


Health-Related and Behavioral Factors Associated With Lung Cancer Stage at Diagnosis: Observations From Alberta's Tomorrow Project

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Abstract

Background: Lung cancer is the leading cause of cancer death in Canada, with stage at diagnosis among the top predictors of lung cancer survival. Identifying factors associated with stage at diagnosis can help reduce lung cancer morbidity and mortality. This study used data from a prospective cohort study of adults living in Alberta, Canada to examine factors associated with lung cancer stage at diagnosis.

Methods: This cohort study used data from adults aged 35–69 years enrolled in Alberta's Tomorrow Project. Partial Proportional Odds models were used to examine associations between sociodemographic characteristics and health-related factors and subsequent lung cancer stage at diagnosis.

Results: A total of 221 participants (88 males and 133 females) developed lung cancer over the study period. Nearly half (48.0%) of lung cancers were diagnosed at a late stage (stage IV), whereas 30.8% and 21.3% were diagnosed at stage I/II and III, respectively. History of sunburn in the past year was protective against late-stage lung cancer diagnosis (odds ratio (OR) .40, $P=.005$). In males, a higher number of lifetime prostate specific antigen tests was associated with reduced odds of late-stage lung cancer diagnosis (odds ratio .66, $P=.02$). Total recreational physical activity was associated with increased odds of late-stage lung cancer diagnosis (OR 1.08, $P=.01$).

Discussion: Lung cancer stage at diagnosis remains a crucial determinant of prognosis. This study identified important factors associated with lung cancer stage at diagnosis. Study findings can inform targeted cancer prevention initiatives towards improving early detection of lung cancer and lung cancer survival.

Keywords

Canada, cancer screening, lung cancer symptoms, prostate specific antigen, recreational activity, sun exposure

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Background

Lung cancer is the most commonly diagnosed cancer (excluding non-melanoma skin cancers) and the leading cause of cancer-attributable deaths in Canada¹ and worldwide.² In 2020, an estimated 29 800 Canadians were diagnosed with lung cancer and 21 200 died from the disease.³ Although lung cancer has historically affected more males than females, the gap in incidence and mortality rates has narrowed over recent years,^{1,3} coinciding with decreasing trends in tobacco smoking over the past 20 to 30 years, particularly among males.³

Smoking remains the most important cause of lung cancer, accounting for approximately 72% of lung cancer cases in Canada.^{4,5} However, lung cancer also develops in never-smokers, highlighting the influence of other risk factors. Notably, residential radon exposure is the second leading cause of lung cancer among smokers and the leading cause of lung cancer among never-smokers.⁶ A number of other risk factors such as exposure to second-hand smoke, occupational exposures (e.g., asbestos, silica, and wood dust), unhealthy dietary patterns (e.g., low fruit and vegetable intake), physical inactivity, and environmental pollutants have also been linked to lung cancer development.⁷⁻¹⁰

Lung cancer stage at diagnosis is among the top predictors of lung cancer survival.¹¹ In Canada (excluding Quebec), nearly 70% of lung cancer cases are diagnosed at late stages (stages III and IV) when curative treatment is no longer viable, while 20.7% and 8.4% of cases are diagnosed at early stages I and II, respectively.¹¹ These observed rates are similar among Alberta residents.¹² Notably, while the 3 year survival of stage I lung cancer is approximately 70%, survival is drastically reduced to only 5% for those diagnosed with stage IV lung cancer.¹

The higher proportion of advanced stage lung cancer cases is largely due to non-specific symptoms or delays in symptom development.¹³ Previous investigations have also identified additional factors associated with late-stage lung cancer diagnosis, such as lower socioeconomic position, presence of comorbidities, living in a rural location, and identifying as younger, male, or unmarried.¹⁴⁻²⁰ However, some studies have failed to find a number of these associations.²¹⁻²⁴ These discrepancies may be in part due to differences in population groups, sample sizes, study designs, and model adjustments. In addition, despite observed associations between various lung cancer risk factors and stage at diagnosis, the role of several other important factors (e.g., dietary intake and physical activity) have yet to be investigated. Finally, given the difference in healthcare systems and policies across nations, further evidence from a Canadian context can help inform public health initiatives in Canada to target those at highest risk of late-stage lung cancer. The Canadian Strategy for Cancer Control 2019–2029 has identified early detection and diagnosis as a priority area to improve lung cancer survival.²⁵ Accordingly, identifying individual factors associated

with lung cancer stage at diagnosis can provide valuable insight into underlying drivers of advanced stage disease.

The objective of this study was to investigate associations between sociodemographic, behavioral, and health-related factors measured before lung cancer development and subsequent lung cancer stage at diagnosis in a large cohort of adults with no personal history of cancer at enrollment. Factors identified in previous studies such as age, biological sex, and marital and smoking status were examined, although some notable risk factors such as radon or occupational exposures were unavailable. Novel factors, such as dietary factors and cancer screening participation were evaluated in exploratory analyses.

Materials and Methods

Cohort Design and Data Collection

This cohort study used data collected from Alberta's Tomorrow Project (ATP), a prospective cohort study examining the etiology of cancer and chronic diseases among healthy adults aged 35 to 69 years living in Alberta, Canada. Complete details of participant recruitment and data collection have been described elsewhere.²⁶ Briefly, participants were eligible if they had no history of cancer (except non-melanoma skin cancer), intended to live in Alberta for at least one year, and who could complete self-reported questionnaires in English.²⁶ Participant reported history of cancer was confirmed by cross-checking reports with the Alberta Cancer Registry (ACR). Participant recruitment began in 2000 using random digit dialing, and by 2015, a total of 55 000 participants were enrolled into the study.²⁶ The type and number of surveys completed by participants varied according to when participants joined ATP. All participants provided informed written consent to join ATP. Ethics approval for this study (HREBA.CC—16-0814) and ATP (HREBA.CC—17-0461) was granted from the Health Research Ethics Board of Alberta—Cancer Committee. The reporting of this study conforms to Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines²⁷

The current study used self-reported baseline data collected from the Health and Lifestyle Questionnaire (HLQ), the Past-Year Total Physical Activity Questionnaire (PYTPAQ),²⁸ and the Canadian Diet History Questionnaire (CDHQ-I).²⁹ The PYTPAQ has been validated,²⁸ and the HLQ used questions from the validated 2000/01 Canadian Community Health Survey cycle 1.1.³⁰ The CDHQ-I was modified to incorporate Canadian foods and fortifications from the validated Diet History Questionnaire developed by the US National Cancer Institute.^{29,31} A total of 26 890 participants completed all 3 questionnaires.³² The HLQ collected self-reported information on sociodemographic characteristics (e.g., age, sex, and marital status) and health-related variables (e.g., cancer screening, smoking status, and family history of cancer).³³ The PYTPAQ assessed the frequency, intensity, and type of

physical activity (i.e., household, occupational, and recreational) over the past year. Finally, the CDHQ-I, a detailed Food Frequency Questionnaire, examined dietary intake over the past year.³³ Questionnaire data were linked to the ACR using participants' Personal Health Numbers, which are unique Alberta health care system identifiers.²⁶

Outcome Measure

This study included all lung cancer diagnoses up until January 18, 2018, identified through the ACR.²⁶ The ACR records all individual cancer cases and cancer-related deaths across Alberta,³⁴ and is gold certified by the North American Association of Central Cancer Registries. Lung cancer stage at diagnosis was defined using the Tumor, Node, Metastasis staging system, comprising stages I–IV.¹¹

Explanatory Variables

This study tested explanatory variables associated with lung cancer stage at diagnosis based on previously published literature and evaluated possible novel factors in exploratory analyses. These novel variables included lifestyle factors associated with lung cancer etiology such as physical inactivity,¹⁰ while others such as cancer screening participation could be surrogates for healthy behaviors. Variables included sociodemographic characteristics (e.g., age, sex, educational level, and total household income), health-related factors (e.g., smoking, cancer screening, and family history of lung cancer), and behavioral factors (dietary intake and physical activity levels).

Statistical Analysis

Preliminary data assessment included removing binary variables with low frequencies (<5 values) and collapsing categorical variables with low frequencies to increase subgroup sizes. Missing responses in continuous variables were imputed using mean value replacement under a missing at random assumption, and missing categorical variables were replaced by reference group. Lung cancer stage I and II were combined due to the smaller number of participants diagnosed at these stages (i.e., n=50 stage I and n=18 stage II).

Partial Proportional Odds (PPO) ordinal response models were used to examine associations between candidate explanatory variables and lung cancer stage at diagnosis. PPO models relax the assumption that a variable has the same level of association (regression slope estimate) across all cancer stages. Variables with a P -value < .2 were evaluated in a multivariable PPO model and were retained if $P < .05$. A random forest analysis (R package partykit version 1.2-5) identified additional variables associated with lung cancer stage at diagnosis, which were also included in the multivariable PPO model. Finally, variables known to be associated with lung cancer (i.e., family history of lung cancer, smoking,

and exposure to second-hand smoke) were forced into the reduced model. The proportional odds assumption was checked, and a PPO model was used where assumptions were violated. Models included interaction terms and functional forms of the continuous variables (e.g., quadratic terms). The influence of potential outliers in the final PPO model was also examined. Model checking was carried out using available methods for the binary logistic setting (Stages I/II vs Stages III and IV) in SAS, because many diagnostic tools were not implemented for the PPO model.

Stratified analyses examined whether associations between explanatory variables and lung cancer stage at diagnosis differed for males and females. Analyses were conducted in R (version 4.1.0, R Foundation for Statistical Computing, Vienna) and SAS version 9.4 (SAS Institute, Cary, NC). Statistical significance was set at $P < .05$.

Results

The flow of ATP participants included in the current study is depicted in Figure 1. From 2000 to 2018, 3359 participants developed cancer, 280 of whom were diagnosed with lung cancer resulting in a crude incidence of 1046.6 per 100 000 people. Following the exclusion of those who did not complete the HLQ and those with missing lung cancer stage (27 participants), a total of 221 participants (88 males and 133 females) were included in the analysis. The higher proportion of females diagnosed with lung cancer reflects higher number of females enrolled in ATP (61.0%).²⁶ Participant characteristics by lung cancer stage at diagnosis (i.e., I/II, III, IV) are presented in Tables 1 and 2. Nearly half (48.0%) of lung cancers were diagnosed at a late stage (stage IV), whereas 30.8

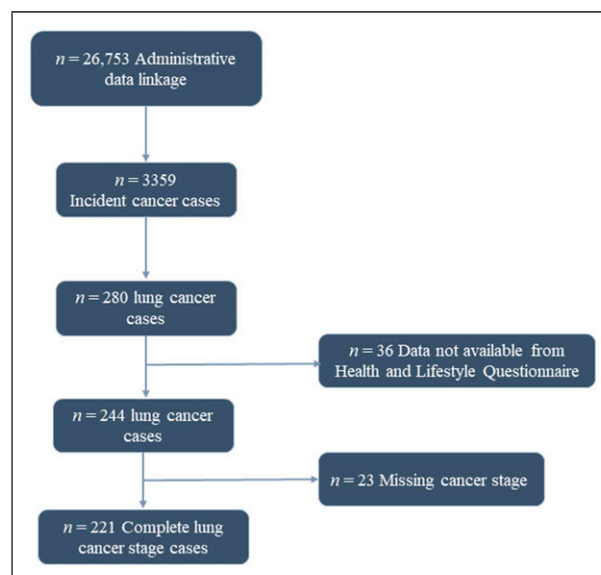


Figure 1. Flow of Alberta's Tomorrow Project (ATP) participants diagnosed with lung cancer from 2000 to 2018 with available data on lung cancer stage.

Table 1. Participant characteristics by lung cancer stage at diagnosis (n=221).

Characteristic N (%)	Stage I&II (n=68)	Stage III (n=47)	Stage IV (n=106)	Total (n=221)
Age at baseline (years)				
<60	32 (14.5)	19 (8.6)	49 (22.2)	100 (45.3)
60+	36 (16.3)	28 (12.7)	57 (25.8)	121 (54.7)
Age at diagnosis (years)				
<60	11 (5.0)	- (2.3)	19 (8.6)	35 (15.8)
60–69	32 (14.5)	27 (12.2)	45 (20.4)	104 (47.1)
70+	25 (11.3)	15 (6.8)	42 (19.0)	82 (37.1)
Sex				
Male	25 (11.3)	20 (9.1)	43 (19.5)	88 (39.8)
Female	43 (19.5)	27 (12.2)	63 (28.5)	133 (60.2)
Education				
High school diploma	33 (14.9)	26 (11.8)	47 (21.3)	106 (48.0)
College and above	35 (15.8)	21 (9.5)	59 (26.7)	115 (52.0)
Married or common in-law				
Yes	50 (22.6)	33 (14.9)	82 (37.1)	165 (74.7)
No	18 (8.1)	14 (6.3)	24 (10.9)	56 (25.3)
Employment				
Yes	38 (17.2)	21 (9.5)	51 (23.1)	110 (49.8)
No	30 (13.6)	26 (11.8)	55 (24.9)	111 (50.2)
Household income (\$)				
<50K	41 (18.6)	24 (10.9)	58 (26.2)	123 (55.7)
50–100K	21 (9.5)	18 (8.2)	36 (16.3)	75 (33.9)
>100K	6 (2.7)	5 (2.3)	12 (5.4)	23 (10.4)
Geography residence				
Rural	12 (5.4)	11 (5.0)	31 (14.0)	54 (24.4)
Urban	56 (25.3)	36 (16.3)	75 (33.9)	167 (75.6)
First degree lung cancer family history				
Yes	9 (4.1)	4 (1.8)	22 (10.0)	35 (15.8)
No	59 (26.7)	43 (19.5)	84 (38.0)	186 (84.2)
Have ever had a digital rectal exam				
Yes	42 (19.1)	32 (14.6)	64 (29.1)	138 (62.7)
No	25 (11.4)	15 (6.8)	42 (19.1)	82 (37.3)
Have ever had a blood stool test				
Yes	29 (13.2)	27 (12.3)	43 (19.6)	99 (45.0)
No	39 (17.7)	20 (9.1)	62 (28.2)	121 (55.0)
Have ever had a sigmoidoscopy or colonoscopy				
Yes	18 (8.2)	19 (8.6)	29 (13.1)	66 (29.9)
No	50 (22.6)	28 (12.7)	77 (34.8)	155 (70.1)
Type of smoker				
Non smoker	8 (3.6)	3 (1.4)	10 (4.5)	21 (9.5)
Past smoker	21 (9.5)	18 (8.1)	35 (15.8)	74 (33.5)
Current smoker	39 (17.7)	26 (11.8)	61 (27.6)	126 (57.0)
Exposure to second-hand smoke ¹				
Yes	23 (10.4)	16 (7.2)	34 (15.4)	73 (33.0)
No	45 (20.4)	31 (14.0)	72 (32.6)	148 (67.0)
Number of hours spent in the sun 11am–4pm in Jun-Aug				
<1	38 (17.2)	25 (11.3)	60 (27.2)	123 (55.7)
≥1	30 (13.6)	22 (10.0)	46 (20.8)	98 (44.3)
Sunburn in last year **				
Yes	22 (10.0)	23 (10.4)	20 (9.1)	65 (29.4)
No	46 (20.8)	24 (10.9)	86 (38.9)	156 (70.6)

(continued)

Table 1. (continued)

Characteristic N (%)	Stage I&II (n=68)	Stage III (n=47)	Stage IV (n=106)	Total (n=221)
Number of stressful situations				
None	32 (14.5)	26 (11.8)	44 (19.9)	102 (46.2)
≥1	36 (16.3)	21 (9.5)	62 (28.1)	119 (53.9)
Number of close friends and relatives, social support				
≤10	47 (21.3)	36 (16.3)	75 (33.9)	158 (71.5)
> 10	21 (9.5)	11 (5.0)	31 (14.0)	63 (28.5)

Significant at * P<.05, ** P<.01.¹ Second-hand smoke is only for never or past smokers. '-' indicates number was <10 so cell entry suppressed.

Table 2. Participant characteristics by lung cancer stage at diagnosis (n=221).

Characteristic median (Q1 - Q3)	Stage I&II (n=68)	Stage III (n=47)	Stage IV (n=106)	Total (n=221)
Age at baseline (years)	60 (54–64)	60 (56–65)	60 (55–64)	60 (55–64)
Distance to accessible health center by a vehicle (minutes)	8 (5–13)	8 (3–13)	7 (3–14)	8 (3–13)
Comorbidity index ²	1 (0–2)	1 (0–2)	1 (0–1)	1 (0–2)
Number of PSA blood tests in lifetime ^{3**}	0 (0–3)	0 (0–2)	0 (0–1)	0 (0–1)
Social support: Someone to take you to doctor if you needed it (range 1-5) ⁴	5 (4–5)	5 (4–5)	5 (4–5)	5 (4–5)
Total recreational physical activity (hours/week) **	2.7 (.6–5.7)	2.8 (.8–5.7)	5.7 (2.2–7.2)	4.2 (1.0–6.3)
Body mass index	25.6 (23.0–29.7)	27.4 (24.7–30.4)	25.4 (23.4–28.7)	26.0 (23.5–29.4)
Total dietary caloric intake (kcal/day)	1826 (1273–2239)	1824 (1214–2205)	1732 (1232–2050)	1804 (1246–2158)

Quartile ¹ to Quartile 3 (Q1 - Q3). Significant at * P<.05, ** P<.01.² Comorbidity index: range (0-7).³ The lifetime number of PSA tests is for males only. ⁴ Scored as 1: none of the time; 2: a little of the time; 3: some of the time; 4: most of the time; 5: all of the time.

% and 21.3% were diagnosed at stage I/II and III, respectively. The distribution of lung cancer stage at diagnosis is comparable to that of the Alberta population in 2016/17¹². The majority of participants diagnosed with lung cancer were current smokers (57.0%), ≥60 years of age (54.7%), and married (74.7%). In addition, over half were of lower socioeconomic position, whereby 50.2% were unemployed and 55.7% had a household income of <\$50,000/year. Late-stage lung cancer diagnoses were highest amongst current smokers (27.6%), females (28.5%), those with a college degree or higher (26.7%), and those who were married (37.1%). No significant differences in lung cancer stage at diagnosis between males and females were observed.

Factors associated with lung cancer stage at diagnosis from the unadjusted and adjusted multivariable PPO models are summarized in Table 3. History of sunburn in the past year was shown to be protective against late-stage lung cancer diagnosis when comparing stages IV vs III, II, and I (odds ratio (OR) .40, 95% confidence interval (CI) .21-.76, P=.005). Similarly, in males only, a higher number of lifetime prostate specific antigen (PSA) tests was associated with reduced odds of late-stage lung cancer diagnosis (OR .66, 95% CI 0.51-.86, P=.02). Conversely, total recreational activity (hours/week) was associated with increased odds of late-stage lung cancer diagnosis (OR 1.08, 95% CI 1.02-1.15, P=.01).

Although the role of social support in lung cancer stage at diagnosis was not significant, the protective effects against late-

stage diagnosis approached statistical significance (OR .77, 95% CI 0.58-1.02, P=.07). In addition, a family history of lung cancer and history of smoking (past or current) were not significantly associated with lung cancer stage at diagnosis, but estimates trended towards increasing the odds of late-stage diagnosis.

Discussion

Lung cancer stage at diagnosis remains a crucial determinant of prognosis.¹¹ Despite therapeutic advances³⁵ and universal healthcare coverage in Canada, the 3-year relative survival for those with late-stage diagnoses is only 5%.¹ Lung cancer screening is a promising approach to detecting lung cancer in its earlier stages,¹⁰ and while lung cancer screening programs have yet to be available in Canada, studies are underway in Alberta and British Columbia.^{36,37} Until organized lung cancer screening programs are implemented, identifying factors associated with lung cancer stage at diagnosis offers the best opportunity for early detection. Accordingly, the current study comprehensively examined a variety of socio-demographic characteristics, health-related factors, and behavioral factors associated with lung cancer stage at diagnosis using data from a prospective cohort of adults living in Alberta, Canada.

This study revealed that higher total recreational activity (e.g., biking and walking) was associated with increased odds of late-stage lung cancer diagnosis. Although studies have

Table 3. Predictors of lung cancer diagnosis at different cancer stages.

Cancer stage	Unadjusted		Multivariable adjusted	
	ORs (95% CI)	P Value	ORs (95% CI)	P Value
Lung cancer family history				
Yes vs No	1.81 (.89–3.69)	.10	1.70 (.80–3.61)	.17
Type of smoker				
Never smoker	1.0		1.0	
Past or current	1.18 (.51–2.73)	.70	1.16 (.46–2.90)	.75
Second hand smoke				
Yes vs No	.93 (.55–1.58)	.79	1.01 (.57–1.79)	.98
Any sunburn in the past year				
Yes vs No				
IV vs III&II&I	.36 (.20–.67)	.001	.40 (.21–.76)	.005
IV&III vs II&I	.82 (.44–1.52)	.52	.90 (.48–1.70)	.76
Social support:				
Someone to take				
you to doctor if you				
needed it, range: 1-5	.79 (.60–1.04)	.09	.77 (.58–1.02)	.07
Total recreational				
physical activity	1.08 (1.02–1.14)	.01	1.08 (1.02–1.15)	.01
(hours/week)				

¹Among males only. PSA Prostate Specific Antigen. Note that: whenever there is entry for cancer stage column, it means the partial proportion odds, otherwise it is the proportion odds where coefficients are same for stages IV vs III&II&I and IV&III vs II&I.

demonstrated protective effects of physical activity against lung cancer development,³⁸ evidence pertaining to the role of recreational activities and lung cancer stage at diagnosis is lacking. In addition, evidence has shown associations between do-it-yourself activities, such as painting and varnishing, and lung cancer development due to prolonged ingestion of carcinogens³⁹; however, the current study did not reveal associations between do-it-yourself activities and stage at diagnosis. Lung cancer symptoms (e.g., cough and fatigue) are often normalized as regular physiological processes of aging and other lifestyle factors.^{40,41} In particular, given the well-established associations between recreational activity and health,⁴² individuals who are more physically active may be less likely to suspect symptoms of lung cancer. Indeed, studies have suggested that individuals who are physically active may be more likely to attribute lung cancer symptoms such as dyspnea, fatigue, and weight loss to factors such as changes in the type, frequency, or intensity of activities.⁴⁰ As a result, these individuals may subsequently delay healthcare visits until symptoms become more severe.⁴¹ Given that delay in lung cancer diagnosis is recognized as a key determinant of late-stage diagnosis, these findings highlight the importance of public health initiatives towards improving early recognition of lung cancer symptoms.

Although exposure to ionizing radiation (e.g., radon) is a well-known risk factor for lung cancer development, non-ionizing radiation (e.g., ultraviolet-B (UVB)) may exert protective effects against lung cancer development and progression. Participants who reported experiencing sunburn in

the past year were found to have a 60% reduction in the odds of late-stage lung cancer. Although this association may have occurred simply by chance, a history of sunburn may also serve as a surrogate for solar UVB irradiation exposure. Studies have demonstrated protective effects of UVB and vitamin D₃ (through in vivo synthesis or dietary and supplementary intake) against lung cancer incidence and mortality.⁴³ Some studies have also suggested that UVB exposure may reduce cancer risk independent of vitamin D₃ production⁴⁴; however, the evidence remains limited in this regard.

The observed association between PSA testing and early-stage lung cancer diagnosis among males likely reflects the clustering of protective health behaviors,⁴⁵ such as regularly attending healthcare visits and participating in cancer screening. Previous studies have shown that positive attitudes towards cancer screening and past screening behaviors predict participation in other screening programs.^{45,46} Indeed, a previous study among ATP participants showed a significant association between PSA testing and perceived cancer susceptibility.⁴⁶ Contrary to our findings, Slatore et al¹⁴ showed that screening for colorectal cancer via sigmoidoscopy or colonoscopy was associated with reduced risk of late-stage lung cancer, while no associations were observed for PSA testing or mammography. However, in line with the current study, the authors also reported a significant trend in the number of overall screening activities and increased likelihood of early stage lung cancer diagnosis.¹⁴ Among ATP participants, PSA testing may have been part of a routine physical exam, providing opportunity for patients to discuss

suspected lung cancer symptoms, and thus prompting lung cancer screening.

The role of social support in influencing help-seeking behaviors is well-documented in the literature. Close social networks, spouses in particular, may validate the presence and severity of lung cancer symptoms and encourage medical assessments.⁴⁷ Indeed, studies have shown that being married was associated with a reduced the risk of emergency lung cancer presentation⁴⁸ and lower odds of advanced stage at diagnosis.⁴⁹ Although the protective effects of social support did not reach statistical significance, it is possible this study was underpowered to detect a significant association.

Strengths

This study examined sociodemographic and health-related factors associated with lung cancer stage at diagnosis using data from a large prospective cohort study, which allowed examination of numerous possible factors associated with lung cancer stage at diagnosis. Data were collected prior to cancer diagnosis using validated survey instruments.^{28,31} Examining important predictors of stage at diagnosis before cancer development limits the risk of recall bias and allows for clearer temporal ordering.⁵⁰ Although the majority of study participants were of European descent, thus limiting generalizability of results, the study sample was representative of the Alberta population at the time baseline data were collected.⁵¹ Finally, cancer diagnoses were ascertained using objective data obtained from the ACR. All cancer diagnoses and deaths in Alberta are legally mandated to be reported to the ACR,³⁴ thus ensuring data accuracy and completeness.⁵²

Limitations

Despite this study's many strengths, some limitations should be considered. With only 211 lung cancer diagnoses over the study period, the sample size was relatively small and, therefore, the study may have been underpowered to identify other factors associated with lung cancer stage at diagnosis. Predictor variables were self-reported, thus increasing the risk of measurement bias and social desirability bias.⁵³ Self-reported measures of physical activity and unhealthy behaviors such as smoking⁵⁴ are particularly susceptible to

social desirability bias. Incorporating objective measures, such as those for physical activity, may help reduce bias associated with self-reports.⁵⁵ At the time of this study, there were few study participants older than 75 years, the age in which incidence rates peak in Canada,¹ which may impact our findings. In addition, the available data precluded examination of other important predictors of lung cancer development and stage at diagnosis such as environmental (e.g., radon) or occupational (e.g., asbestos) exposures. For instance, one study showed that while overall residential radon exposure was not associated with lung cancer stage diagnosis, a larger proportion of those exposed to higher radon concentrations (i.e., >1000 Bq/m³) were diagnosed with later-stage disease.²¹ Moreover, we cannot rule out the possibility of residual and unmeasured confounding by factors such as tumor histologic type. Finally, while the study sample may be representative of the Alberta population, the underrepresentation of other ethnicities may limit the generalizability of results to other jurisdictions across Canada.

Conclusion

This study identified several important factors associated with lung cancer stage at diagnosis, including history of sunburn, recreational activity levels, and PSA testing (among males). Study findings can help inform targeted cancer prevention initiatives towards improving early detection of the disease beyond smoking history. Notably, cancer screening programs, such as PSA testing in males, may serve as important opportunities to increase awareness of lung cancer symptoms and screening. In addition, implementation of lung cancer screening programs is anticipated in Alberta and elsewhere, thus providing greater opportunity for early detection of the disease. Our novel finding linking sunburn and stage at diagnosis may suggest a protective role of UVB exposure and warrants further examination. Further investigation into the mechanisms underlying the association between recreational activity and advanced stage lung cancer, such as exposure to carcinogens during recreational activity or lung cancer symptom perceptions in highly active individuals, is warranted. Finally, given that radon exposure is a top risk factor for lung cancer development, further studies should aim to examine the effects of radon exposure on stage at diagnosis.

Appendix

Abbreviations

ACR	Alberta Cancer Registry
ATP	Alberta Tomorrow Project
CDHQ-I	Canadian Diet History Questionnaire - I
CI	Confidence Interval
HLQ	Health and Lifestyle Questionnaire
IQR	Inter quartile range
OR	Odds ratio

PO	Proportional Odds
PPO	Partial Proportional Odds
PSA	Prostate specific antigen
PYTPAQ	Past-Year Total Physical Activity Questionnaire
UVB	ultraviolet-B.

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Cancer and Health Canada, and substantial in-kind funding from Alberta Health Services. Cancer registry data were obtained through linkage with Surveillance and Reporting, Cancer Research and Analytics, Cancer Care Alberta. The views expressed herein represent the views of the author(s) and not of Alberta's Tomorrow Project or any of its funders. This study is based in part on data provided by Alberta Health. The interpretation and conclusions contained herein are those of the researchers and do not necessarily represent the views of the Government of Alberta. Neither the Government of Alberta nor Alberta Health express any opinion in relation to this study.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Data Availability Statement

Access to individual-level data is available in accordance with the Health Information Act of Alberta and Alberta's Tomorrow Project (ATP) Access Guidelines at <https://myatpresearch.ca>.

Institutional Review Board Statement

Ethics approval for this study (HREBA.CC - 16-0814) and ATP (HREBA.CC - 17-0461) was granted from the Health Research Ethics Board of Alberta - Cancer Committee.

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