Estimates of the current and future burden of cancer attributable to excess body weight and abdominal adiposity in Canada

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ABSTRACT

The increasing prevalence of obesity among Canadians has important implications for newly diagnosed cases of cancer given that excess body weight and abdominal adiposity are known to increase the risk of several cancers. The purpose of this analysis was to estimate the current attributable and future avoidable burden of cancer related to excess body weight and abdominal adiposity among Canadian adults. We estimated the population attributable risk (PAR) for all cancers associated with excess body weight and abdominal adiposity using contemporary cancer incidence, relative risk and exposure prevalence data for body mass index (BMI), waist circumference and waist-to-hip-ratio. Using the partial impact fraction (PIF), we also estimated the future avoidable burden of cancer from 2015 to 2042 in Canada, and by province, through various hypothetical intervention scenarios. In 2003, approximately half (50.5%) of the Canadian population was estimated to be overweight (BMI 25.0–29.9) or obese (BMI ≥ 30.0), 56.5% to have excess abdominal adiposity and 56.8% with a high waist-to-hip ratio. In 2015, the estimated PARs of all incident cancers associated with excess body weight, excess abdominal adiposity and high waist-to-hip ratio were 7.2%, 8.9% and 10.0%, respectively. If the population BMI could revert to its 1994 distribution, 72,157 associated cancer cases could be prevented cumulatively by 2042. A reduction in excess body weight and abdominal adiposity has the potential to decrease the future cancer burden in Canada substantially, and hence efforts to reverse increasing trends in obesity should be prioritized.

1. Introduction

Excess body weight has been consistently associated with an increased risk of colorectal, postmenopausal breast, esophageal adenocarcinoma, stomach-cardia, kidney, gallbladder, liver, advanced prostate, ovarian, endometrial, and pancreatic cancers (World Cancer Research Fund, 2018; World Cancer Research Fund/American Institute

for Cancer Research, 2007). Both overweight (body mass index (BMI) 25.0–29.9) and obesity (BMI ≥ 30.0) combined are considered to be indicative of excess body weight (World Health Organization, 2000). The World Cancer Research Fund (WCRF)/American Institute for Cancer Research (AICR) recommends a BMI in the normal range (18.5–24.9) from age 21 onwards, and to avoid weight gain and increases in waist circumference, to reduce the risk of developing cancer

(World Cancer Research Fund, 2018).

There are several proposed mechanisms whereby excess body weight may increase the risk of cancer, including alterations in the levels of hormones and growth factors, chronic inflammation and gallstone formations (World Cancer Research Fund/American Institute for Cancer Research, 2007). Excess insulin and leptin in obese persons may help promote cancer cell growth and cause insulin resistance, which thereby increases the risk of colon, endometrium and kidney cancers in particular (World Cancer Research Fund/American Institute for Cancer Research, 2007). An increased risk of prostate cancer in men may be associated with lower serum testosterone levels in those who are obese (World Cancer Research Fund/American Institute for Cancer Research, 2007). Obesity increases the risk of gallstone formation, which may then increase the risk of gallbladder cancer (Randi et al., 2006). Insulin resistance and certain growth factors, such as insulin-like growth factor (IGF-1), may mediate the link between obesity and the risk of kidney cancer (Wilson and Cho, 2016; World Cancer Research Fund/American Institute for Cancer Research, 2007).

In the United Kingdom it has been estimated that in 2010, 5.5% of all cancers were attributable to excess body weight (Parkin and Boyd, 2011). In Australia, 3.4% of all cancer cases diagnosed in 2010 were estimated to be attributable to excess body weight (Kendall et al., 2015). We previously estimated that 3.5% of all cancers in Canada could be attributed to excess body weight in 2007 using only BMI (Brenner, 2014). A study which included an expanded set of cancer sites then estimated that in 2010 5.7% of all cancers in Canada were attributable to excess BMI (Zakaria and Shaw, 2017). As the epidemiologic evidence on excess body size and the risk of cancer at additional sites emerges, updating these results becomes necessary. Given that estimates of the population attributable risk (PAR) are driven by exposure prevalence, the steadily rising trends in excess body size and obesity in Canada necessitate updating estimates of their PARs in Canada. In addition, to date no studies have systematically examined the current and future burden of cancer attributable to excess body weight, at both national and provincial levels. Furthermore, providing estimates of future cancer burden in Canada related to excess body weight is needed for informing potential policy and prevention initiatives.

As part of the Canadian Population Attributable Risk of Cancer (ComPARe) Project, the objectives of this analysis were to: 1) estimate the proportion and number of cases of cancer in 2015 that were attributable to past excess body weight and abdominal adiposity, and 2) estimate the proportion and number of cases of cancer that could be avoided by 2042 (i.e., summed between 2015 and 2042) if intervention scenarios were implemented to reduce body weight and abdominal adiposity at the population level.

2. Methods

The detailed methods for these analyses were previously published and are briefly summarized in this issue (Brenner et al., 2018a, 2018b). Three types of data are required to estimate the attributable and avoidable burden of cancer due to excess body weight; 1) relative risk (RR) estimates for the association between excess body weight and cancer, 2) the prevalence of excess body weight and abdominal adiposity in Canada and provinces and 3) cancer incidence.

2.1. Current population attributable burden of cancer

2.1.1. Latency period

A latency period was considered to be the time between the measured exposure and cancer diagnosis. For excess body weight and abdominal adiposity, a latency period of 12 years was assumed based on the prevalence data used. We applied estimates of excess body weight from 2003 to cancer cases in 2015. This latency period for estimated exposure to cancer diagnosis is roughly estimated by median follow-up times in relevant cohort studies. For additional details on the latency

period selection and definitions we refer the reader to Brenner, 2018 (Brenner et al., 2018a, 2018b).

2.1.2. Risk estimates

RRs for each exposure-cancer site from recent literature syntheses, including the WCRF/AICR reports and published meta-analyses were used (Table 1).

2.1.3. Prevalence of exposure

The exposure prevalence data for excess body weight were obtained through public use microdata files from the 2003 cycle of the Canadian Community Health Survey (CCHS) (Beland, 2002). The CCHS is a biennial population-based survey conducted by Statistics Canada. An overview of the CCHS methods has been published previously (Beland, 2002). The response rate to the CCHS for 2003 was 87.1%. For BMI, the CCHS included questions on participants' height (without shoes) and weight which were used to estimate BMI (estimated as kg/m^2) and categorized as normal (< 25), overweight (25–29.9), obese (30–34.9) and very obese (≥ 35).

The prevalence data for abdominal adiposity as defined by waist circumference (WC) and waist-to-hip ratio (WHR) were not available from the CCHS and we therefore obtained data from Cycle 1 (2007–2009) and Cycle 2 (2009–2011) of the Canadian Health Measures Survey (CHMS). The CHMS is a biennial population-based survey by Statistics Canada in which information on both physical measures of health as well as lifestyle behaviors, medical history, demographic and socioeconomic variables are collected (Statistics Canada, 2015a). We assumed that the distribution observed during 2007–2011 was the same as in 2003, so that a 12-year latency period was again applicable. Waist circumference was measured using the Canadian Physical Activity Fitness and Lifestyle Approach (CPAFLA), third edition protocol (Canadian Society for Exercise Physiology, 2010), in which the waist circumference measurement is taken at the top of the iliac crest at the end of a normal expiration. Men with waist circumferences < 94 cm and women < 80 cm were categorized as normal. Individuals with waist circumference higher than the normal threshold were placed in one of the three categories (men: (94–104) cm, (104–114) cm, ≥ 114 cm; women: (80, 90) cm, (90, 100) cm, ≥ 100 cm). Hip circumference is the maximal circumference measured at the hips or buttocks region (whichever is larger) and the WHR is calculated by dividing the waist circumference by the hip circumference to determine body fat distribution. Men with a waist-to-hip ratio < 0.90 and women < 0.85 were categorized as "normal" and above were categorized as high. For estimating PAR, individuals with waist-to-hip ratio higher than the normal threshold were placed in one of the three categories (men: [0.90, 0.95], [0.95, 1.00], ≥ 1.00; women: [0.85, 0.90], ≥ 0.90).

2.1.4. Statistical analysis

The PAR equation of Levin (Levin, 1953) was used to estimate the current attributable burden of cancer due to excess body weight and abdominal adiposity. RRs for cancer associated with BMI were estimated using the following equation:

$$RR_x = R^{M_x - 25}$$

where R represents the RR for one BMI unit (kg/m^2) increase and M_x represents the median BMI for category x, where x represents each of the three overweight/obese categories. RRs for WC and WHR were calculated using the following equation:

$$RR_x = R^x$$

where R represents the incremental risk associated with 10 cm increase in WC or 0.05 unit increase in WHR and x = 1, 2, or 3, representing the 3 risk categories for WC or WHR (International Agency for Research on Cancer, 2007; Zakaria and Shaw, 2017). The PARs were then estimated according to the following formula:

Table 1
Relative risks of cancers for excess body weight and abdominal adiposity.

Exposure	Cancer site	Level of exposure	Relative risk (95% confidence interval)	
			Men	Women
Body mass index	Colon[a]	1 kg/m² increase	1.04 (1.03–1.05)	1.02 (1.01–1.02)
	Rectum[a]	1 kg/m² increase	1.02 (1.01–1.02)	1.01 (1.00–1.02)
	Breast[b,o]	5 kg/m² increase	–	1.12 (1.09–1.15)
	Prostate[c,p]	5 kg/m² increase	1.08 (1.04–1.12)	–
	Endometrium[d]	5 kg/m² increase	–	1.50 (1.42–1.59)
	Thyroid[e]	5 kg/m² increase	1.16 (1.04–1.28)	1.09 (1.06–1.12)
	Kidney[f]	5 kg/m² increase	1.29 (1.23–1.36)	1.28 (1.24–1.32)
	Pancreas[g]	5 kg/m² increase	1.13 (1.04–1.22)	1.10 (1.04–1.16)
	Stomach[h,q]	5 kg/m² increase	1.23 (1.07–1.40)	1.23 (1.07–1.40)
	Myeloma[i]	5 kg/m² increase	1.15 (1.05–1.25)	1.1 (1.05–1.15)
	Ovary[j]	5 kg/m² increase	–	1.06 (1.02–1.11)
	Liver[k]	5 kg/m² increase	1.21 (1.02–1.44)	1.21 (1.10–1.33)
	Esophagus[l,r]	5 kg/m² increase	1.56 (1.39–1.74)	1.48 (1.29–1.71)
	Gallbladder[m]	5 kg/m² increase	1.23 (1.13–1.33)	1.25 (1.07–1.46)
Waist circumference	Colon-rectum[a]	1 in. WC increase	1.02 (1.01–1.04)	1.02 (1.01–1.04)
	Breast[b,o]	10 cm WC increase	–	1.06 (1.01–1.12)
	Prostate[c,p]	10 cm WC increase	1.12 (1.04–1.21)	–
	Endometrium[d]	10 cm WC increase	–	1.13 (1.08–1.18)
	Thyroid[n]	5 cm WC increase	1.05 (1.02–1.08)	1.05 (1.02–1.08)
	Kidney[f]	10 cm WC increase	1.11 (1.05–1.19)	1.11 (1.05–1.19)
	Pancreas[g]	10 cm WC increase	1.11 (1.05–1.18)	1.11 (1.05–1.18)
Waist-to-hip ratio	Colon-rectum[a]	0.1 unit WHR increase	1.17 (1.09–1.25)	1.17 (1.09–1.25)
	Breast[b,o]	0.1 unit WHR increase	–	1.10 (1.05–1.16)
	Prostate[c,p]	0.1 unit WHR increase	1.15 (1.03–1.28)	–
	Endometrium[d]	0.1 unit WHR increase	–	1.21 (1.13–1.29)
	Thyroid[n]	0.1 unit WHR increase	1.14 (1.05–1.24)	1.14 (1.05–1.24)
	Kidney[f]	0.1 unit WHR increase	1.26 (1.18–1.36)	1.26 (1.18–1.36)
	Pancreas[g]	0.1 unit WHR increase	1.19 (1.09–1.31)	1.19 (1.09–1.31)

[a] Estimates from WCRF/AICR CUP: Colorectal Cancer 2011 Report.
[b] Estimates from WCRF/AICR CUP: Breast Cancer 2017 Report.
[c] Estimates from WCRF/AICR CUP: Prostate Cancer 2014 Report.
[d] Estimates from WCRF/AICR CUP: Endometrial Cancer 2013 Report.
[e] Estimates from Wang and colleagues (Wang et al., 2016).
[f] Estimates from WCRF/AICR CUP: Kidney Cancer 2015 Report.
[g] Estimates from WCRF/AICR CUP: Pancreatic Cancer 2012 Report.
[h] Estimates from WCRF/AICR CUP: Stomach Cancer 2016 Report.
[i] Estimates from Wallin and colleagues (Wallin and Larsson, 2011).
[j] Estimates from WCRF/AICR CUP: Ovarian Cancer 2014 Report.
[k] Estimates from WCRF/AICR CUP: Liver Cancer 2015 Report.
[l] Estimates from WCRF/AICR CUP: Oesophageal Cancer 2016 Report.
[m] Estimates from WCRF/AICR CUP: Gallbladder Cancer 2015 Report.
[n] Estimates from Schmid and colleagues (Schmid et al., 2015).
[o] Postmenopausal breast cancer.
[p] Advanced prostate cancer.
[q] Stomach cardia cancer.
[r] Esophageal adenocarcinoma.

$$PAR = \frac{\sum_x P_x (RR_x - 1)}{1 + \sum_x P_x (RR_x - 1)}$$

where P_x is the proportion of the population within each category x and RR_x is the RR for each risk category. To estimate the total number of cancer cases attributable to excess body weight and abdominal adiposity of each site, PARs were applied using cancer incidence data from 2015. The PARs were then multiplied by the age-sex-site-specific cancer incidence in 2015 to estimate the number of cases attributable to excess body weight.

2.2. Future avoidable burden of cancer

2.2.1. Prevalence of exposure projections

To project the future BMI distribution in Canada and in each province (Nova Scotia, New Brunswick, P.E.I., and Newfoundland are grouped as the Atlantic Provinces), we examined past BMI distributions from the National Population Health Survey (1994, 1996, and 1998) and CCHS (2000, 2003, 2005, 2007, and 2011). We assumed a lognormal distribution of BMI among men, women, and post-menopausal women (for breast cancer) (Barendregt and Veerman, 2010). We assumed and modeled a linear trend of the mean and standard deviation of the log of BMI from the past distributions and used the trend coefficients to project the future mean and standard deviation of the population BMI. For the future burden analyses, we took into account a latency period of 10 years at the national and provincial levels to year 2032 (Andersson et al., 2017). We refer the reader to Brenner, 2018 for additional detail and justification of the latency period used for the projection analyses (Brenner et al., 2018a, 2018b).

To project the future prevalence of WC and WHR in Canada, we collected historical data of mean WC and WHR in 1981 and 2007–2009 (Statistics Canada, 2015b). We assumed that the population mean WC and WHR will increase linearly in the future, at the same rate observed in the past, and this gave an annual increase of WC by 0.24 cm. among men and 0.39 cm among women, and an annual increase of WHR by 0.0011 among men and 0.0022 among women.

Table 2
Prevalence of excess body weight and abdominal adiposity in Canada.

Sex	Age (years)	Overweight and obesity prevalence[a] (95% confidence interval)		
		Overweight (25 ≤ BMI < 30)	Obesity I (30 ≤ BMI < 35)	Obesity II, III (BMI ≥ 35)
Men	20–34	35.3 (33.9–36.7)	10.6 (9.8–11.3)	3.5 (3.0–4.1)
	35–44	44.9 (43.4–46.4)	12.7 (11.7–13.6)	3.7 (3.3–4.2)
	45–64	45.5 (44.4–46.7)	15.4 (14.5–16.2)	4.3 (3.8–4.8)
	≥65	44.5 (43.1–45.9)	11.8 (11.0–12.7)	2.4 (2.0–2.8)
	Total	42.4 (41.7–43.1)	12.9 (12.4–13.3)	3.7 (3.4–3.9)
Women	20–34	18.8 (17.8–19.8)	7.2 (6.5–7.9)	3.6 (3.1–4.1)
	35–44	23.7 (22.4–25.1)	9.5 (8.5–10.5)	4.2 (3.6–4.7)
	45–64	32.2 (31.1–33.2)	12.5 (11.8–13.3)	5.8 (5.3–6.2)
	≥65	34.9 (33.7–36.0)	11.9 (11.1–12.6)	3.3 (2.9–3.7)
	Total	27.4 (26.8–28.0)	10.4 (10.0–10.8)	4.4 (4.1–4.7)
All	20–34	27.5 (26.6–28.4)	9.0 (8.4–9.5)	3.6 (3.2–3.9)
	35–44	34.7 (33.6–35.7)	11.1 (10.5–11.8)	3.9 (3.6–4.3)
	45–64	38.9 (38.1–39.7)	14.0 (13.4–14.5)	5.0 (4.7–5.4)
	≥65	39.1 (38.2–40.0)	11.8 (11.3–12.4)	2.9 (2.6–3.2)
	Total	34.9 (34.5–35.4)	11.6 (11.3–11.9)	4.0 (3.9–4.2)

Sex	Age (years)	Abdominal adiposity prevalence[b] (95% confidence interval)	
		High waist circumference[c]	High waist-to-hip ratio[d]
Men	18–39	31.6 (27.7–35.4)	38.6 (33.9–43.3)
	40–59	60.7 (56.3–65.2)	80.4 (76.7–84.0)
	60–80	74.9 (70.2–79.5)	92.6 (90.7–94.5)
	Total	51.9 (48.9–54.9)	66.1 (63.3–69.0)
Women	18–39	45.5 (39.7–51.3)	30.6 (26.4–34.7)
	40–59	66.8 (62.1–71.5)	53.1 (48.7–57.4)
	60–80	77.7 (74.2–81.2)	67.7 (63.6–71.8)
	Total	61.0 (57.4–64.6)	47.6 (45.0–50.3)
All	18–39	38.4 (34.8–42.0)	34.7 (31.5–37.9)
	40–59	63.8 (60.2–67.3)	66.7 (63.6–69.8)
	60–80	76.4 (73.1–79.6)	79.6 (77.2–81.9)
	Total	56.5 (53.6–59.3)	56.8 (54.5–59.2)

[a] Data from cycle 2.1 of the Canadian Community Health Survey (2003).
[b] Data from cycle 1 (spring 2007 to spring 2009) and cycle 2 (August 2009 to November 2011) of the Canadian Health Measures Survey.
[c] High waist circumference defined as ≥94 cm for men and ≥80 cm for women.
[d] High waist-to-hip ratio defined as ≥0.9 for men and ≥0.85 for women.

2.2.2. Cancer incidence projections

Future cancer incidence estimates were required to estimate the number of avoidable cancer cases up to 2042. Detailed methods on these projection analyses have been published previously (Poirier et al., 2019).

2.2.3. Counterfactual scenarios

Multiple intervention or counterfactual scenarios were used to estimate the proportion of cancer cases that could be avoided in the future if trends in excess body weight and abdominal adiposity were to change. In this analysis, we applied a range of hypothetical and evidence-based counterfactual scenarios informed by national and international health organization guidelines. The target counterfactual scenarios we applied for excess body weight were: 1) maintaining the population BMI at the 2012 level, 2) reverting the population BMI to the distribution observed in 1994, and 3) 5%, 10% and 25% reductions in the prevalence of overweight and obesity by 2032. The prevalence of overweight and obesity in Canada in 1994 was 44.2% and 13.1% in men and 26.3% and 13.3% in women, respectively. For both WC and WHR, we applied the same hypothetical counterfactual scenarios of 5%, 10% and 25% reductions in the increasing trend of WC and WHR, given the lack of any evidence-based recommendations.

2.2.4. Estimation of potential impact fractions

We used a distribution shift to estimate the counterfactual intervention effects on BMI:

$$PIF = \frac{\int RR(x)P(x)dx - \int RR(x)P^*(x)dx}{\int RR(x)P(x)dx}$$

where x is the variable of BMI, $RR(x)$ is the RR function of BMI ($RR(x) = 1$ for x < 25.0 and $RR(x) = R^{(x-25)}$ for x ≥ 25.0), $P(x)$ and $P^*(x)$ are the projected BMI distribution and the counterfactual distribution, respectively.

We used a RR shift to estimate the counterfactual intervention effects on WC and WHR:

$$PIF = \frac{\sum_c P_c RR_c - \sum_c P_c RR_c^*}{\sum_c P_c RR_c}$$

where P_c is the prevalence in category c of WC or WHR, RR_c is the original RR for that category, and RR_c^* is the RR of category c after a counterfactual intervention.

2.3. Sensitivity analyses

To acknowledge the bias in self-reported BMI, we repeated all statistical analyses using adjusted prevalence based on correction equations from Shields et al. (Connor Gorber et al., 2008; Shields et al., 2011):

Males: Adjusted BMI = −1.07575 + 1.07592 × (self−reported BMI)

Females: Adjusted BMI = −0.12374 + 1.05129 × (self−reported BMI)

Self-reported individual BMI in CCHS were adjusted with these equations, followed by re-categorizing into normal, overweight, obese,

Table 3a

Cancer cases and proportions attributable to overweight and obesity in Canada (2015).

Age at exposure	Age at Dx	Colon			Rectum			Breast[a]			Prostate[b]			Endometrium			Thyroid			Kidney		
		Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC
Men																						
20–34	30–44	230	8.2	19	165	4.0	7	–	–	–	7	3.5	0	–	–	–	365	6.0	22	215	10.9	24
35–44	45–54	655	9.1	59	600	4.5	27	–	–	–	254	3.5	9	–	–	–	370	6.8	25	600	11.8	71
45–64	55–74	4130	10.3	426	2705	5.1	139	–	–	–	2602	4.0	105	–	–	–	685	7.7	53	2215	13.4	297
≥65	≥75	2930	8.2	242	1260	4.1	52	–	–	–	1009	3.2	33	–	–	–	145	6.5	9	785	11.0	87
Total		7945	9.4	745	4730	4.8	225	–	–	–	3872	3.8	146	–	–	–	1565	7.0	109	3815	12.5	478
Women																						
20–34	30–44	245	2.8	7	180	1.4	3	–	–	–	–	–	–	285	13.6	39	1240	2.3	29	130	7.5	10
35–44	45–54	595	3.4	20	475	1.7	8	2925	3.9	115	–	–	–	970	15.7	153	1190	2.9	35	315	9.0	28
45–64	55–74	3105	4.7	146	1425	2.3	33	12,685	5.3	674	–	–	–	4035	20.4	825	1665	3.9	65	1135	12.0	137
≥65	≥75	3120	4.0	124	825	2.0	16	4705	4.7	220	–	–	–	1050	18.1	190	330	3.7	12	535	10.4	56
Total		7065	4.2	297	2905	2.1	60	20,315	5.0	1009	–	–	–	6340	19.0	1206	4425	3.2	141	2115	10.9	230
Total																						
20–34	30–44	475	5.4	26	345	2.7	9	–	–	–	7	3.5	0	285	13.6	39	1605	3.2	51	345	9.6	33
35–44	45–54	1250	6.4	80	1075	3.3	35	2925	3.9	115	254	3.5	9	970	15.7	153	1560	3.9	60	915	10.9	99
45–64	55–74	7235	7.9	572	4130	4.2	172	12,685	5.3	674	2602	4.0	105	4035	20.4	825	2350	5.0	118	3350	12.9	433
≥65	≥75	6050	6.0	365	2085	3.3	69	4705	4.7	220	1009	3.2	33	1050	18.1	190	475	4.6	22	1320	10.8	142
Total		15,010	6.9	1043	7635	3.7	285	20,315	5.0	1009	3872	3.8	146	6340	19.0	1206	5990	4.2	251	5930	11.9	708

Age at exposure	Age at Dx	Pancreas			Stomach[c]			Myeloma			Ovary			Liver			Esophagus[d]			Gallbladder		
		Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC
Men																						
20–34	30–44	60	5.1	3	30	8.9	3	25	6.1	2	–	–	–	35	7.9	3	14	21.7	3	0	8.2	0
35–44	45–54	195	5.6	11	90	9.6	9	155	6.4	10	–	–	–	160	8.8	14	94	21.2	20	15	9.6	1
45–64	55–74	1315	6.4	84	506	10.9	55	890	7.3	65	–	–	–	1085	10.0	109	644	23.8	153	70	10.9	8
≥65	≥75	750	5.1	39	398	8.6	34	595	5.8	34	–	–	–	410	8.1	33	310	19.1	59	70	8.2	6
Total		2320	5.9	137	1024	9.8	100	1665	6.6	111	–	–	–	1690	9.4	159	1062	22.2	235	155	9.6	15
Women																						
20–34	30–44	40	2.7	1	10	6.3	1	25	2.9	1	205	1.6	3	10	6.0	1	0	12.1	0	5	7.4	0
35–44	45–54	150	3.3	5	31	7.4	2	100	3.3	3	450	2.0	9	45	6.8	3	11	15.1	2	25	8.1	2
45–64	55–74	1025	4.5	47	138	10.0	14	600	4.5	27	1285	2.7	35	250	9.3	23	101	19.9	20	120	10.9	13
≥65	≥75	870	3.8	33	146	8.2	12	495	3.9	19	610	2.4	15	210	8.0	17	106	16.6	18	140	9.3	13
Total		2085	4.1	86	325	8.8	29	1220	4.1	50	2550	2.4	61	515	8.5	44	218	18.0	39	290	9.8	29
Total																						
20–34	30–44	100	4.1	4	40	8.2	3	50	4.5	2	205	1.6	3	45	7.4	3	14	21.7	3	5	7.4	0
35–44	45–54	345	4.6	16	121	9.0	11	255	5.2	13	450	2.0	9	205	8.4	17	105	20.5	22	40	8.6	3
45–64	55–74	2340	5.6	131	644	10.7	69	1490	6.2	92	1285	2.7	35	1335	9.9	132	746	23.3	173	190	10.9	21
≥65	≥75	1620	4.4	72	544	8.5	46	1090	4.9	54	610	2.4	15	620	8.1	50	415	18.5	77	210	9.0	19
Total		4405	5.0	222	1349	9.6	129	2885	5.6	161	2550	2.4	61	2205	9.2	202	1280	21.5	275	445	9.7	43

Abbreviations: Dx = diagnosis, AC = attributable cases due to exposure, Obs. = total number of observed cases per age-sex group, PAR = population attributable risk.

[a] Postmenopausal breast cancer.
[b] Advanced prostate cancer.
[c] Stomach cardia cancer.
[d] Esophageal adenocarcinoma.

and very obese groups, as previously. For future avoidable burden analyses, the data from both NPHS and CCHS surveys were adjusted with the equations, assuming that the magnitude of bias is the same across the cycles of these surveys. New means and standard deviations of log BMI were estimated to project the future population distribution of BMI at national and provincial levels.

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. Current attributable burden of cancer

3.1.1. Body mass index

In 2003, the estimated prevalence of excess body weight in the Canadian population was 50.5% with a higher prevalence found for males (59.0%) than females (42.2%) (Table 2). The majority of those with excess body weight were categorized as overweight (BMI ≥ 25– $< 30\,\mathrm{kg/m^2}$), however, 4% of the Canadian population (3.7% among men and 4.4% among women) were living with severe obesity (BMI $\geq 35\,\mathrm{kg/m^2}$). The highest obesity prevalence (BMI $\geq 30\,\mathrm{kg/m^2}$) was observed in the 45–64 age range in both men (19.7%) and women (18.3%) (Table 2). Provincial prevalence estimates for overweight and obesity are presented in Supplementary Table 1a.

The current burden of cancer attributable to excess body weight is 7.2% for all associated cancers and 3.1% for all incident cancers in 2015 (Tables 3a and 4). There were 14 cancer sites associated with excess body weight that we included in our analysis, and the sites with the highest PAR values are esophageal adenocarcinoma (21.5%), endometrium (19.0%), kidney (11.9%), gallbladder (9.7%), and gastric cardia cancer (9.6%) (Table 4). Despite the fact that postmenopausal breast cancer has a 5.0% population attributable risk, the estimated number of attributable cases is 1009 and it therefore represents a large burden of incident cases. PAR estimates for overweight and obesity with 95% confidence intervals are presented in Supplementary

Table 3b

Cancer cases and proportions attributable to increases in waist circumference in Canada (2015).

Age at exposure	Age at Dx	Colorectal			Breast[a]			Prostate[b]			Endometrium			Thyroid			Kidney			Pancreas		
		Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC
Men																						
18–39	30–49	805	4.0	33	–	–	–	59	6.0	4	–	–	–	515	5.1	26	470	5.5	26	115	5.5	6
40–59	50–69	5685	7.6	433	–	–	–	2164	11.1	239	–	–	–	775	9.5	74	2030	10.2	207	1060	10.2	108
60–80	≥70	6175	10.6	652	–	–	–	1649	15.2	250	–	–	–	275	13.1	36	1315	14.0	184	1145	14.0	160
Total		12,665	6.8	866	–	–	–	3872	10.0	386	–	–	–	1565	8.6	134	3815	9.2	350	2320	9.2	213
Women																						
18–39	30–49	745	6.6	49	–	–	–	–	–	–	585	10.4	61	1810	8.3	149	240	8.8	21	95	8.8	8
40–59	50–69	3955	9.9	391	12,770	7.4	948	–	–	–	3900	15.4	599	2035	12.3	251	1080	13.2	142	775	13.2	102
60–80	≥70	5245	11.9	626	7545	9	679	–	–	–	1855	18.3	340	580	14.8	86	795	15.8	126	1215	15.8	192
Total		9945	9.1	906	20,315	6.8	1386	–	–	–	6340	14.2	902	4425	11.4	504	2115	12.2	257	2085	12.2	254
Total																						
18–39	30–49	1550	5.3	82	–	–	–	59	6.0	4	585	10.4	61	2325	6.7	155	710	7.2	51	210	7.2	15
40–59	50–69	9640	8.8	846	12,770	7.4	948	2164	11.1	239	3900	15.4	599	2810	11.0	308	3110	11.7	364	1835	11.7	215
60–80	≥70	11,420	11.3	1289	7545	9	679	1649	15.2	250	1855	18.3	340	855	14.0	120	2110	14.9	315	2360	14.9	353
Total		22,610	8.0	1808	20,315	6.8	1386	3872	10.0	386	6340	14.2	902	5990	10.0	600	5930	10.7	635	4405	10.7	472

Abbreviations: AC = attributable cases due to exposure, Dx = diagnosis, Obs. = total number of observed cases per age-sex group, PAR = population attributable risk.

[a] Postmenopausal breast cancer.

[b] Advanced prostate cancer.

Table 3c
Cancer cases and proportions attributable to increases in waist-to-hip ratio in Canada (2015).

Age at exposure	Age at Dx	Colorectal			Breast[a]			Prostate[b]			Endometrium			Thyroid			Kidney			Pancreas		
		Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC	Obs.	PAR	AC
Men																						
18–39	30–49	805	5.2	42	–	–	–	59	4.6	3	–	–	–	515	4.3	22	470	7.7	36	115	5.8	7
40–59	50–69	5685	12.1	687	–	–	–	2164	10.8	234	–	–	–	775	10.2	79	2030	17.5	355	1060	13.3	141
60–80	≥70	6175	15.8	974	–	–	–	1649	14.2	234	–	–	–	275	13.3	37	1315	22.4	295	1145	17.3	199
Total		12,665	10.3	1306	–	–	–	3872	9.2	356	–	–	–	1565	8.6	135	3815	15	572	2320	11.4	264
Women																						
18–39	30–49	745	3.6	27	NA	NA	NA	–	–	–	585	9.6	56	1810	6.6	119	240	11.7	28	95	8.7	8
40–59	50–69	3955	6.2	245	12,770	7.3	927	–	–	–	3900	14.3	559	2035	9.9	202	1080	17.2	186	775	13.1	102
60–80	≥70	5245	8.2	432	7545	8.9	673	–	–	–	1855	17.2	320	580	12.1	70	795	20.6	164	1215	15.8	192
Total		9945	5.6	562	20,315	6.7	1355	–	–	–	6340	13.2	839	4425	9.2	405	2115	16	338	2085	12.1	252
Total																						
18–39	30–49	1550	4.4	68	NA	NA	NA	59	4.6	3	585	9.6	56	2325	5.5	129	710	9.8	69	210	7.4	15
40–59	50–69	9640	9.7	932	12,770	7.3	927	2164	10.8	234	3900	14.3	559	2810	10	281	3110	17.3	538	1835	13.2	242
60–80	≥70	11,420	12.3	1406	7545	8.9	673	1649	14.2	234	1855	17.2	320	855	12.7	108	2110	21.5	453	2360	16.5	390
Total		22,610	8.3	1867	20,315	6.7	1355	3872	9.2	356	6340	13.2	839	5990	8.9	533	5930	15.5	919	4405	11.8	518

Abbreviations: AC = attributable cases due to exposure, Dx = diagnosis, Obs. = total number of observed cases per age-sex group, PAR = population attributable risk, NA = not applicable.

[a] Postmenopausal breast cancer.
[b] Advanced prostate cancer.

Table 2a. PAR estimates for overweight and obesity adjusted for self-report bias are presented in Supplementary Table 3. Provincial PAR estimates for overweight and obesity are presented in Supplementary Table 4a.

3.1.2. Waist circumference and waist-to-hip ratio

The prevalence of high waist circumference (2007–2011) in the Canadian population was 56.5% (51.9% among men and 61.0% among women, Table 2). The prevalence of high waist-to-hip ratios (2007–2011) was 56.8% (66.1% among men and 47.6% among women, Table 2). Provincial prevalence estimates for high waist circumference and high waist-to-hip ratio are presented in Supplementary Table 1b.

The burden of cancer attributable to excess abdominal adiposity measured by waist circumference is 8.9% for all associated cancers and 3.3% for all incident cancers in 2015 (Tables 3b and 4). For high waist-to-hip ratio the attributable burden is 10.0% for all associated cancers and 3.7% for all incident cancers in 2015 (Tables 3c and 4). The current burden of cancer attributable to excess abdominal adiposity is 8.0% for colorectal cancer, 6.8% for postmenopausal breast cancer, 10.0% for advanced prostate cancer, 14.2% for endometrium cancer, 10.0% for thyroid cancer and 10.7% for both kidney and pancreatic cancer (Table 4). The attributable burden due to high waist-to-hip ratio is 10.6% for colorectal cancer, 6.7% for postmenopausal breast cancer, 9.2% for advanced prostate cancer, 13.2% for endometrium cancer, 8.9% for thyroid cancer, 15.5% for kidney cancer, and 11.8% for pancreatic cancer (Table 4). PAR estimates for high waist circumference and waist-to-hip ratio with 95% confidence intervals are presented in Supplementary Table 2b. Provincial PAR estimates for high waist circumference and waist-to-hip ratio are presented in Supplementary Table 4b.

3.2. Future avoidable burden of cancer

3.2.1. Body mass index

The BMI of the Canadian population is projected to continue to shift upwards to 2032 if no changes are made (Supplementary Fig. 1). Projected cancer incidence trends show that all cancer sites associated with excess body weight are expected to increase in incidence by 2042. Based on our projection of BMI trends in Canada, the prevalence of excess body weight (BMI ≥ 25 kg/m²) would be 68.3% among men and 56.4% among women by 2032 (data not shown). We therefore estimated the PIF if the projected prevalence was reduced by 5%, 10%, or

25% by 2032. These levels of reduction are estimated to prevent 3570, 6204, or 11,098 associated cancer cases in 2042 and 24,906, 43,867, or 81,100 cases cumulatively by 2042, respectively (Table 5a).

Examining other counterfactual scenarios, if the proportion of individual with a high BMI in Canada were held at those observed in 2012, we estimate that 3933 of all associated cancer cases in 2042 and 27,519 associated cases cumulatively by 2042 for men and women combined could be prevented (Table 5a Scenario 2; Fig. 1). Reducing the population mean BMI by 1 unit by 2032 is estimated to prevent 6044 associated cancer cases in 2042 and 42,742 cumulatively by 2042 (Table 5a – Scenario 2). Further, if the BMI levels in the population could revert to the 1994 distribution, we estimated that 9957 associated cancer cases could be prevented in 2042 and 72,157 cumulatively by 2042 (Table 5a – Scenario 3). The proportions of cancer cases in Canadian provinces that could be prevented in 2038 with various changes in body weight are presented in Supplementary Table 5a. Estimates of the future avoidable burden of cancer based on adjusted BMI prevalence estimates are presented in Supplementary Table 6 and Supplementary Fig. 2.

3.2.2. Waist circumference and waist-to-hip ratio

Based on the historical data, we projected that the Canadian mean waist-circumference and waist-to-hip ratio will continue to increase by 2032. We estimated the potential prevention effect if this increasing trend could be offset by a relative 5%, 10%, or 25%. If the trend of increasing waist circumference decreased as in these scenarios, 578, 1150, or 2838 of all associated cancer cases in 2042 and 6004, 11,971, or 29,642 associated cases cumulatively by 2042 could be prevented for men and women combined, respectively (Table 5b; Fig. 2).

If the trend of increasing waist-to-hip ratio decreased by 5%, 10%, or 25%, we estimated that 442, 842, or 2085 of all associated cancer cases could be prevented in 2042 and 4385, 8751, or 21,727 associated cases cumulatively by 2042 for men and women combined, respectively (Table 5c; Fig. 3). The proportions of cancer cases in Canadian provinces that could be prevented in 2038 with various changes in waist circumference and waist-to-hip ratio are presented in Supplementary Tables 5b and 5c, respectively.

4. Discussion

Consistent epidemiologic evidence suggests that excess body weight is associated with 14 cancer sites including some high incidence sites,

Table 4

Summary of cases and proportions of cancer in Canada in 2015 attributable to overweight and obesity[a], waist circumference increase[b], and waist-to-hip ratio increase[c].

Exposure	Cancer site[d]	Total			Men			Women		
		Observed cases[e]	Attributable cases[f]	% Attributable[g]	Observed cases	Attributable cases	% attributable	Observed cases	Attributable cases	% attributable
Overweight and obesity	Colon	15,010	1043	6.9	7945	745	9.4	7065	297	4.2
	Rectum	7635	285	3.7	4730	225	4.8	2905	60	2.1
	Breast[l]	20,315	1009	5.0	–	–	–	20,315	1009	5.0
	Prostate[m]	3872	146	3.8	3872	146	3.8	–	–	–
	Endometrium	6340	1206	19.0	–	–	–	6340	1206	19.0
	Thyroid	5990	251	4.2	1565	109	7.0	4425	141	3.2
	Kidney	5930	708	11.9	3815	478	12.5	2115	230	10.9
	Pancreas	4405	222	5.0	2320	137	5.9	2085	86	4.1
	Stomach[n]	1348	129	9.6	1024	100	9.8	325	29	8.8
	Myeloma	2885	161	5.6	1665	111	6.6	1220	50	4.1
	Ovary	2550	61	2.4	–	–	–	2550	61	2.4
	Liver	2205	202	9.2	1690	159	9.4	515	44	8.5
	Esophagus[o]	1280	275	21.5	1062	235	22.2	218	39	18.0
	Gallbladder	445	43	9.7	155	15	9.6	290	29	9.8
	All associated cancers[h]	80,211	5742	7.2	29,843	2461	8.2	50,368	3281	6.5
	All cancers[i]	187,070	5742	3.1	94,910	2461	2.6	92,160	3281	3.6
Waist circumference	Colorectal	22,610	1808	8.0	12,665	866	6.8	9945	906	9.1
	Breast[l]	20,315	1386	6.8	–	–	–	20,315	1386	6.8
	Prostate[m]	3872	386	10.0	3872	386	10	–	–	–
	Endometrium	6340	902	14.2	–	–	–	6340	902	14.2
	Thyroid	5990	600	10.0	1565	134	8.6	4425	504	11.4
	Kidney	5930	635	10.7	3815	350	9.2	2115	257	12.2
	Pancreas	4405	472	10.7	2320	213	9.2	2085	254	12.2
	All associated cancers[j]	69,462	6160	8.9	24,237	1950	8.0	45,225	4209	9.3
	All cancers[i]	187,070	6160	3.3	94,910	1950	2.1	92,160	4209	4.6
Waist-to-hip ratio	Colorectal	22,610	2405	10.6	12,665	1306	10.3	9945	1088	10.9
	Breast[l]	20,315	1355	6.7				20,315	1355	6.7
	Prostate[m]	3872	356	9.2	3872	356	9.2	–	–	–
	Endometrium	6340	839	13.2				6340	839	13.2
	Thyroid	5990	533	8.9	1565	135	8.6	4425	405	9.2
	Kidney	5930	919	15.5	3815	572	15.0	2115	338	16.0
	Pancreas	4405	518	11.8	2320	264	11.4	2085	252	12.1
	All associated cancers[k]	69,462	6912	10.0	24,237	2634	10.9	45,225	4277	9.5
	All cancers[i]	187,070	6912	3.7	94,910	2634	2.8	92,160	4277	4.6

[a] Data on prevalence of overweight and obesity from the Canadian Community Health Survey (2000/01).

[b] Data on prevalence of waist circumference increase from cycle 1 (spring 2007 to spring 2009) and cycle 2 (August 2009 to November 2011) of the Canadian Health Measures Survey.

[c] Data on prevalence of waist-to-hip ratio from cycle 1 (spring 2007 to spring 2009) and cycle 2 (August 2009 to November 2011) of the Canadian Health Measures Survey.

[d] Cancer incidence data for the year 2015 from the Canadian Cancer registry.

[e] Number of observed cancer cases in Canada in 2015 at individual cancer sites.

[f] Number of cancer cases at individual cancer sites that can be attributed to overweight and obesity, waist circumference increase, or waist-to-hip ratio increase.

[g] Proportion of cancers at individual cancer sites attributable to overweight and obesity, waist circumference increase, or waist-to-hip ratio increase.

[h] All associated cancers includes all cancers known to be associated with overweight and obesity (as listed in the current table).

[i] All cancers includes all incident cancer cases in Canada for ages 30 and over in 2015.

[j] All associated cancers includes all cancers known to be associated with increases in waist circumference (as listed in the current table).

[k] All associated cancers includes all cancers known to be associated with increases in waist-to-hip ratio (as listed in the current table).

[l] Postmenopausal breast cancer.

[m] Advanced prostate cancer.

[n] Stomach cardia cancer.

[o] Esophageal adenocarcinoma.

such as breast cancer and colorectal cancer. Abdominal adiposity is similarly associated with several elevated incidence cancers. In 2003 in Canada, 50.5% of the Canadian population was classified as overweight or obese and 56.5% had high waist circumference and 56.8% of the population had a higher than recommended waist-to-hip ratio, estimated from the 2007–2011 CHMS. The prevalence of obesity (BMI ≥ 30 kg/m^2) in Canada has been rising since the 1980s and has almost doubled during the past 20 years (NCD Risk Factor Collaboration, 2016). There is an alarming increase in the prevalence of severe obesity (BMI ≥ 35 kg/m^2), especially among Canadian women.

In contrast, the prevalence of normal weight (BMI 18.5–24.9 kg/m^2) has drastically declined and the prevalence of overweight (BMI 25–29.9 kg/m^2) has slightly increased (NCD Risk Factor Collaboration, 2016). Since smoking prevalence is declining while obesity is on the rise, obesity could surpass smoking as the greatest risk factor for many diseases, including cancer (Ahmad et al., 2015). Returning to the body weight levels of the recent past (1990–2000) would meaningfully reduce cancer incidence in the order of 10,000 s of cases in the next 25–30 years.

Our findings can be compared to similar studies conducted in the

Table 5a

Projected cancer cases and proportions attributable to excess body weight and the proportion of cancer cases in Canada that could be prevented in 2042 with various changes in body weight.[a]

Sex	Statistic	CTF[a]	All Associated	Colon	Rectum	Breast[b]	Prostate[c]	Endometrium	Thyroid	Kidney	Pancreas	Stomach[d]
Men	Projected cases	Base	60,266	15,949	11,109	–	7728	–	3591	7230	3967	1904
	PAR (%)		13.1	15.3	7.6	–	5.9	–	11.5	19.9	9.5	16.1
	Attributable cases		7899	2437	849	–	458	–	413	1441	375	307
Women	Projected cases		92,142	14,683	6416	34,217	–	11,266	10,410	3797	3501	669
	PAR (%)		10.3	6.7	3.3	8.1	–	30.1	5.8	17.6	6.5	14.6
	Attributable cases		9524	989	213	2757	–	3396	608	668	227	98
All Associated	Projected cases		152,408	30,631	17,524	34,217	7728	11,266	14,001	11,028	7467	2573
	PAR (%)		11.4	11.2	6.1	8.1	5.9	30.1	7.3	19.1	8.1	15.7
	Attributable cases		17,423	3426	1062	2757	458	3396	1021	2109	602	405
Men	Projected cases	1	58,557	15,426	10,937	–	7637	–	3505	6909	3890	1838
	PIF (%)		2.8	3.3	1.5	–	1.2	–	2.4	4.4	1.9	3.5
	Prevented cases		1709	523	171	–	91	–	86	321	77	66
	Cumulative cases		11,894	3570	1173	–	661	–	617	2260	539	440
Women	Projected cases		89,918	14,462	6370	33,689	–	10,340	10,276	3634	3450	646
	PIF (%)		2.4	1.5	0.7	1.5	–	8.2	1.3	4.3	1.4	3.5
	Prevented cases		2224	220	46	528	–	925	134	163	50	23
	Cumulative cases		15,624	1499	311	3648	–	6618	962	1149	360	151
All Associated	Projected cases		148,475	29,888	17,307	33,689	7637	10,340	13,780	10,543	7340	2483
	PIF (%)		2.6	2.4	1.2	1.5	1.2	8.2	1.6	4.4	1.7	3.5
	Prevented cases		3933	743	217	528	91	925	220	484	127	90
	Cumulative cases		27,519	5069	1484	3648	661	6618	1579	3409	899	591
Men	Projected cases	2	57,723	15,170	10,851	–	7591	–	3462	6754	3851	1805
	PIF (%)		4.2	4.9	2.3	–	1.8	–	3.6	6.6	2.9	5.2
	Prevented cases		2543	779	258	–	137	–	129	476	115	99
	Cumulative cases		17,864	5367	1774	–	1000	–	930	3386	813	660
Women	Projected cases		88,641	14,349	6346	33,237	–	9906	10,206	3554	3425	634
	PIF (%)		3.8	2.3	1.1	2.9	–	12.1	2.0	6.4	2.2	5.2
	Prevented cases		3501	333	70	980	–	1359	203	244	76	35
	Cumulative cases		24,879	2287	476	6843	–	9884	1469	1736	550	229
All Associated	Projected cases		146,364	29,519	17,197	33,237	7591	9906	13,668	10,308	7276	2439
	PIF (%)		4	3.6	1.9	2.9	1.8	12.1	2.4	6.5	2.6	5.2
	Prevented cases		6044	1112	327	980	137	1359	332	720	191	134
	Cumulative cases		42,742	7653	2250	6843	1000	9884	2399	5122	1363	889
Men	Projected cases	3	56,021	14,645	10,671	–	7494	–	3374	6442	3771	1739
	PIF (%)		7.0	8.2	3.9	–	3.0	–	6.1	10.9	4.9	8.7
	Prevented cases		4245	1304	438	–	234	–	217	789	195	165
	Cumulative cases		30,468	9170	3066	–	1735	–	1599	5745	1403	1126
Women	Projected cases		86,430	14,154	6304	32,383	–	9219	10,086	3420	3380	615
	PIF (%)		6.2	3.6	1.7	5.4	–	18.2	3.1	9.9	3.5	8.1
	Prevented cases		5712	529	112	1835	–	2047	323	378	121	54
	Cumulative cases		41,689	3690	773	13,217	–	15,377	2377	2755	888	364
All Associated	Projected cases		142,452	28,799	16,975	32,383	7494	9219	13,460	9861	7151	2354
	PIF (%)		6.5	6.0	3.1	5.4	3.0	18.2	3.9	10.6	4.2	8.5
	Prevented cases		9957	1833	550	1835	234	2047	541	1166	316	219
	Cumulative cases		72,157	12,860	3839	13,217	1735	15,377	3975	8501	2291	1491
Men	Projected cases	4	58,448	15,392	10,926	–	7631	–	3499	6889	3885	1833
	PIF (%)		3.0	3.5	1.6	–	1.3	–	2.6	4.7	2.1	3.7
	Prevented cases		1818	556	183	–	97	–	92	341	82	71
	Cumulative cases		12,671	3803	1251	–	705	–	657	2406	574	468
Women	Projected cases		90,390	14,525	6383	33,693	–	10,591	10,314	3679	3465	652
	PIF (%)		1.9	1.1	0.5	1.5	–	6.0	0.9	3.1	1.0	2.5
	Prevented cases		1752	158	33	524	–	674	96	118	36	17
	Cumulative cases		12,235	1070	221	3621	–	4782	686	825	257	108
All Associated	Projected cases		148,838	29,917	17,309	33,693	7631	10,591	13,813	10,568	7349	2486
	PIF (%)		2.3	2.3	1.2	1.5	1.3	6.0	1.3	4.2	1.6	3.4
	Prevented cases		3570	714	215	524	97	674	188	459	118	87
	Cumulative cases		24,906	4874	1472	3621	705	4782	1344	3231	831	577
Men	Projected cases	5	57,179	15,002	10,794	–	7561	–	3434	6654	3826	1784
	PIF (%)		5.1	5.9	2.8	–	2.2	–	4.4	8.0	3.5	6.3
	Prevented cases		3087	947	315	–	168	–	157	576	141	120
	Cumulative cases		21,824	6561	2176	–	1228	–	1139	4130	997	807
Women	Projected cases		89,025	14,395	6355	33,290	–	10,080	10,234	3586	3435	639
	PIF (%)		3.4	2.0	0.9	2.7	–	10.5	1.7	5.6	1.9	4.5
	Prevented cases		3117	287	60	928	–	1186	175	211	66	30
	Cumulative cases		22,043	1964	408	6469	–	8564	1262	1497	472	197
All Associated	Projected cases		146,205	29,397	17,150	33,290	7561	10,080	13,669	10,240	7261	2423
	PIF (%)		4.1	4.0	2.1	2.7	2.2	10.5	2.4	7.1	2.8	5.8
	Prevented cases		6204	1234	375	928	168	1186	332	788	206	150
	Cumulative cases		43,867	8525	2584	6469	1228	8564	2400	5627	1469	1004

Table 5a (*continued*)

Sex	Statistic	CTF[a]	All Associated	Colon	Rectum	Breast[b]	Prostate[c]	Endometrium	Thyroid	Kidney	Pancreas	Stomach[d]
Men	Projected cases	6	54,968	14,319	10,556	–	7432	–	3318	6251	3721	1698
	PIF (%)		8.8	10.2	5.0	–	3.8	–	7.6	13.5	6.2	10.8
	Prevented cases		5298	1630	553	–	297	–	273	980	246	206
	Cumulative cases		38,670	11,650	3924	–	2225	–	2039	7268	1793	1429
Women	Projected cases		86,342	14,122	6297	32,510	–	9113	10,067	3398	3372	612
	PIF (%)		6.3	3.8	1.9	5.0	–	19.1	3.3	10.5	3.7	8.6
	Prevented cases		5800	561	119	1707	–	2153	343	399	128	57
	Cumulative cases		42,431	3929	824	12,229	–	16,271	2531	2925	945	387
All Associated	Projected cases		141,310	28,441	16,853	32,510	7432	9113	13,385	9649	7093	2309
	PIF (%)		7.3	7.2	3.8	5.0	3.8	19.1	4.4	12.5	5.0	10.2
	Prevented cases		11,098	2191	672	1707	297	2153	616	1379	374	264
	Cumulative cases		81,100	15,579	4748	12,229	2225	16,271	4570	10,193	2738	1816

Sex	Statistic	CTF	Myeloma	Ovary	Liver	Esophagus[f]	Gallbladder
Men	Projected cases	Base	2965	–	3342	2109	373
	PAR (%)		10.8	–	14.8	35.1	16.1
	Attributable cases		321	–	496	740	60
Women	Projected cases		1934	3366	909	287	688
	PAR (%)		6.5	3.9	13.4	29.0	15.8
	Attributable cases		125	131	121	83	109
All Associated	Projected cases		4899	3366	4251	2396	1061
	PAR (%)		9.1	3.9	14.5	34.4	15.9
	Attributable cases		446	131	618	824	169
Men	Projected cases	1	2898	–	3236	1921	360
	PIF (%)		2.2	–	3.2	8.9	3.5
	Prevented cases		67	–	106	187	13
	Cumulative cases		463	–	757	1328	89
Women	Projected cases		1906	3338	880	265	662
	PIF (%)		1.4	0.8	3.2	7.8	3.8
	Prevented cases		28	28	29	23	26
	Cumulative cases		191	205	198	160	172
All Associated	Projected cases		4804	3338	4116	2186	1022
	PIF (%)		1.9	0.8	3.2	8.8	3.7
	Prevented cases		94	28	135	210	39
	Cumulative cases		653	205	954	1488	261
Men	Projected cases	2	2865	–	3184	1836	353
	PIF (%)		3.4	–	4.7	13	5.2
	Prevented cases		100	–	158	273	19
	Cumulative cases		698	–	1138	1965	133
Women	Projected cases		1892	3323	866	254	649
	PIF (%)		2.2	1.3	4.7	11.5	5.7
	Prevented cases		42	43	43	33	39
	Cumulative cases		291	314	300	240	261
All Associated	Projected cases		4757	3323	4050	2090	1002
	PIF (%)		2.9	1.3	4.7	12.8	5.5
	Prevented cases		142	43	201	306	59
	Cumulative cases		989	314	1438	2205	394
Men	Projected cases	3	2796	–	3077	1672	340
	PIF (%)		5.7	–	7.9	20.7	8.7
	Prevented cases		168	–	265	437	32
	Cumulative cases		1200	–	1947	3250	227
Women	Projected cases		1867	3297	841	237	627
	PIF (%)		3.5	2.1	7.4	17.4	8.8
	Prevented cases		67	69	67	50	61
	Cumulative cases		470	510	479	373	415
All Associated	Projected cases		4664	3297	3919	1909	968
	PIF (%)		4.8	2.1	7.8	20.3	8.8
	Prevented cases		235	69	332	487	93
	Cumulative cases		1671	510	2426	3623	642
Men	Projected cases	4	2894	–	3229	1910	359
	PIF (%)		2.4	–	3.4	9.4	3.7
	Prevented cases		71	–	113	199	14
	Cumulative cases		493	–	806	1412	94
Women	Projected cases		1914	3346	888	271	669
	PIF (%)		1.0	0.6	2.3	5.7	2.7
	Prevented cases		20	20	21	16	19
	Cumulative cases		136	146	142	116	124
All Associated	Projected cases		4808	3346	4117	2181	1028
	PIF (%)		1.9	0.6	3.1	9.0	3.1
	Prevented cases		91	20	134	215	33
	Cumulative cases		629	146	948	1528	218
Men	Projected cases	5	2843	–	3150	1782	349

Table 5a (*continued*)

Sex	Statistic	CTF	Myeloma	Ovary	Liver	Esophagus[f]	Gallbladder
	PIF (%)		4.1	–	5.8	15.5	6.3
	Prevented cases		121	–	192	327	23
	Cumulative cases		855	–	1392	2378	163
Women	Projected cases		1898	3329	871	258	654
	PIF (%)		1.9	1.1	4.1	10.1	4.9
	Prevented cases		36	37	37	29	34
	Cumulative cases		250	269	258	207	225
All Associated	Projected cases		4741	3329	4021	2040	1003
	PIF (%)		3.2	1.1	5.4	14.9	5.4
	Prevented cases		158	37	229	356	57
	Cumulative cases		1105	269	1650	2585	387
Men	Projected cases	6	2753	–	3011	1578	332
	PIF (%)		7.1	–	9.9	25.2	10.8
	Prevented cases		212	–	331	531	40
	Cumulative cases		1532	–	2476	4046	288
Women	Projected cases		1863	3293	837	234	624
	PIF (%)		3.7	2.2	7.8	18.3	9.4
	Prevented cases		71	73	71	53	64
	Cumulative cases		501	544	509	395	440
All Associated	Projected cases		4616	3293	3848	1813	956
	PIF (%)		5.8	2.2	9.5	24.3	9.9
	Prevented cases		282	73	402	583	105
	Cumulative cases		2033	544	2985	4441	728

Abbreviations: PIF = potential impact fraction. CTF = counterfactual scenario.

[a] Scenario 1 = population BMI held at 2018 level. Scenario 2 = population mean BMI reduced by 1. Scenario 3 = Population BMI reverted to 1994 distribution. Scenario 4 = 5% within guideline. Scenario 5 = 10% within guideline. Scenario 6 = 25% within guideline.

[b] Postmenopausal breast cancer.

[c] Advanced prostate cancer

[d] Stomach cardia cancer
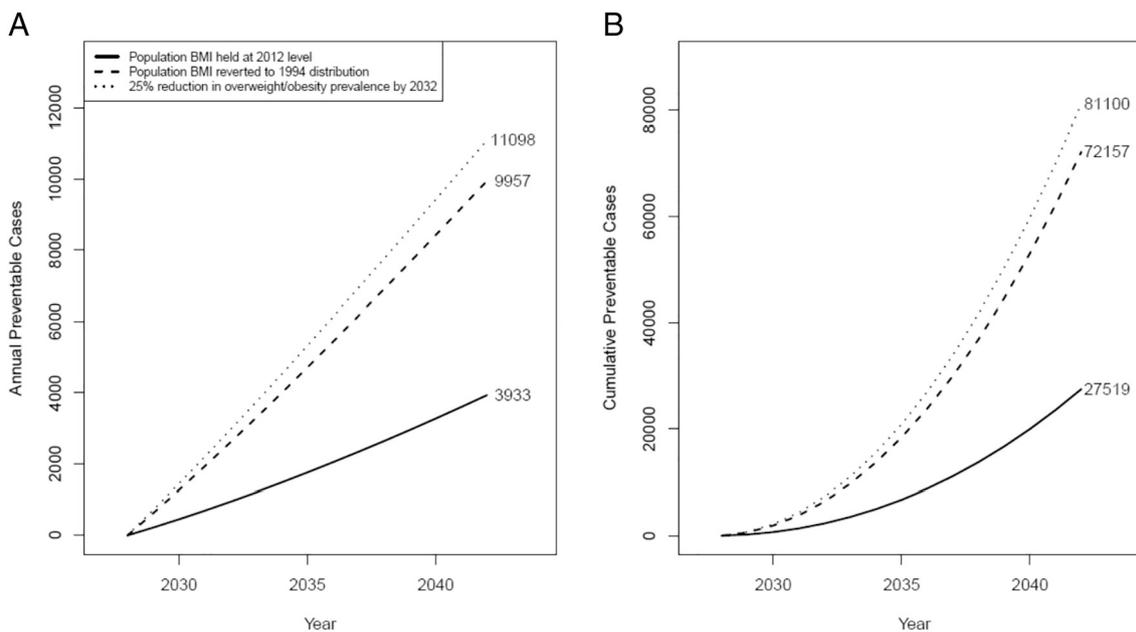
[f] Esophageal adenocarcinoma.

Fig. 1. A) Projected annual preventable cases attributable to excess body weight by applying three counterfactual scenarios; B) projected cumulative preventable cancer cases attributable to excess body weight by applying three counterfactual scenarios.

UK and Australia. Kendall et al. estimated that in Australia in 2010, 3.4% of all cancers or 3917 cases were attributable to excess body weight (Kendall et al., 2015) which is similar to our estimate of 3.1%. Parkin and Boyd estimated that 5.5% of all cancers, or 17,294 cases in 2010, were attributable to excess body weight in the UK (Parkin and Boyd, 2011). The greater number of attributable cases in the UK, when compared to our estimates and those from Australia, can be explained by the larger population in the UK and their inclusion of pre-and post-

menopausal breast cancer cases, which differed from our estimates and those from Australia, which included only postmenopausal breast cancer.

Recently, we estimated that in Alberta in 2010, 4.2% of all cancers and 13.3% of all associated cancers (colorectal, breast, kidney, pancreas, esophagus, endometrium and gallbladder) were attributable to excess body weight as measured by BMI (Brenner et al., 2017). A similar study that estimated the cancers attributable to excess body

Table 5b

Projected cancer cases and proportions attributable to waist circumference increase and the proportion of cancer cases in Canada that could be prevented in 2042 with various changes in waist circumference.

Sex	Statistic	CTF[a]	All Associated	Colon-rectum	Breast[b]	Prostate[c]	Endometrium	Thyroid	Kidney	Pancreas
Men	Projected cases	Base	50,610	28,094	–	7728	–	3591	7230	3967
	PAR (%)		12.6	10.8	–	15.8	–	13.6	14.5	14.5
	Attributable cases		6379	3042	–	1221	–	488	1051	577
Women	Projected cases		84,255	21,064	34,217	–	11,266	10,410	3797	3501
	PAR (%)		18.0	17.5	13.1	–	27.0	21.8	23.2	23.2
	Attributable cases		15,193	3686	4497	–	3046	2267	883	814
All Associated	Projected cases		134,865	49,158	34,217	7728	11,266	14,001	11,028	7467
	PAR (%)		16.0	13.7	13.1	15.8	27.0	19.7	17.5	18.6
	Attributable cases		21,572	6728	4497	1221	3046	2755	1934	1390
Men	Projected cases	1	50,475	28,031	–	7702	–	3581	7207	3954
	PIF (%)		0.3	0.2	–	0.3	–	0.3	0.3	0.3
	Prevented cases		135	63	–	27	–	10	23	12
	Cumulative cases		1409	635	–	295	–	111	237	130
Women	Projected cases		83,812	20,959	34,094	–	11,170	10,342	3771	3476
	PIF (%)		0.5	0.5	0.4	–	0.8	0.6	0.7	0.7
	Prevented cases		443	105	123	–	96	68	27	25
	Cumulative cases		4596	1049	1269	–	1013	722	279	263
All Associated	Projected cases		134,287	48,990	34,094	7702	11,170	13,923	10,978	7430
	PIF (%)		0.4	0.3	0.4	0.3	0.8	0.6	0.4	0.5
	Prevented cases		578	168	123	27	96	78	49	37
	Cumulative cases		6004	1684	1269	295	1013	834	516	393
Men	Projected cases	2	50,341	27,968	–	7675	–	3570	7185	3942
	PIF (%)		0.5	0.4	–	0.7	–	0.6	0.6	0.6
	Prevented cases		269	125	–	53	–	21	45	25
	Cumulative cases		2811	1267	–	589	–	222	473	259
Women	Projected cases		83,374	20,855	33,972	–	11,076	10,275	3744	3452
	PIF (%)		1.0	1.0	0.7	–	1.7	1.3	1.4	1.4
	Prevented cases		881	210	246	–	190	134	53	49
	Cumulative cases		9159	2092	2533	–	2016	1439	555	524
All Associated	Projected cases		133,715	48,823	33,972	7675	11,076	13,846	10,929	7394
	PIF (%)		0.9	0.7	0.7	0.7	1.7	1.1	0.9	1.0
	Prevented cases		1150	335	246	53	190	155	98	74
	Cumulative cases		11,971	3359	2533	589	2016	1661	1028	783
Men	Projected cases	3	49,943	27,783	–	7597	–	3540	7118	3905
	PIF (%)		1.3	1.1	–	1.7	–	1.4	1.5	1.5
	Prevented cases		667	311	–	132	–	51	112	61
	Cumulative cases		6985	3152	–	1462	–	552	1175	644
Women	Projected cases		82,084	20,547	33,609	–	10,801	10,079	3667	3381
	PIF (%)		2.6	2.5	1.8	–	4.1	3.2	3.4	3.4
	Prevented cases		2171	518	608	–	465	330	130	120
	Cumulative cases		22,657	5182	6289	–	4966	3556	1370	1294
All Associated	Projected cases		132,027	48,329	33,609	7597	10,801	13,619	10,786	7286
	PIF (%)		2.1	1.7	1.8	1.7	4.1	2.7	2.2	2.4
	Prevented cases		2838	829	608	132	465	382	242	181
	Cumulative cases		29,642	8334	6289	1462	4966	4108	2545	1938

[a] Scenario 1 = reduced the trend of increasing waist circumference by 5%. Scenario 2 = reduced the trend of increasing waist circumference by 10%. Scenario 3 = reduced the trend of increasing waist circumference by 25%. Abbreviations: PAR = population attributable risk, PIF = potential impact fraction.

[b] Postmenopausal breast cancer.

[c] Advanced prostate cancer.

weight in Canada in 2010 was recently reported by the Public Health Agency of Canada (Zakaria and Shaw, 2017); Zakaria and Shaw estimated that 9645 cancer cases in 2010, which represents 5.7% of all cancers and 14.9% of associated cancers, were attributable to high BMI. The result differs somewhat from our estimation that 5742 cancer cases in 2015, representing 3.3% of all cancers and 7.2% of associated cancers were attributable to high BMI. The difference is largely explained by the different reference BMI set in the two studies. Zakaria and Shaw used RR for median BMI of the overweight or obese category relative to $21 \, kg/m^2$, an accepted optimal value, whereas we used RR for median BMI of the overweight, obese, or severe obese category relative to $25 \, kg/m^2$, a threshold commonly used in research (Zakaria and Shaw, 2017). Both approaches are reasonable, but their differences underline the importance of explicitly stating the reference exposure in population attributable risk studies.

To our knowledge, our study is the first to estimate the current burden and future avoidable burden of cancer due to excess abdominal adiposity, including waist circumference measures and waist-to-hip ratios. All other population attributable risk estimates only include BMI as their estimate of excess body weight, which may not adequately capture body fat distribution and composition (Nevill et al., 2006). By including abdominal adiposity measures such as waist circumference and waist-to-hip ratio, this analysis provides more accurate information about the impact of body shape and fat distribution on cancer burden. As additional evidence continues to emerge, body fat distribution appears to be a more relevant risk factor not only for cancer, but also for all-cause mortality (De Ridder et al., 2016; Staiano et al., 2012). Cardiometabolic dysfunction is likely the driver of this increased risk (Piche et al., 2018). Waist circumference and waist-to-hip ratio are independently associated with cancer risk and are thus important to include when estimating the burden of cancer attributable to both total and abdominal adiposity. Future research could also estimate the overall PAR of BMI, WC, and WHR combined if additional information on the risk interactions and the correlations of these three exposures
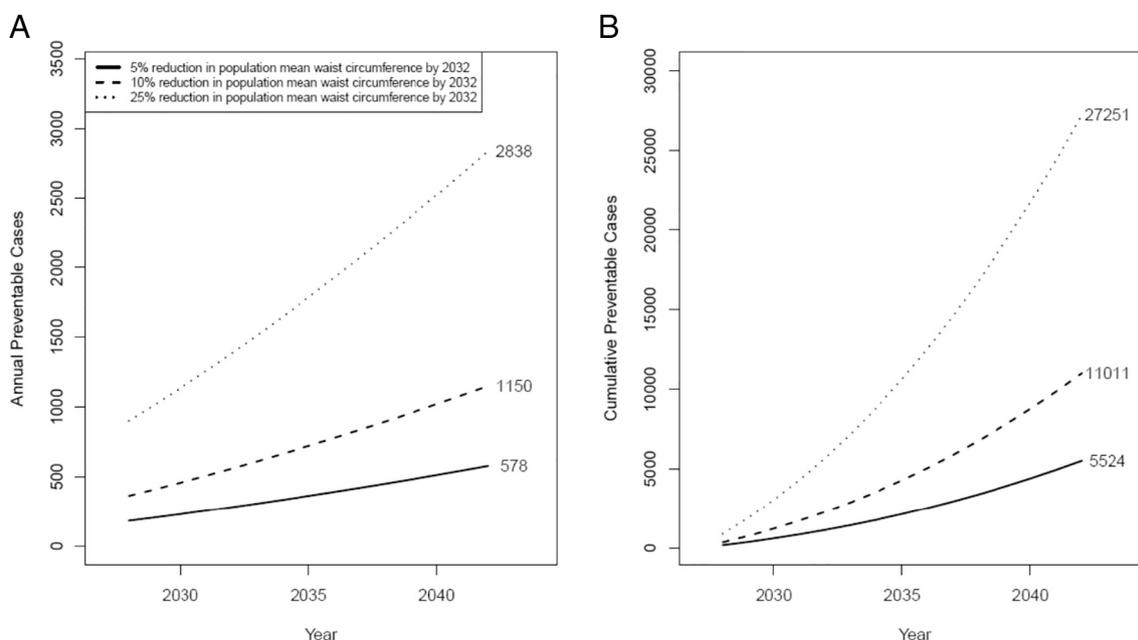
Fig. 2. A) Projected annual preventable cases attributable to waist circumference increase by applying three counterfactual scenarios; B) projected cumulative cases attributable to waist circumference increase by applying three counterfactual scenarios.

were available in a valid form within the literature across the cancer sites of interest. Nevertheless, we acknowledge this knowledge gap as an interesting topic for upcoming research.

In our analyses we have estimated attributable and avoidable fractions of cancer associated with three related measures of excess body size. We acknowledge the high correlation between the measures and present all of the measures to better reflect the state of the evidence around excess body size and cancer burden than can be obtained by using only BMI. Furthermore, our results suggest that the choice of measure used for excess body weight (BMI, waist circumference, or waist-to-hip ratio) has a meaningful impact on the attributable burden estimates. The first difference is that, while we included 13 associated cancer sites for BMI (if grouping colon and rectal cancer as colorectal cancer), we only included seven sites for waist circumference and waist-to-hip ratio. More research is needed on the BMI-associated cancer sites for which there is insufficient evidence to date to elucidate the association with measures of abdominal adiposity. Second, the estimated attributable fraction and number of cases differ among the three measurements. When limited to the seven sites for waist circumference and waist-to-hip ratio, PAR for high BMI, for waist circumference, and for waist-to-hip ratio is 7.2%, 8.9%, and 10.0%, respectively. These differences can be explained by the difference in the period of measured prevalence and the different risk estimates for some cancer sites. BMI prevalence was measured from CCHS in 2003, while waist circumference and waist-to-hip ratio were obtained from CHMS in 2007–2011. When estimating current burden attributable to the latter two measurements, we assumed that the prevalence is representative of the 2003 population, which likely overestimated the prevalence and the attributable fraction, and this is, therefore, a limitation of our study. Third, the BMI measure from CCHS was self-reported, whereas the waist circumference and waist-to-hip ratios from CHMS were measured and calculated by specialists at mobile examination centers (Statistics Canada, 2011). Self-reported BMI values from CCHS are known to underestimate true BMI (Shields et al., 2011).

Another strength of our analysis is that we used updated cancer incidence data in Canada, while adding more provincial data to our previous Alberta-only analyses (Brenner et al., 2017). Finally, our analysis is more inclusive of cancer sites associated with excess body weight than both the Australia and UK studies. The additional cancer

sites included in our analysis for excess body weight are liver, advanced prostate, stomach-cardia, thyroid, and myeloma. The addition of these cancer sites represents recent updates in WCRF/AICR Continuous Update Projects and meta-analyses regarding the risk between cancer and excess body weight and abdominal adiposity. Finally, our study expands the current literature base by providing projection estimates of future avoidable burden of cancer to 2042.

One limitation of our analysis is that exposure prevalence data from the CCHS are self-reported. Validation of Canadian data on obesity has shown that self-reported measures underestimate the prevalence of obesity by 4%–7% (Public Health Agency of Canada, 2011). We therefore conducted sensitivity analyses with the adjusted BMI using correction formulas from a study that addressed the bias in self-reported heights and weights among CCHS respondents (Shields et al., 2011). After adjusting for self-reporting bias, we estimated that 7226 cases (3044 for men, 4182 for women) were attributable to excess body weight, which accounts for 9.0% of associated cancers in 2015 (Supplementary Table 3). Another limitation of using CCHS prevalence data is the missing data in the height and weight fields, particularly among female respondents. We found that 6.0% of female respondents did not report their weight and/or height, while only 0.6% of male respondents did not. Nevertheless, the missing data are unlikely to impact the validity of our study. Under the missing-at-random assumption, our sensitivity analysis showed that the attributable cases (adjusted for self-reporting) increased from 3044 to 3060 for men, and from 4182 to 4344 for women (data not shown). While the CCHS and CHMS have attempted to be representative of the Canadian population, the rapidly changing ethnography of Canada may impact the validity of the results to all ethnic groups. Furthermore, our study is limited by conducting separate analyses for excess body weight and physical activity, which are actually strongly related. By conducting separate analyses we are likely overestimating the burden due to excess body weight and abdominal adiposity, considering that some of the attributable burden may actually be due to physical inactivity and other related lifestyle factors such as dietary intake.

Our study also estimated the future cancer burden attributable to excess body weight in Canada and the preventable cases under proposed intervention targets. A similar projection has been carried out in the Nordic countries (Andersson et al., 2017). Andersson et al. (2017)

Table 5c

Projected cancer cases and proportions attributable to waist-to-hip ratio increase and the proportion of cancer cases in Canada that could be prevented in 2042 with various changes in waist-to-hip ratio.

Sex	Statistic	CTF[a]	All Associated	Colon-rectum	Breast[b]	Prostate[c]	Endometrium	Thyroid	Kidney	Pancreas
Men	Projected cases	Base	50,610	28,094	–	7728	–	3591	7230	3967
	PAR (%)		16.3	15.6	–	13.9	–	13.1	22.6	17.2
	Attributable cases		8247	4383	–	1078	–	470	1633	683
Women	Projected cases		84,255	21,064	34,217	–	11,266	10,410	3797	3501
	PAR (%)		10.3	11.8	7.1	–	14.4	9.9	17.5	13.1
	Attributable cases		8707	2495	2436	–	1625	1026	666	460
All Associated	Projected cases		134,865	49,158	34,217	7728	11,266	14,001	11,028	7467
	PAR (%)		12.6	14	7.1	13.9	14.4	10.7	20.8	15.3
	Attributable cases		16,955	6878	2436	1078	1625	1496	2299	1143
Men	Projected cases	1	50,445	28,007	–	7707	–	3582	7196	3953
	PIF (%)		0.3	0.3	–	0.3	–	0.3	0.5	0.3
	Prevented cases		165	87	–	21	–	9	35	14
	Cumulative cases		1722	880	–	235	–	98	364	145
Women	Projected cases		83,998	20,990	34,148	–	11,216	10,380	3777	3487
	PIF (%)		0.3	0.4	0.2	–	0.4	0.3	0.6	0.4
	Prevented cases		257	74	69	–	49	30	21	14
	Cumulative cases		2663	737	713	–	527	321	218	148
All Associated	Projected cases		134,443	48,997	34,148	7707	11,216	13,962	10,972	7440
	PIF (%)		0.3	0.3	0.2	0.3	0.4	0.3	0.5	0.4
	Prevented cases		422	161	69	21	49	39	55	28
	Cumulative cases		4385	1617	713	235	527	419	582	293
Men	Projected cases	2	50,280	27,921	–	7687	–	3573	7161	3939
	PIF (%)		0.7	0.6	–	0.5	–	0.5	1.0	0.7
	Prevented cases		330	173	–	42	–	18	69	27
	Cumulative cases		3437	1757	–	470	–	196	725	289
Women	Projected cases		83,743	20,917	34,080	–	11,167	10,350	3756	3473
	PIF (%)		0.6	0.7	0.4	–	0.9	0.6	1.1	0.8
	Prevented cases		512	147	138	–	98	59	42	28
	Cumulative cases		5314	1470	1423	–	1050	641	434	296
All Associated	Projected cases		134,023	48,837	34,080	7687	11,167	13,923	10,917	7412
	PIF (%)		0.6	0.7	0.4	0.5	0.9	0.6	1.0	0.7
	Prevented cases		842	321	138	42	98	78	111	55
	Cumulative cases		8751	3227	1423	470	1050	837	1159	585
Men	Projected cases	3	49,792	27,664	–	7624	–	3546	7060	3899
	PIF (%)		1.6	1.5	–	1.3	–	1.3	2.4	1.7
	Prevented cases		818	430	–	104	–	45	170	68
	Cumulative cases		8542	4369	–	1168	–	488	1799	718
Women	Projected cases		82,988	20,700	33,875	–	11,023	10,262	3695	3433
	PIF (%)		1.5	1.7	1	–	2.2	1.4	2.7	1.9
	Prevented cases		1267	365	342	–	243	147	102	68
	Cumulative cases		13,185	3646	3541	–	2600	1591	1073	734
All Associated	Projected cases		132,780	48,363	33,875	7624	11,023	13,808	10,755	7331
	PIF (%)		1.5	1.6	1	1.3	2.2	1.4	2.5	1.8
	Prevented cases		2085	795	342	104	243	192	273	136
	Cumulative cases		21,727	8015	3541	1168	2600	2080	2872	1452

[a] Scenario 1 = reduced the trend of increasing waist-to-hip ratio by 5%. Scenario 2 = reduced the trend of increasing waist-to-hip ratio by 10%. Scenario 3 = reduced the trend of increasing waist-to-hip ratio by 25%. Abbreviations: PAR = population attributable risk, PIF = potential impact fraction.

[b] Postmenopausal breast cancer.

[c] Advanced prostate cancer.

projected the future cancer incidence in the Nordic countries up to 2045 and assumed constant future prevalence of overweight and obesity at the levels observed in the most recent year. They applied the proportions shift method (Barendregt and Veerman, 2010) on the categorical BMI prevalence and studied the potential impact fractions of both short and longer term interventions. These authors showed that both interventions resulted in a considerable number of preventable cancer cases, highlighting the importance of setting priorities on the prevention of excess body weight. Our study used BMI as a continuous exposure instead of a categorical one, which allowed us to use the distribution shift method, and which has been shown to perform much better than the proportions shift method (Barendregt and Veerman, 2010). It also has the capability of applying more versatile intervention targets. Based on the past trend in Canada, it is unreasonable to assume a constant future prevalence of excess body weight. Therefore, we modeled and projected the future BMI trend under the assumptions that the population BMI is approximately lognormal and that the mean and standard deviation of

this lognormal distribution increase linearly over time. These assumptions have not been seriously violated in the historical data (Supplemental Fig. 1). Although our method of estimating future cancer burden and effects of interventions is simplistic and should be interpreted with caution, it has nevertheless incorporated most of our current knowledge on excess body weight in Canada and provides important messages for obesity intervention and cancer control.

4.1. Conclusions and implications for practice, policy or future research

The estimates from this study are useful for national and provincial stakeholders to inform decisions regarding future cancer prevention initiatives. Changes to excess body weight and abdominal adiposity in the Canadian population are likely to have broad impacts on other modifiable lifestyle risk factors and health outcomes, which strengthens the rationale for interventions targeted at improving body weight and composition. It is an urgent task for policymakers and public health
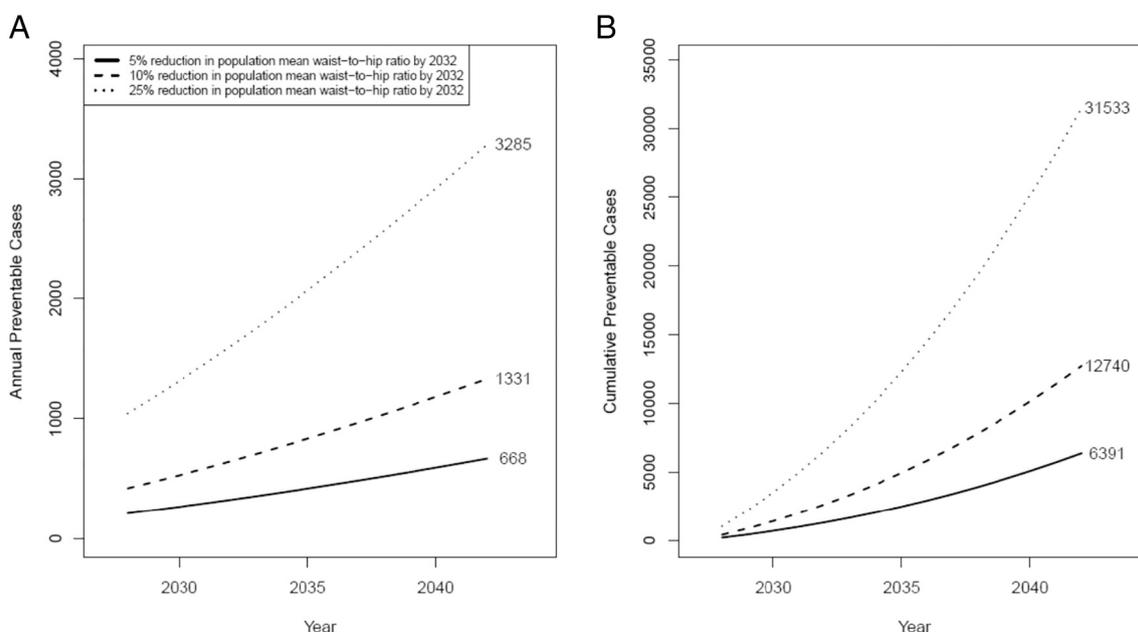
Fig. 3. A) Projected annual preventable cases attributable to waist-to-hip ratio increase by applying three counterfactual scenarios; B) projected cumulative cases attributable to waist circumference increase by applying three counterfactual scenarios.

agencies to intervene on the rising trend of obesity.

5. Conclusion

Our analysis provides evidence that could be used for interventions focused on reductions in excess body weight and abdominal adiposity, with the intent of reducing the future burden of cancer in Canada. The multiple counterfactual scenarios that we considered demonstrated that tens of thousands of associated cancer cases could be avoided by 2042 if reductions in body weight, waist circumference and waist-to-hip ratio were made now. If the population BMIs were returned to their 1994 distribution, 72,157 associated cancer cases could be prevented cumulatively by 2042. The results from this analysis provide potential aims for the effort to reduce cancer in burden in Canada by modifying factors associated with excess weight and abdominal adiposity.

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Conflict of interest

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2019.03.014.

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