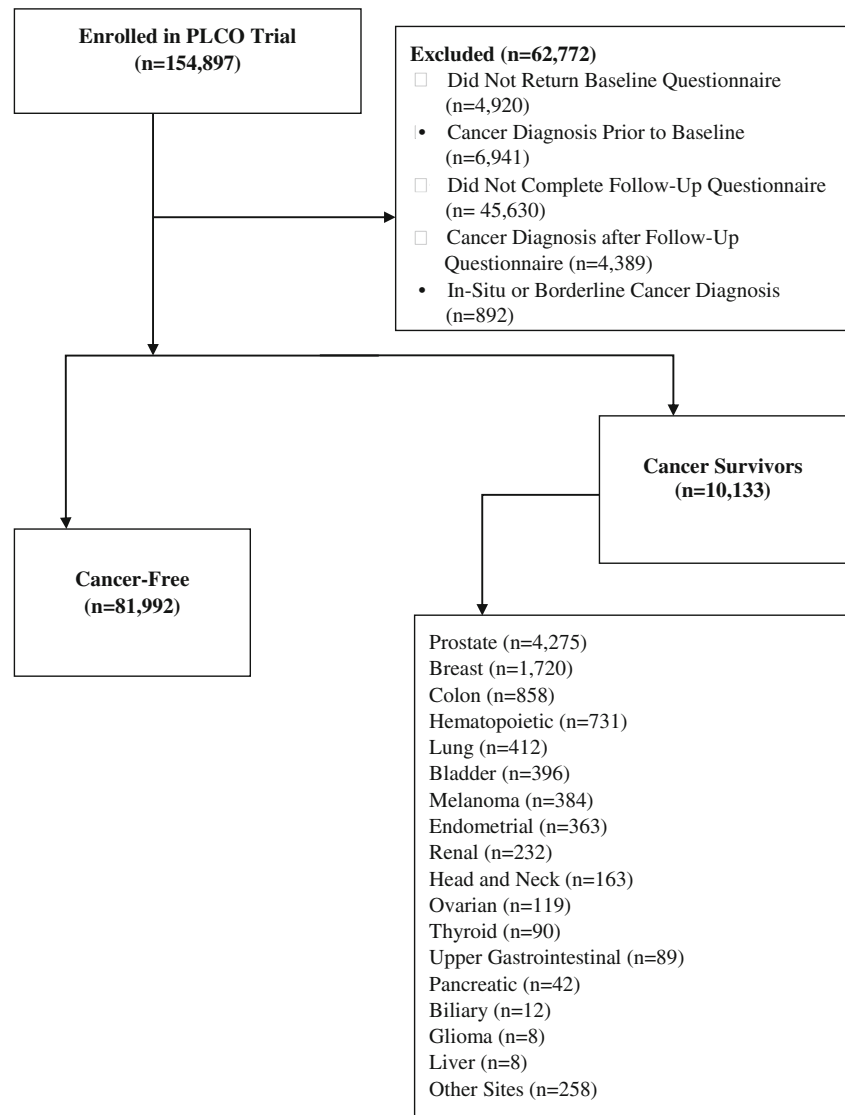
Annual updates about cancer diagnosis, type of cancer, date of diagnosis, and hospital or clinic of diagnosis were collected from study participants. All self-reported cancers were confirmed from medical records, and the data abstraction of these records included diagnosis, cancer behavior, morphology, and grade as assigned by the study abstractor based on the ICD-O-2 code [27]. The baseline questionnaire collected self-reported information on personal sociodemographic characteristics, tobacco, family history of cancer, height, weight, aspirin and ibuprofen use, and medical history. The follow-up questionnaire included self-reported information on the following: income level, religion at birth, work status, height, weight, family history of cancer, health history, nonsteroidal anti-inflammatory drug (NSAID) and aspirin use, physical activity, and tobacco use. To assess smoking status, participants were asked the following: at baseline, "Have you ever smoked cigarettes regularly for 6 months or longer?" and at follow-up, "Have you ever smoked at least 100 cigarettes in your lifetime?" Questions with more detail about physical activity and NSAID use and some smoking behaviors were only collected at follow-up.

Measures

The baseline questionnaire was used to examine the sociodemographic characteristics of participants. BMI data were obtained from the follow-up questionnaire. Participants were asked about physical activity over the year prior to completion of the follow-up questionnaire. Participants were queried about the type of physical activity they engaged in, duration of time spent doing the activity, and the average frequency of participating in the activity each week. To estimate meeting physical activity recommendations, a rough mean was created from the reported number of days per week of moderate activity and the reported duration of each session of moderate activity. The original responses for frequency of moderate activity were collected as follows: "0 = none or <1 day/week," "1 = 2–3 days/week," "2 = 4–5 days/week," and "3 = 6–7 days/week." Duration of moderate activity was collected as follows: "0 = none or <15 min," "1 = 16–19 min," "2 = 20–29 min," "3 = 30–39 min," and "4 = 40+ min." A rough mean was calculated for each response option as follows: moderate duration (0 = 0, 1 = 2.5, 2 = 4.5, and 3 = 6.5) and moderate duration frequency (0 = 0, 1 = 17.5, 2 = 24.5, 3 = 34.5, and 4 = 40). The same procedure was conducted for the strenuous activity and strenuous activity duration. Two variables were then created for those who reported over 150 min of moderate and 75 min of strenuous activity. Questions about aspirin and NSAID use included current intake, strength of medication, and how many years medication had been taken. Low intake of aspirin and NSAIDs was defined as less than once per week and high intake was

defined as at least once per week. Most recent smoking status was obtained from the follow-up questionnaire.

Statistical analysis

Differences between cancer survivors and those without cancer were compared. Participant characteristics and health behaviors at baseline and follow-up were examined using descriptive statistics. t tests were performed for all continuous data categories. Multivariable logistic regression was used to analyze differences between cancer survivors and cancer-free with stratification by BMI at baseline, smoking status at baseline, education level at baseline, sex, income at follow-up, and age at follow-up. The mean household income in the United States for 2009 was $54,925/year [28]. This approximate value was used to create the household income level stratification (<$50,000 vs ≥$50,000). Further analysis was performed with stratification into short-term (< 5 years) and long-term (≥ 5 years) survivors. Years of survival were calculated by taking the number of days to follow-up questionnaire completion from randomization minus the number of days to diagnosis of cancer from randomization. A significance level of $\alpha = 0.05$ was used for analyses. To correct for the false discovery rate in multiple comparisons, the Benjamini-Hochberg method was used with a 0.05 point-wise threshold [29]. Following this correction, all p values equal to or greater than 0.021 were considered to be non-significant. All significant findings are bolded in the tables (Tables 1, 2, 3, and 4; data not shown) to indicate remaining significance following this correction method. Stata (version 14.0, College Station TX) was used for data analysis.

Results

Demographics

At randomization, cancer survivors were older compared to the cancer-free individuals ($p < 0.001$; Table 1). The majority of cancer survivors were male as compared to the cancer-free population ($p < 0.001$; Table 1). White, non-Hispanic individuals constituted roughly 90% of the population for both cancer-free and cancer survivors. Education level varied somewhat, trending toward slightly higher education levels in cancer survivors at enrollment ($p < 0.001$; Table 1). No statistically significant difference was seen in income level at follow-up between the groups.

Body mass index

At the end of the last follow-up, roughly 33% of both cancer-free individuals and cancer survivors had a normal BMI of

Table 1 Demographics and health behaviors of cancer-free vs cancer survivors in the PLCO study

	Cancer Survivors		Cancer -Free	
Population	10,133		81,992	
	No.	%	No.	%
Age at randomization				
Less than 59 years	2609	25.7	30,474	37.2
60 to 64 years	2695	26.6	25,973	31.7
65 to 69 years	3495	34.5	17,078	20.8
Greater than 70	1334	13.2	8467	10.3
P-value				*<0.001*
Gender				
Male	6469	63.8	37,937	46.3
Female	3664	36.2	44,055	53.7
P-value				*<0.001*
Race				
White, Non-Hispanic	9401	92.8	74,624	91.0
Black, Non-Hispanic	298	2.9	2619	3.2
Hispanic	116	1.1	1302	1.6
Asian	256	2.5	2863	3.5
Pacific Islander	44	0.4	379	0.5
American Indian	16	0.2	174	0.2
Missing	2	0	31	0
P-value				*<0.001*
Education level				
Less than 8 years	49	0.5	404	0.5
8 to 11 years	483	4.8	3913	4.8
12 years or completion of high school	2108	20.8	18,475	22.5
Post-high school training other than college	1198	11.8	10,328	12.6
Some college	2147	21.2	17,756	21.7
College graduate	1920	18.9	14,750	18.0
Postgraduate	2201	21.7	16,178	19.7
Missing	27	0.3	188	0.2
P-value				*<0.001*
Household income level (at follow-up)				
Less than $20,000	1036	11.2	8802	10.7
$20,000 to $49,000	3666	39.5	29,281	35.7
$50,000 to $99,000	2582	27.8	20,803	25.4
$100,000 to $200,000	672	7.2	5829	7.1
Greater than $200,000	134	1.4	1036	1.3
Prefer not to answer	1190	12.8	9725	11.9
Missing	849	8.4	6516	7.9
P-value				*0.285*
Health status and health behaviors at follow-up				
Body mass index at follow-up				
0 to 18.5	108	1.1	745	0.9
18.5 to 25	3160	32.6	25,746	32.8
25 to 30	4168	43.0	32,667	41.6

Table 1 (continued)

Population	Cancer Survivors 10,133		Cancer -Free 81,992	
	No.	%	No.	%
30+	2246	23.2	19,328	24.6
P-value				*0.003*
Smoking status at follow-up				
Never smoked	4155	41.9	40,361	47.1
Former smoker	5174	52.1	39,683	46.3
Current smoker	597	6.0	5666	6.6
P-value				*<0.001*
Physical activity at least 1 time per month for last 12 months				
No	1143	12.5	8275	11.0
Yes	8035	87.5	66,668	89.0
P-value				*<0.001*
Physical activity compared to 10 years ago				
More active	613	6.2	6788	8.4
Less active	5865	58.9	41,648	51.6
About The Same	3478	34.9	32,284	40.0
P-value				*<0.001*

between 18.5 and 25 kg/m^2 (Table 1). The majority of both cancer survivors and those without cancer were overweight (BMI between 25 and 30 kg/m^2) or obese (BMI greater than or equal to 30 kg/m^2). Cancer survivors were significantly more likely to be underweight as compared to the cancer-free (OR = 1.33, 95% CI = 1.07–1.65; Table 2). Between groups, there was no statistically significant difference in likelihood of being overweight or obese at follow-up. However, cancer survivors who were obese at baseline were significantly more likely to be at a normal BMI at follow-up than the cancer-free who were obese at baseline (OR = 1.90, 95% CI = 1.42–2.54; Table 3). Of those who were overweight at baseline, cancer survivors were significantly more likely to be at a normal BMI at follow-up when compared to the cancer-free (OR = 1.15, 95% CI = 1.05–1.26, Table 3) but were also significantly more likely to be obese at follow-up compared to the cancer-free (OR = 1.11, 95% CI = 1.01–1.18; Table 3). Upon stratification by income level at follow-up, cancer survivors who made less than $50,000 a year were significantly more likely to be underweight as compared to the cancer-free (OR = 1.38, 95% CI = 1.03–1.85; data not shown).

Tobacco use

A higher number of cancer survivors were former smokers at follow-up as compared to the cancer-free, while a lower number of cancer survivors were never smokers as compared to the cancer-free ($p < 0.001$; Table 2). Cancer survivors who smoked at baseline were significantly more likely to be former smokers at follow-up compared to the cancer-free who smoked at baseline (OR = 1.50, 95% CI = 1.30–1.74; Table 4). Cancer survivors who made less than $50,000 a year were significantly more likely to be current smokers as compared to the cancer-free (OR = 1.18, 95% CI = 1.04–1.33; data not shown). Cancer survivors with a high school education or less were also significantly more likely to be current smokers as compared to the cancer-free (OR = 1.22, 95% CI = 1.03–1.45; data not shown).

Physical activity

A higher proportion of cancer survivors (12.5%) reported having not participated in physical activity at least once a month for the last 12 months compared to the cancer-free individuals (11.0%) ($p < 0.001$; Table 1). Almost 60% of cancer survivors reported being less active at follow-up than they were 10 years ago ($p < 0.001$) and were more likely to report being less active at follow-up than 10 years ago compared to those without cancer (OR = 1.28, 95% CI = 1.22–1.34; Table 2). Cancer survivors were less likely to participate in moderate and strenuous exercise each week than the cancer-free ($p < 0.001$; Table 1). Cancer survivors were also

Table 2 Odds ratio of BMI, tobacco behavior, physical activity, NSAID use and aspirin use at follow-up in cancer survivors compared to cancer-free in the PLCO study

	Cancer Survivors	Cancer-Free	OR*	C.I.
BMI				
Normal weight (BMI 18.5 to 25)	108	745	1.00	
Underweight (BMI < 18.5)	3160	25,746	1.33	[1.07–1.65]
Overweight (BMI 25 to 30)	4168	32,667	0.95	[0.90–1.00]
Obese (BMI > 30)	2246	19,328	0.98	[0.92–1.04]
Smoking status				
Never smoked	4155	38,227	1.00	
Current smoker	597	5167	1.13	[1.02–1.24]
Former smoker	5174	37,119	1.12	[1.07–1.17]
Plans to quit				
No	2078	228	1.00	
Next 30 days	1190	175	1.36	[1.09–1.70]
Next 60 days	1712	176	1.04	[0.84–1.30]
Physical activity at least 1 time/month for last 12 months				
No	1143	8275	1.00	
Yes	8035	66,668	0.82	[0.77–0.88]
Physical activity compared to 10 years ago				
About the same	3478	32,284	1.00	
More active	613	6788	0.96	[0.87–1.05]
Less active	5865	41,648	1.28	[1.22–1.34]
Moderate physical activity				
None or <1 day/week	3642	26,978	1.00	
2 to 3 days/week	4086	34,550	0.89	[0.85–0.94]
4 to 5 days/week	1445	12,391	0.88	[0.82–0.94]
6 to 7 days/week	302	5360	0.80	[0.73–0.88]
Strenuous physical activity				
None or <1 day/week	5385	40,920	1.00	
2 to 3 days/week	3097	26,869	0.87	[0.83–0.92]
4 to 5 days/week	1001	8607	0.87	[0.81–0.94]
6 to 7 days/week	364	3278	0.80	[0.71–0.90]
At least 150 min of moderate activity per week				
No	8703	69,203	1.00	
Yes	1430	12,789	0.89	[0.83–0.94]
At least 75 min of strenuous activity per week				
No	7535	58,868	1.00	
Yes	2598	23,124	0.87	[0.83–0.92]
Current NSAID use				
None	5662	43,390	1.00	
Low	1947	16,848	1.00	[0.95–1.06]
High	1836	16,984	1.00	[0.94–1.06]
NSAID frequency				
None	5662	43,390	1.00	
Less than 1 time/month	1003	8429	0.99	[0.92–1.06]
1 to 3 times/month	944	8419	1.02	[0.94–1.10]

Table 2 (continued)

	Cancer Survivors	Cancer-Free	OR*	C.I.
1 to 2 times/week	473	4404	1.00	[0.90–1.12]
3 to 6 times/week	466	4129	1.02	[0.92–1.13]
7+ times/week	897	8451	0.98	[0.91–1.10]
Current aspirin use				
None	2197	17,216	1.00	
Low	1970	16,701	0.92	[0.86–0.99]
High	5581	45,314	0.85	[0.81–0.90]
Aspirin strength				
None	2197	17,216	1.00	
Adult (325 mg)	2940	25,535	0.83	[0.78–0.89]
Baby strength (81 mg)	4134	32,568	0.90	[0.85–0.96]
Some other strength	128	1218	0.76	[0.63–0.93]
Aspirin frequency				
None	2197	17,216	1.00	
Less than 1 time/month	1330	10,947	0.94	[0.87–1.02]
1 to 3 times/month	640	5754	0.88	[0.79–0.97]
1 to 2 times/week	342	3209	0.82	[0.72–0.93]
3 to 6 times/week	974	8441	0.83	[0.76–0.90]
7+ times/week	4265	33,664	0.86	[0.82–0.92]

*Odds ratio after controlling for age at follow-up, sex, race, education level, and income

less likely to meet the physical activity recommendations of at least 150 min of moderate activity a week or 75 min of vigorous activity per week (OR = 0.89, 95% CI = 0.83-0.94; OR = 0.87, 95% CI = 0.83-0.92, respectively Table 2). Of those who were overweight and obese at baseline, cancer survivors, when compared to the cancer-free, were significantly more likely to report being less active than they were 10 years ago (OR = 1.26. 95% CI = 1.18–1.09; OR = 1.31, 95% CI = 1.18–1.46, respectively; Table 3). Similarly, of those who were current and former smokers at baseline, cancer survivors were significantly more likely than the cancer-free to be less active as compared to 10 years ago (OR = 1.27, 95% CI = 1.08–1.50; OR =1.25, 95% C.I. = 1.16–1.34, respectively; Table 4). Upon stratification by income, cancer survivors in both income groups (<$50,000/year and ≥$50,000/year) were significantly less likely to have been physically active at least once a month in the last 12 months than those without cancer (OR = 0.80, 95% CI = 0.73–0.87; OR = 0.89, 95% CI = 0.81–0.98, respectively; data not shown).

NSAID and aspirin use

No difference was seen for intake or frequency of intake of NSAIDS between cancer survivors and cancer-free use

(Table 2). A difference was seen in likelihood of aspirin use, where cancer survivors were significantly less likely to use either adult (325 mg) or baby strength (81 mg) aspirin as compared to those without cancer (OR = 0.83, 95% CI = 0.78–0.89; OR = 0.90, 95% CI = 0.85–0.96, respectively; Table 2). Similarly, cancer survivors were less likely to report any frequency of aspirin intake than were the cancer-free. No differences were seen in NSAID use between cancer survivors and the cancer-free after stratification by income level, education level, or age. Both income groups for cancer survivors were significantly less likely to report high aspirin use as compared to the cancer-free (less than $50,000/year: OR = 0.87, 95% CI = 0.81–0.94; $50,000 and more/year: OR = 0.83, 95% CI = 0.78–0.90).

Short-term vs long-term cancer survivors

No statistically significant differences were observed in BMI, smoking status, or NSAID use between short-term and long-term survivors (data not shown). After controlling for age at follow-up, sex, race, education, and income level at follow-up, short-term cancer survivors were more likely to engage in moderate physical activity 6 to 7 days a week as compared to long-term survivors (OR = 1.36, 95% CI = 1.13–1.63; data not shown). Short-term

Table 3 Odds ratio of health behaviors of cancer survivors compared to the cancer free by bmi at baseline in the PLCO study

	Overweight at Baseline				Obese at Baseline			
	Cancer Survivors = 4542, Cancer-Free = 34,508				Cancer Survivors = 2197, Cancer-Free = 18,668			
	Cancer Survivors	Cancer-Free	OR*	C.I.	Cancer Survivors	Cancer-Free	OR*	C.I.
BMI at follow-up								
Normal weight (BMI 18.5 to 25)	744	4976	1.15	[1.05–1.26]	61	287	1.90	[1.42–2.54]
Underweight (BMI <18.5)	9	47	1.20	[0.53–2.70]	3	16	1.67	[0.47–5.89]
Overweight (BMI 25 to 30)	2948	23,244	1.00		482	3474	1.12	[1.00–1.26]
Obese (BMI >30)	482	4811	1.11	[1.01–1.23]	1554	13,986	1.00	
Smoking status at follow-up								
Never Smoked	1788	15,372	1.00		914	8360	1.00	
Current Smoker	251	2077	1.10	[0.95–1.28]	99	959	1.02	[0.81–1.28]
Former Smoker	2420	16,434	1.10	[1.02–1.18]	1136	9025	0.99	[0.90–1.10]
Physical activity at least 1 time/month for last 12 months								
No	478	3159	1.00		366	2783	1.00	
Yes	3637	28,392	0.83	[0.74–0.92]	1597	14,099	0.80	[0.71–0.91]
Physical activity compared to 10 years ago								
About the same	1561	13,573	1.00		542	5499	1.00	
More active	264	2777	0.97	[0.84–1.12]	1469	1593	1.02	[0.83–1.25]
Less active	2639	17,623	1.26	[1.18–1.35]	145	11,294	1.31	[1.18–1.46]
Current NSAID use								
None	2585	18,534	1.00		1085	8636	1.00	
Low	854	7125	0.98	[0.90–1.07]	438	3899	0.98	[0.87–1.11]
High	791	6823	0.99	[0.91–1.09]	519	4970	0.98	[0.87–1.10]
Current aspirin use								
None	916	6704	1.00		464	3892	1.00	
Low	861	6913	0.91	[0.81–1.01]	394	3270	1.02	[0.88–1.18]
High	2585	19,701	0.84	[0.78–0.92]	1255	10,841	0.89	[0.79–1.01]

*Odds ratio after controlling for age at follow-up, sex, race, education level, and income at follow-up

survivors were also more likely to engage in strenuous physical activity 2 to 3 days a week as compared to long-term survivors (OR = 1.19, 95% CI = 1.09–1.31; data not shown).

Discussion

With the differing data on the adoption of healthier lifestyle habits by cancer survivors, our goal was to better understand the behavior of cancer survivors compared to those without cancer. The health behaviors evaluated in this study (smoking, physical activity, body mass index, and NSAID/aspirin use) have been associated with many of the prevalent chronic diseases in the United States

[30–33]. As cancer survivors have been found to have a higher prevalence of chronic conditions compared to cancer-free individuals [34, 35], the adoption of healthful lifestyle behaviors is an important aspect in survivorship care, and public health efforts promoting the optimal health of cancer survivors should address these issues.

In almost all aspects of physical activity, the cancer-free population reported higher levels of activity and longer durations of time spent in physical activity. Although it might be expected that a diagnosis of cancer would motivate behavior change, recent studies found little support for this. In the NHANES study, cancer survivors were more likely to be sedentary (measured as time spent sitting or reclining) [36], and cancer survivors in the English longitudinal study of aging were not only more likely to be sedentary (hardly ever or never

Table 4 Odds ratio of health behaviors of cancer survivors compared to the cancer free by smoking status at baseline in the PLCO study

	Current Smoker at Baseline				Former Smoker at Baseline			
	Cancer Survivors = 980, Cancer-Free = 6709				Cancer Survivors = 4700, Cancer-Free = 34,803			
	Cancer Survivors	Cancer-Free	OR*	C.I.	Cancer Survivors	Cancer-Free	OR*	C.I.
BMI								
Normal weight (BMI 18.5 to 25)	361	2318	1.00		1324	9372	1.00	
Underweight (BMI <18.5)	18	139	1.40	[0.89–2.17]	44	222	1.45	[1.04–2.04]
Overweight (BMI 25 to 30)	358	2498	0.90	[0.76–1.06]	1962	14,000	0.92	[0.85–0.99]
Obese (BMI >30)	193	1419	0.94	[0.78–1.15]	1028	8722	0.87	[0.80–0.96]
Smoking status								
Current smoker	452	3960	1.00		136	1112	1.03	[0.85–1.25]
Former smoker	501	2647	1.50	[1.30–1.74]	4371	32,152	1.00	
Physical activity at least 1 time/month for last 12 months								
No	166	1058	1.00		507	3352	1.00	
Yes	699	4884	0.88	[0.73–1.07]	3643	27,571	0.88	[0.79–0.98]
Physical activity compared to 10 years ago								
About the same	250	2037	1.00		1546	12,863	1.00	
More active	43	429	0.93	[0.66–1.33]	279	17,373	0.94	[0.81–1.08]
Less active	659	4092	1.27	[1.08–1.50]	1546	12,863	1.25	[1.16–1.34]
Current NSAID use								
None	540	3591	1.00		2525	17,551	1.00	
Low	191	1392	1.01	[0.84–1.22]	898	7027	1.01	[0.93–1.10]
High	169	1300	1.07	[0.88–1.30]	829	7236	0.94	[0.86–1.02]
Current aspirin use								
None	215	1304	1.00		889	6461	1.00	
Low	189	1463	0.75	[0.60–0.93]	885	6480	0.99	[0.89–1.10]
High	537	3688	0.80	[0.67–0.95]	2606	19,665	0.85	[0.78–0.93]

*Odds ratio after controlling for age at follow-up, sex, race, education level, and income at follow-up

participated in mildly energetic activity), but also less likely to be physically active (moderate to vigorous activity at least once a week) [25]. A prospective study of breast cancer survivors in the Kaiser Permanente Northern California Medical Care Program found a decrease in moderate physical activity and recreational activities 6 months after diagnosis as compared to baseline activity levels [37]. Similarly, colorectal cancer survivors in the Eindhoven Cancer Registry who experienced co-morbidities associated with cancer were less likely to engage in physical activity [38]. Lower levels of physical activity may be a result of frailty or from chronic fatigue reported by cancer survivors [39–41]. A postal questionnaire-survey looking at exercise barriers in cancer survivors found that fatigue and illness were prominent barriers to engaging in physical exercise; however, the majority of these participants also reported an interest in participating in an exercise program [42].

While there was no difference in likelihood of being overweight or obese between cancer survivors and the cancer-free after adjusting for race, sex, education at baseline, age at follow-up, and income at follow-up, the stratification by baseline health status provides evidence that cancer survivors who were overweight or obese prior to cancer diagnosis may be more likely to practice healthier lifestyle behaviors after diagnosis such as weight management. A similar finding was seen in a prospective population-based cohort study from the United States and United Kingdom which found that cancer survivors who were obese prior to cancer diagnosis were more likely to lose weight than obese adults without cancer [43]. However, as cachexia is a common adverse effect of cancer diagnosis and treatment, the weight loss seen in overweight and obese cancer survivors may be due to this condition rather than practice of healthier behaviors [44]. Additionally, while cancer survivors seemed to achieve healthier BMIs at follow-up than the cancer-free, the cancer survivors in this study follow the current trend of obesity in the United States: as of 2010, two in three adults are considered overweight or obese [45].

The diagnosis of cancer appears to improve the likelihood of smoking cessation in participants that were current smokers at baseline. A study from the Cancer Prevention Study-II Nutrition Cohort found that the quit rates of current smokers over the course of 2 years was higher in those diagnosed with cancer as compared to smokers without cancer [46]. Cancer site may also play a role in smoking cessation; a matched comparison study from the California Cancer Registry found that current smokers who were diagnosed with bladder cancer were significantly more likely to quit smoking compared to smokers in the general population [47]. As our study showed that cancer survivors had a higher intention to quit smoking as compared to the cancer-free, the diagnosis of cancer may present an ideal opportunity to encourage this behavior change.

The use of NSAIDs after a cancer diagnosis has been shown to reduce mortality in several types of cancer including those of the upper aerodigestive tract, colorectal, and breast [48–50]. However, no significant difference was shown in NSAID use between cancer survivors and the cancer-free. These results may be due to controlling for confounders, specifically age. In 2010, over 45% of individuals over the age of 65 were experiencing at least 2 chronic conditions [51]. As NSAIDs are a widely accepted form of pain and inflammation management, and since the mean age of both groups at follow-up was over 65 years, the presence of chronic conditions may be influencing NSAID use.

Cancer survivors were significantly less likely to use aspirin as compared to those without cancer after adjusting for age at follow-up, race, sex, income at follow-up, and education level. This is concerning as significant prevention benefits have been associated with aspirin use in cancer survivors. Specifically, findings from a prospective cohort study found that the risk of recurrence and mortality greatly decreased in colorectal cancer survivors who regularly take aspirin [52, 53]. A systematic review and meta-analysis of aspirin treatment of cancer found that aspirin reduced the risk of metastatic spread [54]. Additionally, regular aspirin use is a key intervention strategy for many chronic conditions such as heart attack and stroke [31].

Strengths of this study include the utilization of data from a large, national prospective cohort which may limit selection bias and minimize temporal ambiguity. The longitudinal nature of this study is necessary to support the causal link between cancer diagnosis and limited adoption of improved health behaviors by cancer survivors. Participants in the PLCO trial were closely followed over the course of the study through administration of questionnaires and annual updates. Participants diagnosed with cancer during the study were actively tracked to obtain and collect accurate medical records related to diagnostic follow-up and treatment [55]. Furthermore, the ability to account for the smoking status and BMI prior to cancer diagnosis strengthened the results found in this study.

As cancer diagnosis continued throughout the follow-up period, the reporting of health behaviors at follow-up may have been affected by the difference in time since cancer diagnosis. Responder bias is an inherent limitation of self-reported data. There is a well-known downward bias of weight status in self-reports, which has remained a stable trend over the last decade [56] and a systematic review of direct versus self-reported measures of physical activity found self-reports measured both higher and lower than direct measures [57]. This study did not consider comorbid conditions among participants, which may have an influence on all health behaviors and status at follow-up. This is an area, however, for future investigation.

In conclusion, the findings of this study provide evidence that while cancer survivors may make some improvements to practice healthier lifestyle behaviors as compared to those without cancer, there is still concern that cancer survivors appear to be engaging in less physical activity than those without cancer and are not meeting recommendations for aspirin and NSAID intake. As cancer survival rates are increasing, the consideration of health and quality of life post-diagnosis are exceedingly important. The American Society of Clinical Oncology includes guidance on health promotion activities, diet, and exercise as a part of high-quality survivorship care [58] and health behavior counseling and other support should be prioritized as a key component to comprehensive survivorship care. The low adoption of healthy behaviors may be amenable to interventions. Specifically, successful behavior change by cancer survivors has been seen in interventions based on social cognitive theory [59]. Rehabilitation and intervention programs should specifically target health behavior changes, and health care providers should encourage behavior change in cancer survivors, which may improve long-term survival and quality of life.

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