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The effects of shift work and sleep duration on cancer incidence in Alberta`s Tomorrow Project cohort

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ABSTRACT

Introduction: We investigated the main effects of shift work and sleep duration on cancer incidence, and effect modification of the shift work-cancer incidence association by sleep duration.
Methods: Shift work and sleep duration were assessed among 21,804 participants from Alberta`s Tomorrow Project. Incident cases of breast, prostate, colorectal and lung cancers were identified through registry linkage.
Results: Having worked ≥6 years of rotating shift work (HR = 1.59, 95 % CI = 1.07, 2.37; P = 0.02) and having ever worked night shifts were associated with an increased risk of lung cancer (HR = 1.71, 95 % CI = 1.18, 2.47; P = 0.01), whereas having ever worked night shifts was associated with a reduced risk of prostate cancer in the latency-adjusted model only (HR = 0.70, 95 % CI = 0.51, 0.98; P = 0.04). No associations were found between shift work or sleep duration on the risks of breast and colorectal cancers. Some evidence of effect modification by sleep duration for the rotating shift work-lung cancer incidence association was noted (P = 0.06), with stratified analyses revealing borderline increased risk of lung cancer in participants with ≥6 years of rotating shift work and < 7 h of sleep/day (HR = 2.27, 95 % CI = 0.95, 5.41; P = 0.07), and an increased risk of lung cancer in participants with 0.1 − 5.9 years of rotating shift work and > 9 h of sleep/day (HR = 2.99, 95 % CI = 1.12, 7.97; P = 0.03). No additional evidence of effect modification by sleep duration for shift work and cancer incidence was noted.
Discussion: A consistent association between shift work employment and lung cancer risk was noted in this Canadian sample. Furthermore, some evidence of effect modification of the rotating shift work-lung cancer risk association by sleep duration was noted.

1. Introduction

The length of shift work employment has been most consistently associated with prostate [1,2] and breast [3,4] cancers, whereas less consensus has been noted for colorectal [5,6] and lung [5,7] cancers. The relation between shift work length and cancer risk may also be modified by sleep duration. Two studies conducted in China have assessed the effects of night shift work and sleep duration on combined cancer risk [8] and breast cancer risk in females [9]. The first study noted an increased risk of combined cancers in males with at least two of the following risk factors: working night shifts ≥20 years, no daytime napping and a sleep duration ≥10 h/day [8]. The second study reported an increased risk of breast cancer in night shift workers who also reported shorter (< 6 h/day) and longer (≥9 h/day) sleep durations. Given the variations in sleep habits and site-specific cancer incidence across geographical locations, additional studies in North American populations are needed to complement these initial findings from stratified analyses.

This study aimed to investigate the associations between shift work in the form of years of rotating shift work or having ever (versus never) worked night shifts, as well as sleep duration, with breast, prostate, colorectal and lung cancer incidence within Alberta`s Tomorrow Project (ATP) cohort. This study also assessed whether sleep duration is an effect modifier of the association between shift work and cancer incidence.

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Table 1
Descriptive statistics for Alberta's Tomorrow Project study participants who have data on rotating and night shift work employment and consented to data linkage, n = 21,804, 2001-2018.

	Mean (Standard deviation) or N (Percent)											
	Breast Cancer Cases[§] n = 366	Non-Breast Cancer Cases[§] n = 13,091	*P*-value*	Prostate Cancer Cases[§] n = 321	Non-Prostate Cancer Cases[§] n = 8,026	*P*-value*	Colorectal Cancer Cases n = 152	Non-Colorectal Cancer Cases n = 21,652	*P*-value*	Lung Cancer Cases n = 162	Non-Lung Cancer Cases n = 21,642	*P*-value*
Age (years)	56.7 (9.1)	53.6 (9.2)	< 0.0001	59.3 (7.3)	53.6 (9.0)	< 0.0001	59.6 (8.5)	53.7 (9.1)	< 0.0001	62.5 (6.7)	53.7 (9.1)	< 0.0001
Sex												
Male	NA	NA	NA	NA	NA	NA	72 (47.4)	8,275 (38.2)	0.07	55 (34.0)	8,292 (38.3)	0.37
Female	NA	NA	NA	NA	NA	NA	80 (52.6)	13,377 (61.8)	0.16	107 (66.1)	13,350 (61.7)	0.48
Body mass index												
< 25 kg/m^2	142 (38.8)	5,231 (40.0)	0.95	66 (20.6)	1,793 (22.3)	0.82	29 (19.1)	7,203 (33.3)	0.01	59 (36.4)	7,173 (33.1)	0.78
≥25 kg/m^2	221 (60.4)	7,660 (58.5)	0.90	253 (78.8)	6,173 (76.9)	0.95	121 (79.6)	14,186 (65.5)	0.10	101 (62.4)	14,206 (65.6)	0.86
Missing	3 (0.8)	200 (1.5)	0.55	2 (0.6)	60 (0.8)	0.95	2 (1.3)	263 (1.2)	1.00	2 (1.2)	263 (1.2)	1.00
Ethnicity												
Caucasian	334 (91.3)	12,049 (92.0)	1.00	300 (93.5)	7,363 (91.7)	0.95	141 (92.8)	19,905 (91.9)	1.00	150 (92.6%)	19,896 (91.9)	1.00
Other	30 (8.2)	995 (7.6)	0.90	19 (5.9)	627 (7.8)	0.50	11 (7.2)	1,660 (7.7)	1.00	12 (7.4)	1,659 (7.7)	1.00
Missing	2 (0.6)	47 (0.4)	0.86	2 (0.6)	36 (0.5)	0.90	0 (0)	87 (0.4)	0.74	0 (0)	87 (0.4)	0.70
Marital Status												
Married or living with someone	271 (74.0)	9,981 (76.2)	0.98	275 (85.7)	6,706 (83.6)	0.98	118 (77.6)	17,115 (79.1)	1.00	117 (72.2)	17,116 (79.1)	0.80
Divorced, separated or widowed	67 (18.3)	2,484 (19.0)	0.99	31 (9.7)	836 (10.4)	0.98	27 (17.8)	3,391 (15.7)	0.94	44 (27.2)	3,374 (15.6)	0.003
Single, never married	28 (7.7)	617 (4.7)	0.09	15 (4.7)	479 (6.0)	0.83	7 (4.6)	1,132 (5.2)	0.99	1 (0.6)	1,138 (5.3)	0.09
Missing	0 (0)	9 (0.1)	0.96	0 (0)	5 (0.1)	0.98	0 (0)	14 (0.1)	0.99	0 (0)	14 (0.1)	0.99
Education												
High school or less	119 (32.5)	3,776 (28.8)	0.43	87 (27.1)	1,993 (24.8)	0.74	52 (34.2)	5,923 (27.4)	0.27	71 (43.8)	5,904 (27.3)	0.0003
Some post-high school education or a post-high school degree or certificate	247 (67.5)	9,307 (71.1)	0.70	233 (72.6)	6,027 (75.1)	0.86	100 (65.8)	15,714 (72.6)	0.61	91 (56.2)	15,723 (72.7)	0.05
Missing	0 (0)	8 (0.1)	0.90	1 (0.3)	6 (0.1)	0.35	0 (0)	15 (0.1)	0.95	0 (0)	15 (0.1)	0.95
Total household income												
$0 - $49,999	125 (34.2)	4,044 (30.9)	0.75	84 (26.2)	1,640 (20.4)	0.18	65 (42.8)	5,828 (26.9)	0.003	83 (51.2)	5,810 (26.9)	< 0.0001
$50,000 - $99,999	132 (36.1)	4,573 (34.9)	0.99	134 (41.7)	3,171 (39.5)	0.94	54 (35.5)	7,956 (36.7)	0.99	53 (32.7)	7,957 (36.8)	0.87
≥$100,000	78 (21.3)	3,662 (28.0)	0.13	84 (26.2)	2,931 (36.5)	0.03	27 (17.8)	6,728 (31.1)	0.04	18 (11.1)	6,737 (31.1)	0.0001
Missing	31 (8.5)	812 (6.2)	0.41	19 (5.9)	284 (3.5)	0.19	6 (4.0)	1,140 (5.3)	0.92	8 (4.9)	1,138 (5.3)	1.00
Employment status												
Yes	211 (57.7)	8,442 (64.5)	0.27	223 (69.5)	6,425 (80.1)	0.12	80 (52.6)	15,221 (70.3)	0.04	66 (40.7)	15,235 (70.4)	0.00004
No	155 (42.4)	4,640 (35.4)	0.09	98 (30.5)	1,594 (19.9)	0.0002	72 (47.4)	6,415 (29.6)	0.0003	96 (59.3)	6,391 (29.5)	< 0.0001
Missing	0 (0)	9 (0.1)	0.86	0 (0)	7 (0.1)	0.86	0 (0)	16 (0.1)	0.95	0 (0)	16 (0.1)	0.95
Smoking status												
Never	235 (64.2)	8,162 (62.4)	0.99	219 (68.2)	4,831 (60.2)	0.51	91 (59.9)	13,356 (61.7)	0.99	39 (24.1)	13,408 (62.0)	< 0.0001
Former	76 (20.8)	3,034 (23.2)	0.92	69 (21.5)	1,915 (23.9)	0.95	34 (22.4)	5,060 (23.4)	0.99	39 (24.1)	5,055 (23.4)	1.00
Occasional	7 (1.9)	317 (2.4)	0.98	8 (2.5)	249 (3.1)	0.98	3 (2.0)	578 (2.7)	0.99	6 (3.7)	575 (2.7)	0.95
Daily	47 (12.8)	1,559 (11.9)	0.99	25 (7.8)	1,022 (12.7)	0.20	24 (15.8)	2,629 (12.1)	0.79	78 (48.2)	2,575 (11.9)	< 0.0001
Missing	1 (0.3)	19 (0.2)	0.98	0 (0)	9 (0.1)	0.98	0 (0)	29 (0.1)	0.99	0 (0)	29 (0.1)	0.99
Presence of at least 1 medical condition or co-morbidity												
No	80 (21.9)	3,647 (27.9)	0.10	92 (28.7)	2,890 (36.0)	0.10	34 (22.4)	6,675 (30.8)	0.17	20 (12.4)	6,689 (30.9)	0.0001
Yes	286 (78.1)	9,426 (72.0)	0.39	228 (71.0)	5,118 (63.8)	0.29	118 (77.6)	14,940 (69.0)	0.45	141 (87.0)	14,917 (68.9)	0.02
Missing	0 (0)	18 (0.1)	0.78	1 (0.3)	18 (0.2)	0.95	0 (0)	37 (0.2)	0.86	1 (0.6)	36 (0.2)	0.39
Family history of cancer												
No	150 (41.0)	5,864 (44.8)	0.27	124 (38.6)	3,956 (49.3)	0.01	52 (34.2)	10,042 (46.4)	0.03	62 (38.3)	10,032 (46.4)	0.13
Yes	216 (59.0)	7,227 (55.2)	0.34	197 (61.4)	4,070 (50.7)	0.01	100 (65.8)	11,610 (53.6)	0.04	100 (61.7)	11,610 (53.7)	0.16
Follow-up time (years)	5.5 (3.5)	11.0 (2.5)	< 0.0001	5.8 (3.5)	11.0 (2.6)	< 0.0001	5.8 (3.2)	10.9 (2.7)	< 0.0001	6.0 (3.6)	10.9 (2.7)	< 0.0001
Rotating shift work employment category												
Having never worked rotating shifts	258 (70.3)	9,087 (69.4)	1.00	165 (51.4)	3,691 (46.0)	0.37	84 (55.3)	13,117 (60.6)	0.70	91 (56.2)	13,110 (60.6)	0.78
0.1-5.9 years	64 (17.4)	2,493 (19.0)	0.78	89 (27.7)	2,528 (31.5)	0.50	40 (26.3)	5,134 (23.7)	0.82	35 (21.6)	5,139 (23.7)	0.86

(*continued on next page*)

Table 1 (*continued*)

	Mean (Standard deviation) or N (Percent)											
	Breast Cancer Cases§ n = 366	Non-Breast Cancer Cases§ n = 13,091	*P*-value*	Prostate Cancer Cases§ n = 321	Non-Prostate Cancer Cases§ n = 8,026	*P*-value*	Colorectal Cancer Cases n = 152	Non-Colorectal Cancer Cases n = 21,652	*P*-value*	Lung Cancer Cases n = 162	Non-Lung Cancer Cases n = 21,642	*P*-value*
≥6 years	45 (12.3)	1,512 (11.6)	0.70	67 (20.9)	1,812 (22.6)	0.82	28 (18.4)	3,408 (15.7)	0.70	36 (22.2)	3,400 (15.7)	0.12
Night shift work employment category												
Having never worked night shifts	324 (88.5)	11,449 (87.4)	1.00	267 (83.2)	6,166 (76.8)	0.21	125 (82.2)	18,081 (83.5)	1.00	124 (76.5)	18,082 (83.5)	0.34
Having ever worked night shifts	42 (11.5)	1,645 (12.6)	0.58	54 (16.8)	1,866 (23.2)	0.02	27 (17.8)	3,580 (16.5)	0.75	38 (23.5)	3,569 (16.5)	0.03
Sleep duration category												
< 7 h/day	64 (17.5)	1,921 (14.7)	0.37	63 (19.6)	1,600 (19.9)	1.00	27 (17.8)	3,621 (16.7)	0.95	30 (18.3)	3,618 (16.7)	0.90
7 − 9 h/day	267 (73.2)	9,864 (75.3)	0.90	236 (73.3)	5,981 (74.2)	1.00	115 (75.6)	16,233 (74.8)	1.00	113 (68.9)	16,235 (74.9)	0.67
> 9 h/day	34 (9.3)	1,313 (10.0)	0.90	23 (7.1)	473 (5.9)	0.67	10 (6.6)	1,833 (8.5)	0.74	21 (12.8)	1,822 (8.4)	0.16

NA, Not applicable.

* *P*-values for the differences in descriptive data between all cancer cases and all non-cancer cases.

§ Analyses for breast and prostate cancer incidence are limited to female and male participants, respectively. One male breast cancer case was excluded from these analyses because there was not sufficient statistical power to run these analyses by sex, or adjust for sex as a covariate.

2. Methods

The methods for ATP Phase I have been previously described [10]. Ethical approval was obtained from the Health Research Ethics Board of Alberta–Cancer Committee (HREBA.CC-16-0495) and written informed consent was obtained from participants. Surveys 2004 and 2008 from Phase I of ATP collected information on rotating and night shift work employment and sleep duration. Participants were asked: “For how many years did you work a schedule that included day or evening work that rotated with nights in the same month?” and “For how many years did you work straight night shifts?” Participants who completed Survey 2004 were also asked: “On average, how many hours did you sleep each night during the past 4 weeks?”, whereas participants who completed Survey 2008 were asked: “On average over the past 7 days, at what time did you normally go to sleep?” and “On average over the past 7 days, at what time did you normally wake up?” This information was used to estimate sleep duration.

Data on primary incident cancers were obtained through linkage with the Alberta Cancer Registry (ACR) in August 2018. Incident cases of breast, prostate, colorectal and lung cancers were included in these analyses based on scientific plausibility [1–5,11,12] and the number of cancer cases exceeding 100 cases/site. Covariates of interest included: age (years), sex (male/female), body mass index (< 25 kg/m^2/≥ 25 kg/m^2), highest level of education (high school or less/some post-high school education or a post-high school certificate or degree), total household income (\$0 to \$49,999/\$50,000 to \$99,999/≥\$100,000), employment status (yes/no), ethnicity (Caucasian/Other), marital status (married or living with someone/divorced, separated, or widowed/single, never married), smoking status (daily/occasional/former/never), presence of at least one medical condition/co-morbidity (e.g. diabetes, depression) (yes/no), and having a family history of cancer (yes/no). A proxy for menopausal status (< 55 years of age/≥55 years of age) was included in the breast cancer incidence analysis. Follow-up time was determined as the elapsed time between the date of questionnaire completion and the date of cancer diagnosis or linkage with the ACR in August 2018, whichever came first.

Baseline characteristics were examined as means ± standard deviations for continuous variables or as counts and percentages for categorical variables. Differences in covariate characteristics between cancer and non-cancer cases were assessed using ANOVA for continuous variables and chi-square tests for categorical variables. Cox proportional hazard regression models estimated multivariable-adjusted hazards ratios (HR) and 95 % confidence intervals (95 % CIs) between years of rotating shift work employment (never having worked shifts as the referent group versus 0.1 − 5.9 years of shift work and ≥6 years of shift work) and having ever (versus never as the referent group) worked night shifts with breast, prostate, colorectal and lung cancer incidence. We dichotomized night shift work as ever/never because < 10 cases per cancer site investigated reported ≥6 years of shift work experience. Cox proportional hazard regression models were also used to estimate multivariable-adjusted HRs and 95 % Cis between sleep duration categories (7 − 9 h of sleep/day as the referent group versus < 7 h of sleep/day and > 9 h of sleep/day) with cancer incidence. We repeated all risk analyses after excluding cancer cases that were diagnosed within two years of questionnaire completion to address the potential issue of a short latency period between exposure measurement and cancer incidence. For our second aim, we examined whether sleep duration is an effect modifier of the association between shift work and cancer incidence by adding a sleep duration-rotating/continuous night shift work interaction term to the multivariable-adjusted models. Stratified analyses were conducted if the interaction term reached $P < 0.10$. All statistical analyses were performed using STATA v14 (College Station, Texas, USA). Statistical significance was set at $P < 0.05$, unless otherwise specified.

Table 2
Cox regression hazard ratios for rotating and night shift work employment, and sleep duration, with breast, prostate, colorectal and lung cancer incidence.

Years of rotating shift work employment	Cases	Multivariable-adjusted HR (95 % CI)[1]	*P* value	Cases	Latency multivariable-adjusted HR (95 % CI)[2]	*P* value
Breast cancer						
Having never worked rotating shifts	258	1.00 (Referent group)		213	1.00 (Referent group)	
0.1 − 5.9 years of rotating shift work	64	0.92 (0.70, 1.21)	0.57	51	0.89 (0.65, 1.21)	0.45
≥6 years of rotating shift work	45	1.02 (0.74, 1.41)	0.89	34	0.94 (0.65, 1.36)	0.75
Prostate cancer						
Having never worked rotating shifts	165	1.00 (Referent group)		140	1.00 (Referent group)	
0.1 − 5.9 years of rotating shift work	89	0.86 (0.66, 1.12)	0.26	74	0.84 (0.63, 1.11)	0.22
≥6 years of rotating shift work	67	0.88 (0.66, 1.17)	0.36	55	0.84 (0.61, 1.15)	0.28
Colorectal cancer						
Having never worked rotating shifts	84	1.00 (Referent group)		73	1.00 (Referent group)	
0.1 − 5.9 years of rotating shift work	40	1.21 (0.82, 1.78)	0.33	33	1.15 (0.75, 1.74)	0.53
≥6 years of rotating shift work	28	1.15 (0.74, 1.79)	0.53	23	1.10 (0.68, 1.77)	0.71
Lung cancer						
Having never worked rotating shifts	91	(Referent group)		79	1.00 (Referent group)	
0.1 − 5.9 years of rotating shift work	35	1.17 (0.79, 1.74)	0.44	30	1.16 (0.75, 1.78)	0.50
≥6 years of rotating shift work	36	1.59 (1.07, 2.37)	0.02	29	1.48 (0.96, 2.30)	0.08

Ever versus never night shift work employment	Cases	Multivariable-adjusted HR (95 % CI)[1]	*P* value	Cases	Latency multivariable-adjusted HR (95 % CI)[2]	*P* value
Breast cancer						
Having never worked night shifts	324	1.00 (Referent group)	a	263	1.00 (Referent group)	
Having ever worked night shifts	42	0.88 (0.64, 1.23)	0.44	34	0.87 (0.61, 1.25)	0.47
Prostate cancer						
Having never worked night shifts	267	1.00 (Referent group)		226	1.00 (Referent group)	
Having ever worked night shifts	54	0.76 (0.57, 1.02)	0.07	43	0.70 (0.51, 0.98)	0.04
Colorectal cancer						
Having never worked night shifts	125	1.00 (Referent group)		106	1.00 (Referent group)	
Having ever worked night shifts	27	1.07 (0.70, 1.63)	0.77	23	1.08 (0.68, 1.71)	0.74
Lung cancer						
Having never worked night shifts	124	1.00 (Referent group)		105	1.00 (Referent group)	
Having ever worked night shifts	38	1.71 (1.18, 2.47)	0.01	33	1.76 (1.18, 2.62)	0.01

Sleep duration	Cases	Multivariable-adjusted HR (95 % CI)[1]	*P* value	Cases	Latency multivariable-adjusted HR (95 % CI)[2]	*P* value
Breast cancer						
7 − 9 h/day	267	1.00 (Referent group)	a	216	1.00 (Referent group)	
< 7 h/day	64	1.06 (0.80, 1.39)	0.69	55	1.10 (0.81, 1.48)	0.55
> 9 h/day	34	1.01 (0.70, 1.45)	0.96	25	0.96 (0.63, 1.47)	0.86
Prostate cancer						
7 − 9 h/day	236	1.00 (Referent group)		199	1.00 (Referent group)	
< 7 h/day	63	1.04 (0.78, 1.37)	0.81	54	1.04 (0.76, 1.40)	0.82
> 9 h/day	23	1.30 (0.84, 2.02)	0.23	18	1.23 (0.75, 2.01)	0.41
Colorectal cancer						
7 − 9 h/day	115	1.00 (Referent group)		98	1.00 (Referent group)	
< 7 h/day	27	0.97 (0.63, 1.48)	0.88	23	0.97 (0.61, 1.53)	0.88
> 9 h/day	10	0.76 (0.39, 1.46)	0.41	8	0.72 (0.34, 1.49)	0.37
Lung cancer						
7 − 9 h/day	113	1.00 (Referent group)		97	1.00 (Referent group)	
< 7 h/day	30	1.14 (0.76, 1.71)	0.53	25	1.08 (0.69, 1.69)	0.73
> 9 h/day	21	1.40 (0.87, 2.26)	0.16	18	1.42 (0.85, 2.38)	0.19

[1] Adjusted for: age, sex (colorectal and lung cancers), body mass index (BMI), highest level of education, total household income, employment status, ethnicity, marital status, smoking status, presence of at least one medical condition/co-morbidity, family history of cancer, menopausal status (breast cancer only).
[2] Cancers occurring < 2 years after questionnaire completion were removed.

3. Results

Descriptive results are presented in Table 1. Cancer cases were older, more likely to be unemployed, have a lower total household income and a family history of cancer. A greater proportion of lung cancer cases and non-prostate cancer cases reported longer night shift work employment.

Results on the associations between shift work and sleep duration with cancer incidence are presented in Table 2. Having worked ≥6 years of rotating shift work was associated with an increased risk of lung cancer in the multivariable-adjusted model. Having ever worked night shifts was also associated with an increased risk of lung cancer in the multivariable- and latency-multivariable-adjusted models, whereas having ever worked night shifts was associated with a reduced risk of prostate cancer in the latency-adjusted model only. No associations were found between shift work or sleep duration on the risks of breast and colorectal cancer. The rotating shift work-sleep duration interaction term was borderline significant ($P = 0.06$) when added to the multivariable-adjusted models. Stratified analyses revealed borderline increased risk of lung cancer in participants with ≥6 years of rotating shift work and < 7 h of sleep/day, and an increased risk of lung cancer in participants with 0.1 − 5.9 years of rotating shift work and > 9 h of sleep/day (Table 3). There was no evidence of an increased risk of lung cancer according to rotating shift work categories in participants with 7 − 9 h of sleep/night (Table 3). There was also no additional evidence of effect modification by sleep duration for rotating and night shift work with breast, prostate and colorectal cancer incidence, nor night shift work with lung cancer incidence (all *P*-values > 0.10). Therefore, no additional stratified analyses were conducted.

Table 3
Stratified results by sleep duration for the association between rotating shift work employment with lung cancer incidence.

Stratified analyses - 7 − 9 h of sleep/day	Cases	Multivariable-adjusted HR (95 % CI)	*P* value
Having never worked rotating shifts	69	1.00 (Referent group)	
0.1 − 5.9 years of rotating shift work	20	0.91 (0.55, 1.52)	0.73
≥6 years of rotating shift work	22	1.38 (0.84, 2.26)	0.20
Stratified analyses - < 7 h of sleep/day	Cases	Multivariable-adjusted HR (95 % CI)	*P* value
Having never worked rotating shifts	20	1.00 (Referent group)	
0.1 − 5.9 years of rotating shift work	7	1.39 (0.54, 3.58)	0.49
≥6 years of rotating shift work	8	2.27 (0.95, 5.41)	0.07
Stratified analyses - > 9 h of sleep/day	Cases	Multivariable-adjusted HR (95 % CI)	*P* value
Having never worked rotating shifts	22	1.00 (Referent group)	
0.1 − 5.9 years of rotating shift work	10	2.99 (1.12, 7.97)	0.03
≥6 years of rotating shift work	4	1.79 (0.54, 5.96)	0.35

[1]Adjusted for: age, sex, body mass index (BMI), highest level of education, total household income, employment status, ethnicity, marital status, smoking status, presence of at least one medical condition/co-morbidity, family history of cancer.

4. Discussion

In this subsample of the ATP cohort, we found that having worked ≥6 years of rotating shift work and having ever worked night shifts were associated with an increased risk of lung cancer, whereas having ever worked night shifts was associated with a reduced risk of prostate cancer in the latency-adjusted model only. No evidence of a main effect of sleep duration on cancer incidence was noted. There was some evidence of effect modification by sleep duration for the rotating shift work-lung cancer incidence association in this sample, with stratified results suggesting an increased risk of lung cancer in individuals with < 7 h and > 9 h of sleep/day, but no evidence of an increased risk of lung cancer with rotating shift work exposure in individuals with 7 − 9 h of sleep/day.

There is some strong and consistent evidence that longer exposures to shift work are associated with cancer incidence, especially with breast and prostate cancers. Three major studies found statistically significant associations between > 5 years of shift work exposure and breast cancer incidence [3,13,14]. An increased risk of prostate cancer was found in three of the most recent meta-analyses [1,2,15], with another recent study noting linear increases in prostate cancer risk with length of rotating or night shift work [16]. Finally, associations between shift work length with colorectal and lung cancers have been inconsistent to date. One study reported that increasing lifetime exposure to rotating shift work was associated with an increased risk of colorectal cancer [6], and another reported an increased risk of lung cancer with ≥15 years of shift work in smokers only [7]. Conversely, no evidence of a shift work-cancer risk association for both colorectal and lung cancer incidence were noted in a sample of Canadian men [5].

We observed some evidence of an increased risk of lung cancer with rotating shift work exposure in participants with both shorter and longer sleep durations, which was not present in participants reporting 7 − 9 h of sleep/day. These results partially corroborate findings from two studies conducted in China that have reported greater combined cancer risk in retired male night shift workers [8], and greater breast cancer risk in females having ever worked night shifts who also reported short (≤6 h/day) and long (≥9 h/day) sleep durations [9]. Biologic mechanisms hypothesized to predispose shift workers to shorter sleep durations and an increased risk of cancer include reductions in glucose tolerance, the upregulation of appetite, and increased inflammation [17]. Shift workers may also have poorer lifestyle choices due to work schedules, which may include tobacco use, greater unhealthy food consumption, and lower physical activity participation [17]. Conversely, long sleep duration can often be confounded by the presence of comorbidities and/or poorer sleep quality [18], which may also increase the risk of cancer.

Strengths of these analyses include the availability of information on a large number of covariates, the use of prospectively-collected data, and the identification of cancer cases through registry linkage. Limitations include the measurement of self-reported shift work and sleep duration with questionnaires which may lead to exposure misclassification, no information collected on job/industry work to complement shift work employment data, and the low proportion of participants who reported ≥6 years of night shift work employment and < 7 or > 9 h of sleep/night.

Our findings provide preliminary evidence of an association between shift work employment and increased lung cancer risk in a Canadian sample. Furthermore, some evidence of an increased risk of lung cancer with rotating shift work exposure in participants with both shorter and longer sleep durations was noted. Additional studies are needed to confirm our results. Studies using objective sleep measurements are also needed to complement these findings.

Author contribution statement

J.M., C.M.F. and D.R.B. conceptualized the research questions. R.F.W. and J.M. completed data cleaning. J.M. completed the analysis. J.M., E.H. and R.F.W. drafted the manuscript. All authors critically revised the manuscript and approved the final version.

CRediT authorship contribution statement

Jessica McNeil: Conceptualization, Formal analysis, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Emily Heer:** Writing - original draft, Writing - review & editing. **Romy F. Willemsen:** Data curation, Writing - original draft. **Christine M. Friedenreich:** Conceptualization, Supervision, Writing - review & editing. **Darren R. Brenner:** Conceptualization, Supervision, Writing - review & editing.

Declaration of Competing Interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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