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Estimates of the current and future burden of cancer attributable to sedentary behavior in Canada

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ABSTRACT

Leisure-time sedentary behavior is an emerging modifiable risk factor for cancer. We estimated the proportion of cancers attributed to leisure-time sedentary behavior as a separate risk factor from physical activity in Canada for 2015. We projected numbers of future avoidable cancers by 2042 using various assumed levels of reduced leisure-time sedentary behavior in the population. We calculated population attributable risks (PAR) for associated cancers and all-cancers associated with leisure-time sedentary behavior. Our analysis used pooled data on leisure-time sedentary behavior from the Canadian Community Health Survey (CCHS), and incident cancer data from the Canadian Cancer Registry (CCR). Survey respondents were categorized into three levels of leisure-time sedentary behavior, "< 3 h/day", "≥3– < 6 h/day", and "≥6 h/day". Estimates for the future burden of leisure-time sedentary behavior were calculated using the potential impact fractions framework (PIF) and counterfactual scenarios, from 10% to 50% decreases in leisure-time sedentary behavior. The estimated prevalence of leisure-time sedentary behavior at the highest level (≥6 h/day) in Canada during the 2000s was 9.9% among both sexes combined across age-groups. The total attributable burden due to leisure-time sedentary behavior was estimated to be 10.3% for associated cancers and 6.5% for all-cancers in 2015. A 50% reduction in leisure-time sedentary behavior across the Canadian population could avoid 4054 cancers by 2042. We estimated that over 3000 cancer cases in Canada were attributable to leisure-time sedentary behavior in 2015, and that that 4054 incident cancer cases could be prevented by 2042 with meaningful reductions in leisure-time sedentary behavior.

1. Introduction

Physical inactivity has been widely recognized as a lifestyle risk factor for cancer incidence and mortality (Parkin, 2011b). The 2018 Third Expert Report produced by the World Cancer Research Fund (WCRF)/American Institute for Cancer Research (AICR) determined that there is *strong* evidence that physical activity decreases the risk of several cancers (World Cancer Research Fund International/American

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Institute for Cancer Research, 2018). Besides physical activity, another related but distinct cancer risk factor that has more recently been recognized is sedentary behavior (Lynch, 2010). Changes in the physical, social, and economic environments such as advancements in technology, increased use of vehicles, and transitions to a computerized workplace have predisposed populations to a sedentary lifestyle devoid of physical movement throughout daily activities (Owen et al., 2010). One study using the 2010 Canadian Community Health Survey (CCHS) found that, on average, adults were sedentary for 20–24 h a week during leisure time (Anderson et al., 2016). Sedentary behavior is described as any prolonged, non-sleep activity, absent of bodily movement with a low energy expenditure of 1.0 to 1.5 metabolic equivalents (METs) (Ainsworth et al., 2000). Examples of sedentary activities include sitting, television viewing, reading, non-active video gaming, computer use, non-active transportation or driving (Owen et al., 2010; Patterson et al., 2018). Sedentary behavior and physical activity are two different constructs, with each having distinct physiological health effects and outcomes including cancer (Lynch et al., 2010; Owen et al., 2010). Several systematic reviews provide consistent findings that sedentary behavior is associated with all-cause mortality and cardiovascular mortality (de Rezende et al., 2014; Grontved and Hu, 2011; Proper et al., 2011; Thorp et al., 2011). Additional systematic reviews have indicated an association between sedentary behavior and cancer-related mortality (Lynch, 2010; van Uffelen et al., 2010).

In the 2018 WCRF Report, the panel concluded that there is *limited – suggestive* evidence to suggest an increased risk for endometrium cancers in relation to leisure-time sedentary behavior (World Cancer Research Fund International/American Institute for Cancer Research, 2018). Additional information for other cancers was not included, because of insufficient evidence. However, research on this topic is rapidly accumulating which warrants consideration of this risk factor for cancer burden estimation.

In 2011, the Canadian Society for Exercise Physiology (CSEP) developed the first set of evidence-based leisure-time sedentary behavior guidelines for Canadian children and youth aged 0 to 17 years (Tremblay et al., 2012; Tremblay et al., 2011). However, leisure-time sedentary behavior guidelines exclusively for adults (aged 18 and up) do not currently exist or have often been included as a subtopic in physical activity guidelines. LeBlanc and colleagues (LeBlanc et al., 2015), found that knowledge and awareness of Canadian physical activity and leisure-time sedentary behavior guidelines was low among the general population, with 10% and < 5% of surveyed respondents being aware of physical activity and sedentary behavior guidelines, respectively. In addition, there is a lack of awareness that leisure-time sedentary behavior is a potential risk factor for chronic diseases including cancer (Martínez-Ramos et al., 2015).

The purpose of this study was to estimate the number of cancer cases attributable to leisure-time sedentary behavior for the Canadian population in 2015, and to project the future number of cancers that could be avoided by 2042 using evidence-based and other hypothetical reductions in leisure-time sedentary behavior. Population Attributable Risk (PAR) estimates have been assessed for a variety of cancer risk factors in several countries (Owen et al., 2011; Parkin, 2011a). However, PAR studies examining the impact of leisure-time sedentary behavior independent of physical inactivity are limited. Moreover, Canadian estimates of the current and future burden of cancers attributable to leisure-time sedentary behavior are non-existent. We conducted the Canadian Population Attributable Risk of Cancer Study (ComPARe) to generate risk estimates and project the impact of prevention initiatives on cancer incidence for a variety of risk factors including leisure-time sedentary behavior (Brenner et al., 2018).

2. Methods

This manuscript is part of a series of exposure-specific topics providing the proportion and number of incident cancer cases in Canada, both currently and in the future, that could be prevented by changing exposure to factors known to be associated with cancer risk. A detailed methodologic framework has been previously published (Brenner et al., 2018), but is included briefly in this issue.

2.1. Current population attributable burden

2.1.1. Latency period

Cancer attributable to leisure-time sedentary behavior is the result of past exposure. To account for the period of time between data collection on leisure-time sedentary behavior and cancer diagnosis, pooled data from the 2000/2001 and 2003 cycles of the Canadian Community Health Survey (CCHS) were used for estimates of leisure-time sedentary behavior, and cancer incidence data were obtained for 2015.

2.1.2. Risk estimates

The association between leisure-time sedentary behavior and cancer is an emerging field. The few meta-analyses (Cong et al., 2014; Schmid and Leitzmann, 2014; Shen et al., 2014) on the subject-reported relative risks of all sedentary time, including occupational and leisure-time behavior. We were only able to estimate the cancer burden in relation to leisure-time sedentary behavior because of the lack of exposure prevalence data on occupational sedentary behavior for the Canadian population. In addition, since the American Cancer Society's Cancer Prevention Study-II results on the association between leisure-time sitting and site-specific cancer incidence were published after these reviews (Patel et al., 2015), we conducted an updated meta-analysis combining all studies (Patel et al., 2015; Schmid and Leitzmann, 2014). In brief, we included all 43 articles used in the meta-analysis by Schmid and Leitzmann and excluded those which did not report a risk estimate on leisure-time sedentary behavior. To identify studies published after February 2014, we conducted a literature search in PubMed from 2014 to August 2016, using the following search terms: ((cancer OR neoplasm* (MeSH) OR carcinoma (MeSH) OR adenocarcinoma (MeSH) OR sarcoma (MeSH) OR tumor OR “cancer patient” OR “cancer patients” OR survivors (MeSH) OR survivor) AND (sedentary behavior OR “sitting time” OR “screen time” OR “occupational sitting time”)). This yielded 18 articles published before February 2014 and four articles published between February 2014 and August 2016 that reported cancer site-specific risk estimates and confidence intervals associated with leisure-time sedentary behaviors for eight cancers: endometrium, breast, renal, colorectal, lung, prostate, ovarian, and non-Hodgkin's lymphoma. We used random-effects models to derive pooled risk estimates for each cancer site. We used I^2 statistics to evaluate heterogeneity, and Begg and Egger tests to assess publication bias (Begg and Mazumdar, 1994; Egger et al., 1997). Results of our updated meta-analysis are included in Supplementary Table 3.

The cancer sites for which there is strong evidence of an association with leisure-time sedentary behavior are endometrium, colorectal, ovarian and breast. For most studies, the risk estimates were obtained by comparing the highest levels of leisure-time sedentary behavior (usually ≥6 h per day) to the lowest levels (< 3 h per day). We assumed that those with 3 to 6 h per day of leisure-time sedentary activity were at moderate risk, and that there is a log-linear relation between the length of leisure-time sedentary behaviors and cancer risk. The updated risk estimates are presented in Table 1.

2.1.3. Prevalence of exposure

The prevalence of leisure-time sedentary behavior at the provincial and national levels was derived from the CCHS. The CCHS was designed to be a nationally-representative, cross-sectional survey of the Canadian population over the age of 12 living in private residences in the ten provinces and three territories. Our analysis only included CCHS participants aged 20 and older. Further details about the CCHS survey methods and sampling strategy have been previously published (Beland, 2002). Specifically, CCHS asked participants how many hours

Table 1
Relative risks of cancers for leisure-time sedentary behavior[a].

Cancer site	Level of exposure (hours being sedentary/day)	Relative risk (95% confidence interval)	
		Men	Women
Breast	3–6 h/day	–	1.04 (1.01–1.07)
	≥6 h/day	–	1.08 (1.02–1.14)
Colorectal	3–6 h/day	1.10 (1.01–1.21)	1.10 (1.01–1.21)
	≥6 h/day	1.22 (1.02–1.46)	1.22 (1.02–1.46)
Endometrium	3–6 h/day	–	1.15 (1.08–1.23)
	≥6 h/day	–	1.33 (1.16–1.52)
Ovarian	3–6 h/day	–	1.18 (1.04–1.34)
	≥6 h/day	–	1.40 (1.08–1.80)

[a] Estimates from meta-analysis conducted by ComPARe research group.

in a typical week they spent on a computer, on watching television or videos, and on reading, while not at work or at school. We pooled the data from Cycle 1.1(2000–2001) and Cycle 2.1 (2003) to estimate the past prevalence of exposure corresponding to the cancer burden that would be observed in 2015. Only the residents of New Brunswick, Quebec, Ontario, Manitoba, and Saskatchewan answered these questions in Cycle 1.1 of the CCHS, and only the residents of Alberta, British Columbia, Ontario, and Manitoba answered these questions in Cycle 2.1. Where possible, we pooled the data from these two cycles and used averaged sampling weights to estimate the prevalence of leisure-time sedentary behavior in each province. We also estimated the prevalence at the national level, based on the provinces for which data were available. Data were missing for Newfoundland, Prince Edward Island, Nova Scotia and the territories.

2.1.4. Statistical analysis

We applied previously developed methodology (Parkin, 2011b) to estimate PARs associated with leisure-time sedentary behavior using the following equation:

$$\mathrm{PAR} = \frac{(\mathrm{P_{e1}} \times \mathrm{ERR_1}) + (\mathrm{P_{e2}} \times \mathrm{ERR_2})}{1 + ((\mathrm{P_{e1}} \times \mathrm{ERR_1}) + (\mathrm{P_{e2}} \times \mathrm{ERR_2}))}$$

where Pe_1 is the prevalence of moderate sedentary leisure-time behavior (3–6 h/day), Pe_2 is the prevalence of high leisure-time sedentary behavior (> 6 h/day), ERR_1 is the excess RR associated with moderate leisure-time sedentary behavior and ERR_2 is the excess RR associated with leisure-time sedentary behavior.

For each site-specific cancer, we multiplied the PARs by the number of incident cancer cases of interest, including colorectal, breast, ovarian, and endometrium cancers in the Canadian Cancer Registry in 2015, to estimate the excess attributable cases. Where applicable and appropriate, we performed these estimations for individual sex and age groups as well as for each province. The total proportion of cancer cases estimated to be attributable to leisure-time sedentary behavior at each cancer site was estimated as the total number of excess attributable cases for that cancer across all sex and age groups, divided by the total number of observed cancers at that site.

2.2. Future avoidable burden

2.2.1. Projected exposure prevalence

To estimate the future trend of leisure-time sedentary behavior in Canada, we extracted the historical prevalence of leisure-time sedentary behavior from the CCHS (years 2000, 2003, 2005, 2007, and 2011). Cycle 3.1 of CCHS (2005) was excluded because the questions relating to leisure-time sedentary behavior were addressed only to the residents of Saskatchewan. Data from CCHS in 2000 and 2003 were pooled because the questions were not administered in all provinces. For CCHS in 2007 and 2011, the questions were asked to participants from all provinces.

We used multinomial logistic regression to model the past prevalence of leisure-time sedentary behavior at national and provincial levels. Coefficients from these regression models were then used to project future prevalence. Our models incorporated a latency period of 10 years and projected the prevalence at the national and provincial levels to year 2032 in order to match the projected incidence by 2042.

2.2.2. Cancer incidence projections

We have previously described the methods used to estimate future cancer incidence in Canada to 2042 (Poirier et al., 2019). The methods are also summarized in the methods overview included in this issue (Brenner et al., 2019).

2.2.3. Counterfactual scenarios

Counterfactual scenarios simulate situations where interventions change the proportion of individuals 'exposed' in the population. The counterfactual is the distribution in the prevalence of leisure-time sedentary behavior exposure when changes occur or when an intervention is in effect (13). For this analysis, we considered three counterfactual scenarios to project the incidence of all-cancer and site-specific cancers if sedentary behavior exposure across the population were reduced by 10%, 25% or 50% by 2032, i.e., the prevalence of the Canadians exposed to 3 h or more leisure-time sedentary behavior per day is reduced to 10%, 25% or 50%. These scenarios were chosen as target levels that were considered possible to aspirational.

2.2.4. Estimation of potential impact fractions

To evaluate the future burden of avoidable cancers attributable to leisure-time sedentary behavior we used potential impact fractions (PIF) estimates. For PIF estimates, we modelled alternate or "counterfactual" distributions for leisure-time sedentary behavior to examine how cancer incidence would be decreased under a variety of population exposures, with projections made until 2042.

Potential impact fraction was estimated using the equation for proportional shifts:

$$PIF = \frac{\sum_{c=1}^{n} P_c RR_c - \sum_{c=1}^{n} P_c^* RR_c}{\sum_{c=1}^{n} P_c RR_{c.}}$$

where $n = 3$ (the 3 categories of leisure-time sedentary behavior level), P_c is the prevalence in category c, RR_c is the RR for that category, and P_c^* is the counterfactual prevalence in category c. The counterfactual cancer incidence counts after an intervention is $I^* = (1 - PIF)I$, where I is the projected cancer incidence count.

Ethics approval was granted for this project by the Health Research Ethics Board of Alberta - Cancer Committee (HREBA.CC-14-0220_REN4).

3. Results

3.1. Relative risks of cancers for leisure-time sedentary behavior

We estimated relative risks for colorectal, breast, endometrium and ovarian cancers (Table 1) comparing the estimates for both 3 to 6 h per day and ≥6 h per day which we respectively defined as moderate and high levels of leisure-time sedentary behavior. For colorectal cancers, we pooled all studies to obtain relative risk estimates for both men and women for sedentary exposure between 3 and 6 h per day at 10%, and at 22% for exposure for ≥6 h per day. For women, over 6 h per day leisure-time sedentary behavior increases the relative risks for endometrium, breast and ovarian cancer by 33% 8% and 40%, respectively.

3.1.1. Prevalence of leisure-time sedentary behavior

The prevalence of leisure-time sedentary behavior in Canada, as estimated from the CCHS surveys from 2000 to 1 and 2003 for both sexes and across all age groups, was 32.5% for < 3 h/day, 52.1% for 3

Table 2
Prevalence of moderate and low leisure-time sedentary behavior in Canada[a,b], (2000/01, 2003).

Age (years)	Sedentary behavior prevalence (95% confidence interval)		
	< 3 h/day	3–6 h/day	≥6 h/day
Men	32.0 (31.4–32.6)	49.9 (49.2–50.5)	11.2 (10.8–11.7)
20–34	32.6 (31.4–33.9)	48.0 (46.7–49.4)	12.4 (11.5–13.4)
35–44	34.7 (33.3–36.0)	48.8 (47.3–50.2)	10.9 (10.0–11.8)
45–64	32.5 (31.5–33.6)	49.9 (48.8–51.1)	11.6 (10.8–12.3)
≥65	25.2 (24.0–26.4)	55.2 (53.8–56.6)	8.7 (7.9–9.5)
Women	32.9 (32.3–33.5)	54.2 (53.6–54.8)	8.8 (8.4–9.1)
20–34	35.5 (34.3–36.7)	49.6 (48.3–50.8)	10.7 (9.9–11.5)
35–44	37.8 (36.4–39.2)	51.0 (49.5–52.4)	8.6 (7.9–9.4)
45–64	31.4 (30.4–32.4)	55.6 (54.6–56.7)	9.5 (8.8–10.1)
≥65	25.3 (24.3–26.3)	62.7 (61.5–63.8)	4.9 (4.4–5.4)
Total	32.5 (32.0–32.9)	52.1 (51.6–52.5)	9.9 (9.7–10.3)
20–34	34.0 (33.2–34.9)	48.8 (47.9–49.7)	11.6 (10.9–12.2)
35–44	36.2 (35.3–37.2)	49.9 (48.9–50.9)	9.8 (9.2–10.3)
45–64	32.0 (31.2–32.7)	52.8 (52.0–53.6)	10.5 (10.0–11.0)
≥65	25.3 (24.5–26.0)	59.4 (58.5–60.3)	6.6 (6.1–7.0)

[a] Data from cycle 1.1 and cycle 2.1 of the Canadian Community Health Survey (2000/01, 2003).
[b] Cycle 1.1 included sedentary behavior data from residents of New Brunswick, Quebec, Ontario, Manitoba, and Saskatchewan. Cycle 2.1 included sedentary behavior data from the residents of Alberta, British Columbia, Ontario, and Manitoba. Data for Newfoundland, Prince Edward Island, Nova Scotia and the territories were not available in either cycle.

to 6 h/day, and 9.9% for ≥6 h/day (Table 2). Most of the population reported between 3 and 6 h of leisure-time sedentary behavior per day and these proportions increased with age and were slightly higher among females than males. For the provinces included in our analysis, the prevalence of having between 3 and 6 h per day of leisure-time sedentary behavior was > 50% in 5 of the 7 provinces included, for both sexes and all ages combined (Supplementary Table 1).

3.2. Current attributable burden of sedentary behavior on cancer

We estimated that 1.7% of all cancers (Table 3), equivalent to 3230 cases (Table 4) were attributable to leisure-time sedentary behavior in Canada for 2015. Specifically, for each sex, 0.9% of all cancers for men, and 2.5% of all cancers for women were attributable to sedentary behavior. For all cancers known be associated with sedentary behavior (i.e., colorectal, breast, endometrium, ovarian cancers), 5.8% were found to be attributable to leisure-time sedentary behavior. For colorectal cancers, leisure-time sedentary behavior was attributable to 7% for both men and women, while the absolute number of excess cases was slightly higher among men (n = 890) than women (n = 695). Among women, leisure-time sedentary behavior was attributed to 11.9% of ovarian cancers, 10.2% of endometrium cancers, and 2.8% of breast cancers. Although leisure-time sedentary behavior contributed to only 2.8% of breast cancers, the actual number of excess attributable cases were higher for breast at 695 cases, compared to ovarian (n = 304) and endometrium (n = 644) cancers. PAR estimates for the Canadian provinces are presented in Supplementary Table 2.

3.3. Future avoidable burden of cancer

3.3.1. Counterfactual scenarios

The prevalence of sedentary behavior during leisure time was projected to 2042 (Fig. 1). The proportion of Canadians spending less than 3 h sedentary during leisure time is projected to decrease, whereas the proportion projected to spend between three and 6 h sedentary is expected to increase. We projected that if the current leisure-time sedentary behavior trend were to be maintained, 8.1% of cancers (equating to 8496 cases) could be attributable to leisure-time sedentary behavior exposure by 2042 (Table 5). As expected, for both men and women, a 50% reduction in leisure-time sedentary behavior resulted in the highest potential number of cancers to be avoided at 3.9%, compared to only 0.8% of cancers avoided with a 10% reduction in leisure-time sedentary behavior. For all cancers, and across all three scenarios, men had higher PIFs compared to women, however, the absolute number of projected and prevented cancer cases among women was higher than men since there were more cancer sites associated with leisure-time sedentary behavior in women. For colorectal cancer, for both men and women combined, 4.6% of cases (equivalent to 2249 cases) could be prevented with a 50% decrease in leisure-time sedentary behavior. For site-specific cancers, 7.8% of ovarian, 6.7% of endometrium and 1.9% of breast cancers could be avoided with a 50% reduction in leisure-time sedentary behavior in women. Breast and endometrium cancers had similar numbers of estimated prevented cases across all three intervention scenarios, while endometrium cancer had much higher PIF values. Provincial estimates of the future burden of cancer attributable to sedentary behavior during leisure time are presented in Supplementary Table 4. The projected proportions of cancer cases in Canadian provinces that could be prevented by 2042 with three different counterfactual scenarios applied to leisure-time sedentary behavior are presented in Supplementary Table 5.

4. Discussion

In our analyses, from 2000 to 2003, approximately half of the Canadian population was spending at least 3 to 6 h and approximately

Table 3
Summary of cases and proportions of cancer in Canada in 2015 attributable to leisure-time sedentary behavior[a].

Cancer site	Total			Men			Women		
	Observed cases[b]	Attributable cases[c]	% attributable[d]	Observed cases	Attributable cases	% attributable	Observed cases	Attributable cases	% attributable
Colorectal	22,610	1585	7.0	12,665	890	7.0	9945	695	7.0
Breast	24,555	697	2.8				24,555	697	2.8
Ovarian	2550	304	11.9				2550	304	11.9
Endometrium	6340	644	10.2				6340	644	10.2
All associated cancers[e]	56,055	3230	5.8	12,665	890	7.0	43,390	2340	5.4
All cancers[f]	187,070	3230	1.7	94,910	890	0.9	92,160	2340	2.5

[a] Data on prevalence of sedentary behavior from the Canadian Community Health Survey (2000/01).
[b] Number of observed cancer cases in Canada in 2015 at individual cancer sites from the Canadian Cancer Registry.
[c] Number of cancer cases at individual cancer sites that can be attributed to sedentary behavior.
[d] Proportion of cancers at individual cancer sites attributable to sedentary behavior.
[e] All associated cancers includes all cancers known to be associated with sedentary behavior (as listed in the current table).
[f] All cancers includes all incident cancer cases in Canada for all ages in 2015.

Table 4
Cancer cases and proportions attributable to leisure-time sedentary behavior in Canada (2015) ***NO Confidence Intervals.

Age at exposure	Age at Dx	Colorectal			Breast			Ovarian			Endometrium		
		Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC
Men													
20–34	30–44	385	6.9	27									
35–44	45–54	1265	6.7	85									
45–64	55–74	6820	7.1	484									
≥65	≥75	4195	7.0	294									
Total		12,665	7.0	890									
Women													
20–34	30–44	415	6.8	28	2245	2.7	62	205	11.6	24	285	9.8	28
35–44	45–54	1050	6.6	69	4920	2.7	131	450	11.2	51	970	9.5	93
45–64	55–74	4530	7.2	325	12,685	2.9	370	1285	12.2	157	4035	10.3	417
≥65	≥75	3950	6.9	273	4705	2.9	135	610	11.9	73	1050	10.2	107
Total		9945	7.0	695	24,555	2.8	697	2550	11.9	304	6340	10.2	644
Total													
20–34	30–44	800	6.8	55	2245	2.7	62	205	11.6	24	285	9.8	28
35–44	45–54	2315	6.7	154	4920	2.7	131	450	11.2	51	970	9.5	93
45–64	55–74	11,350	7.1	809	12,685	2.9	370	1285	12.2	157	4035	10.3	417
≥65	≥75	8145	7.0	567	4705	2.9	135	610	11.9	73	1050	10.2	107
Total		22,610	7.0	1585	24,555	2.8	697	2550	11.9	304	6340	10.2	644

Abbreviations: Dx = Diagnosis, AC = Attributable cases due to sedentary behavior, Obs. = Total number of observed cases per age-sex group, PAR = Population attributable Risk.

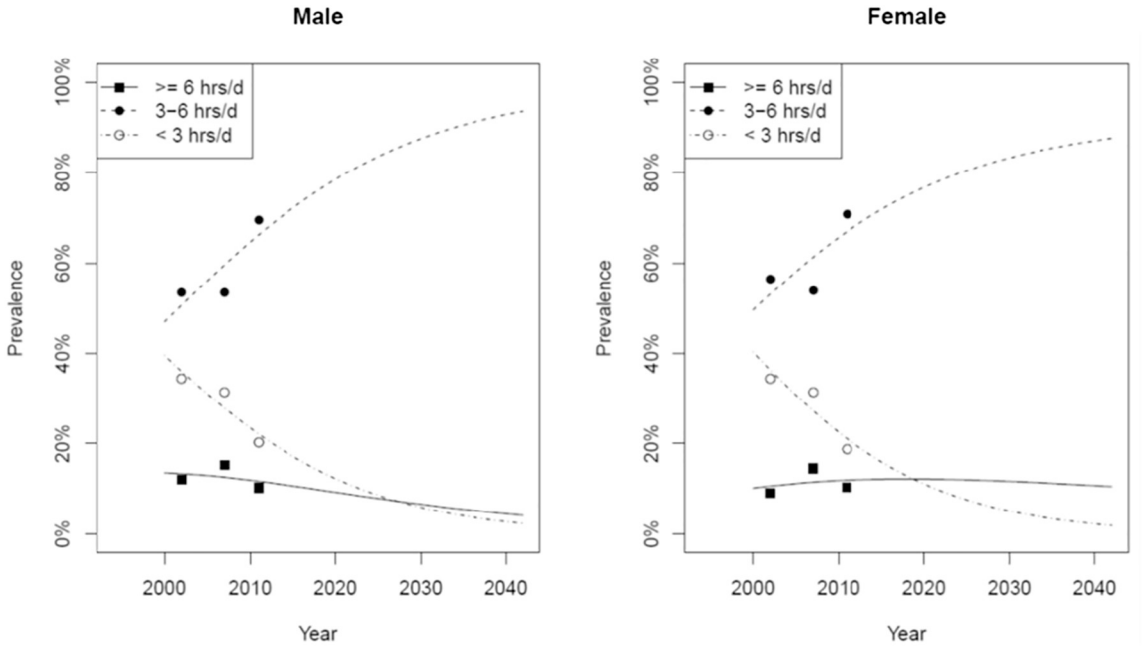

Fig. 1. The projected prevalence of < 3 h, 3–6 h, and ≥6 h of leisure time sedentary behavior in males and females.

another 10% spent ≥6 h daily being sedentary in their leisure-time (Beland, 2002). In this analysis, we estimated that in 2015, 5.8% of colorectal, breast, ovarian and endometrium cancers and 1.7% of all cancer sites combined in Canada were attributable to leisure-time sedentary behavior. Without any changes to these levels of leisure-time sedentary behavior, this risk factor could contribute to 8.1% of excess cancers by 2042. Our findings project that a 50% decrease in the prevalence of leisure-time sedentary behavior could potentially avoid 3.9% of cancers diagnosed by 2042 among both sexes whereas a 25% reduction in leisure-time sedentary behavior could prevent 1.9% of cancers and a 10% reduction could prevent 0.8% of cancers.

The results of this analysis are comparable to a 2008 European study (Friedenreich et al., 2010) that estimated PARs for physical activity and leisure-time sedentary behavior and site-specific cancers in 15 European countries. Across Europe, 8.0% of colorectal cancers among men were attributable to a sedentary lifestyle (Friedenreich et al., 2010). For women, PARs for sedentary lifestyle were estimated to be 10.0% for colorectal, 10.0% for breast, 7.0% for ovarian and 13.0% for endometrium cancers (Friedenreich et al., 2010). Our results for the Canadian population were similar to the European estimates for colorectal among men at 7.0%, colorectal among women at 10.0% and endometrium cancers among women at 10.2%. Greater differences were found when comparing Canadian PARs for breast cancer (2.8%) to the European PAR estimates. Possible reasons for these differences include the fact that in the European study, sedentary behavior was measured using metabolic equivalents of task (MET) (Friedenreich et al., 2010) values, which are often used to measure physical activity. In addition, leisure-time sedentary behavior was used as a second definition of physical inactivity, where individuals who did not meet the criteria of being sufficiently active (< 600 MET-minutes over 7 days) were categorized as sedentary. Our estimates used definitions and measures exclusively for leisure-time sedentary behavior and independently of

Table 5
Projected cancer cases and proportions attributable to leisure-time sedentary behavior and the proportion of cancer cases that could be prevented in 2042 with various changes in sedentary behavior levels in 2042 in Canada.

Sex	CTF[a]	Statistics	All associated	Colorectal	Breast	Endometrium	Ovarian
	Base	Projected cases	28,094	28,094			
Men		PAR(%)	9.3	9.3			
		AC	2607	2607			
		Projected cases	76,260	21,064	40,564	11,266	3366
Women		PAR(%)	7.7	9.9	4.1	14.1	16.5
		AC	5890	2078	1667	1589	555
		Projected cases	104,354	49,158	40,564	11,266	3366
Both		PAR(%)	8.1	9.5	4.1	14.1	16.5
		AC	8496	4685	1667	1589	555
	1	Projected cases	27,841	27,841			
		PIF(%)	0.9	0.9			
Men		Prevented cases	253	253			
		Cumulative cases	1818	1818			
		Projected cases	75,703	20,867	40,407	11,115	3314
		PIF(%)	0.7	0.9	0.4	1.3	1.6
Women		Prevented cases	558	197	158	151	53
		Cumulative cases	4090	1404	1155	1131	400
		Projected cases	103,544	48,708	40,407	11,115	3314
		PIF(%)	0.8	0.9	0.4	1.3	1.6
Both		Prevented cases	811	450	158	151	53
		Cumulative cases	5907	3221	1155	1131	400
	2	Projected cases	27,462	27,462			
		PIF(%)	2.3	2.3			
Men		Prevented cases	632	632			
		Cumulative cases	4544	4544			
		Projected cases	74,866	20,572	40,170	10,889	3235
		PIF(%)	1.8	2.3	1	3.3	3.9
Women		Prevented cases	1395	492	394	376	132
		Cumulative cases	10,225	3509	2888	2828	999
		Projected cases	102,327	48,034	40,170	10,889	3235
		PIF(%)	1.9	2.3	1	3.3	3.9
Both		Prevented cases	2027	1124	394	376	132
		Cumulative cases	14,769	8053	2888	2828	999
	3	Projected cases	26,830	26,830			
		PIF(%)	4.5	4.5			
Men		Prevented cases	1264	1264			
		Cumulative cases	9088	9088			
		Projected cases	73,471	20,080	39,775	10,513	3103
		PIF(%)	3.7	4.7	1.9	6.7	7.8
Women		Prevented cases	2789	985	789	753	263
		Cumulative cases	20,450	7019	5776	5656	1999
		Projected cases	100,301	46,909	39,775	10,513	3103
		PIF(%)	3.9	4.6	1.9	6.7	7.8
Both		Prevented cases	4054	2249	789	753	263
		Cumulative cases	29,537	16,107	5776	5656	1999

Abbreviations: AC = Attributable cases due to sedentary behavior, PAR = Population attributable risk, CTF = counterfactual scenario, PIF = Potential impact fraction.

[a] Base = continuing prevalence trends with no change. Scenario 1 = 10% reduction in the prevalence of sedentary behavior by 2032. Scenario 2 = 25% reduction in the prevalence of sedentary behavior by 2032. Scenario 3 = 50% reduction in the prevalence of sedentary behavior by 2032.

physical activity, which may have contributed to the differences between studies.

There are several plausible biologic mechanisms that may explain the association between some cancers and leisure-time sedentary behavior. Firstly, a sedentary lifestyle can affect energy balance and promote the accumulation of excess body fat and lead to obesity (Shen et al., 2014). Several studies have linked excess body fat to higher levels of adipokines, inflammation, and sex hormones, which may promote cancer (Lynch, 2010). Increased exposure to biologically available sex hormones increases the risk for hormone-related cancers, such as breast, and endometrium cancers (Lynch, 2010). Secondly, sedentary behavior could affect chronic inflammation factors including increasing adipokines, specifically, tumor necrosis factor-α, interleukin-6, and leptin which have been identified as predictors for cancer (Lynch, 2010; van Kruijsdijk et al., 2009). A study by Fung and colleagues found a positive association between increased television viewing time and leptin in men, independent of physical activity and BMI (Fung et al., 2000). Lastly, sedentary behavior has been associated with metabolic dysfunction contributing to insulin resistance, which is characterized by hyperglycemia and hyperinsulinemia (Lynch, 2010). Hyperglycemia may influence carcinogenesis by creating a favourable environment for tumor growth by elevating levels of insulin/IGF-1 and inflammatory cytokines in circulation (Anisimov and Bartke, 2013).

A clear strength of this study is that leisure-time sedentary behavior was considered as a separate risk factor from physical inactivity in examining PAR, which has only been done in one previous study (Friedenreich et al., 2010). We are unaware of previous efforts to estimate PARs exclusively on cancer and leisure-time sedentary behavior, independent of physical inactivity. Ours is also the first analysis to provide national and provincial estimates on the current and future burden of cancers attributable to leisure-time sedentary behavior in Canada. Our estimates used current cancer incidence data from a high quality cancer registry, which permitted the estimation of both national and provincial level results. Moreover, access to nationally

representative population survey data, combined with repeated historical data facilitated the estimation of current attributable and future avoidable cancers due to leisure-time sedentary behavior.

There are several limitations in our analysis that must also be considered. The main data source for this study used self-reported leisure-time sedentary behavior from the CCHS. Discrepancies have been observed between self-reported and monitored leisure-time sedentary behavior (Dyrstad et al., 2014; Schuna et al., 2013). In addition, self-reported leisure-time sedentary behavior has been found in some cases to be underestimated compared to accelerometer measured leisure-time sedentary behavior (Dyrstad et al., 2014). Hence, the total current and future burden of cancer attributable to leisure-time sedentary behavior estimated in this study could be underestimated. The CCHS excludes survey information from individuals serving in the armed forces, living in prisons, or reserve lands, at the time of data collection and our results are not generalizable to these population groups. Leisure-time sedentary behavior data from the CCHS were not available for some provinces and all of the territories, and national estimates were conducted with missing provincial data. Furthermore, there may have been a selection bias in the survey participants with those who agreed to participate being more physically active and less sedentary than the entire Canadian population. We assumed a log-linear dose response between the length of leisure-time sedentary behaviors and cancer risk. However, this dose relation is unclear at present and requires more high-quality studies to elucidate In addition, leisure-time sedentary behavior as a risk factor for cancer was analyzed independently from other lifestyle factors that may influence cancer and could be potential confounders. Finally, occupational sedentary behavior was excluded since only leisure-time sedentary behavior was available from the national surveys used for this analysis. Consequently, the total cancer burden attributable to sitting and sedentary time was likely underestimated.

Given the future burden of cancer that could be prevented by reducing leisure-time sedentary behavior, evidence-based, Canadian sedentary behavior guidelines that are tailored to Canadian adult population should be produced and widely disseminated via public education and awareness campaigns. Efforts to reduce excessive sedentary behavior during leisure time through the use of technology may be especially valuable. A systematic review and meta-analysis on reducing sedentary behavior with the use of computers, mobiles and wearable technology found that such devices can be effective at reducing sedentary behavior and even enhanced interventions aimed at changing sedentary behavior in adults (Stephenson et al., 2017). These intervention studies were conducted at a variety of settings including communities, home, and workplace (Stephenson et al., 2017). Examples of technology captured in the study included activity trackers with online apps, motivational emails and text messages, online education, and commercial websites (Stephenson et al., 2017). The results of the systematic review and meta-analysis found a mean reduction of 41 min (40 min for workplace interventions) per day of sedentary behavior with the use of technology (Stephenson et al., 2017). Online programs, mobile applications, and wearable devices may provide cost-effective and large-scale interventions that decrease adult sedentary behavior (Direito et al., 2017; Lyons et al., 2014; Stephenson et al., 2017).

Similarly, although not the focus of this analysis, sedentary behavior in the workplace is also an important consideration for population-based interventions since a large portion of the Canadian population's waking hours are spent at work. A systematic review by the Alberta Centre for Active Living of the best workplace interventions that increase physical activity and reduce sedentary behavior found that in terms of reducing sedentary behavior, interventions that targeted access and the physical environment were the most effective (Alberta Centre for Active Living, 2015). For example, making modifications to the workplace design (e.g. moving equipment like printers farther away from workstations), installing workstations that encourage movement (e.g. sit-stand desks, cycling desks and treadmill workstations) and increasing access to physical activity at work (e.g. providing access to an exercise facility or secure bike storage) can offer employees greater opportunities for incidental and purposeful physical activity (Alberta Centre for Active Living, 2015).

4.1. Conclusion

Leisure-time sedentary behavior is increasingly being recognized as a modifiable risk factor associated with cancer. During the early 2000s, well over half of Canadian adults were spending at least 3 h of their leisure-time being sedentary. While evidence for leisure-time sedentary behavior and cancer is limited, we estimated that leisure-time sedentary behavior was attributable to 5.8% of all associated cancers, equivalent to 3230 cases in Canada for 2015. Reducing sedentary time among Canadians could lead to meaningful reductions in the occurrence of several site-specific cancers including all-cancers combined. Our counterfactual scenarios estimated that decreasing the prevalence of leisure-time sedentary behavior in Canada by 50% could lead to 3.9% fewer cases of cancer by 2042. Reducing leisure-time sedentary behavior may lead to other decreases in related lifestyle cancer risk factors such as obesity and physical inactivity. Estimating cancers attributed to leisure-time sedentary behavior provides evidence to support strategies in reducing sedentary lifestyles to prevent a substantial number of cancers in Canada in the future.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2019.03.009.

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