

BMJ Open How did the tobacco ban increase inmates' body weight during incarceration in Canadian federal penitentiaries? A cohort study

Claire Johnson,¹ Jean-Philippe Chaput,² Maikol Diasparra,³ Catherine Richard,⁴ Lise Dubois⁴

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¹Interdisciplinary School of Health Sciences, University of Ottawa, Ottawa, Ontario, Canada

²Department of Human Nutrition, Children's Hospital of Eastern Ontario Research Institute, Ottawa, Ontario, Canada

³School of Epidemiology and Public Health, University of Ottawa Faculty of Medicine, Ottawa, Ontario, Canada

⁴School of Epidemiology and Public Health, University of Ottawa, Ottawa, Ontario, Canada

Correspondence to

Claire Johnson;
cjohn127@uottawa.ca

ABSTRACT

Objective This study aimed to determine how inmates' body weight changed during incarceration in Canadian federal penitentiaries, based on their history of tobacco use. Since tobacco was banned from all Canadian federal penitentiaries in 2008, little is known about the unintended health consequences of this ban, especially on inmates' body weight.

Design Cohort study.

Setting Participants were male and female inmates incarcerated for at least 6 months in Canadian federal penitentiaries. We collected data from 10 institutions in two Canadian regions (Ontario and Atlantic).

Participants We collected data from 754 inmates who volunteered to participate in the study.

Intervention This study examined weight change in relation to a history of tobacco use. In 2016–2017, anthropometric data were collected and compared with recorded anthropometric data at the beginning of incarceration (mean follow-up of 5.0±8.3 years). Self-reported data on tobacco and substance use were collected. Weight change was compared between inmates with and without a history of tobacco use.

Outcomes The main outcome measures were body weight change (kg), body mass index (BMI) change (kg/m²), annual weight change (kg/year), and BMI and waist circumference (cm) at the time of the interview.

Results During incarceration, ex-smokers gained more than twice the amount of weight compared with non-smokers (7.5 kg weight gain for smokers vs 3.7 kg weight gain for non-smokers). Once adjusted for covariates in a regression analysis, for inmates who gained the most weight (75th and 90th percentiles), non-smokers had, respectively, 1.64 and 2.3 lower BMI points than ex-smokers.

Conclusions During incarceration in Canadian federal penitentiaries, inmates with a history of tobacco use gained significantly more weight than non-smokers. This put them at increased risk of developing obesity-related health problems. This information is important for the prison setting when planning related programmes and regulation.

INTRODUCTION

Smoking, whether permitted or not, is a major part of the prison culture, mainly because so

Strengths and limitations of this study

- A strength of this study is its large sample size.
- Another strength is the prison setting, where it is possible to assess objectively measured weight change (outcome measurement) from admission to follow-up in a closed controlled environment.
- A limitation is that the data related to tobacco use were self-reported and therefore subject to recall and social desirability biases.
- The recruitment process was voluntary, and therefore there is a risk for selection bias.
- Another limitation is the observational nature of the data, which precludes inferences about causality, and residual confounding by unmeasured variables is possible.

many inmates identify as smokers. In Canada, smoking rates among inmates, prior to incarceration, are estimated to be between 50% and 93%.^{1–7} Those rates are four to five times the smoking rate of the general Canadian population,⁵ estimated to be between 13% and 17%.^{8–10} The primary reason why smoking rates are so high among prisoners is because many of them suffer from conditions that correlate with high tobacco use, including substance misuse, psychiatric disorders, poor impulse control and low socioeconomic backgrounds.^{11 12} Traditionally, before the tobacco ban in Canadian federal penitentiaries, the high rates of smoking meant inmates and staff were exposed to unusually high amounts of secondhand smoke.¹³ We know from studies on tobacco control in prison that total tobacco bans have reached their goal of reducing harmful exposure to secondhand smoke and subsequently reducing related ailments.¹⁴ In 2008, Canada proactively took the lead and adopted a total tobacco ban for all 41 federal correctional institutions.¹⁵ This means of the 14 000 inmates incarcerated

in federal penitentiaries across Canada, approximately 10 000 were forced to quit smoking on admission to the penitentiary (or quit smoking when the ban occurred in 2008).¹⁶ Although the tobacco ban is considered a good public health measure in several aspects (eg, improving air quality), there is a lack of research on the unintended consequences of tobacco bans in prisons.^{17–19} It is relevant to examine these unintended consequences because many prisons are now implementing tobacco control policies (from partial indoor bans to completely prohibiting tobacco) worldwide.^{7 20–22} Our findings on weight gain as an unintended consequence of a total tobacco ban could influence decision makers on their choice of tobacco control regulation and the support provided to inmates withdrawing from tobacco during incarceration.

Generally, studies on obesity in prison found obesity prevalence in male inmates to be similar or lower than the general population.^{23–25} However, many of the studies were self-reported, cross-sectional and did not assess change in weight during incarceration. Of the studies that did assess weight gain in prison, findings revealed that 50%–80% of inmates gained weight during incarceration.²⁶ Moreover, there appears to be important variability in weight gain, ranging from a modest 0.96 kg over 2 years²⁷ to a substantial 0.5 kg gain per week.²⁸ When inmates gained substantial amounts of weight, authors often speculated it is because of withdrawal from tobacco, alcohol or drugs.^{28 29} However, they lack data to back up these claims, since there are few data on the factors that contribute to weight gain during incarceration.²⁴ An American study demonstrated that female prisoners who participated in a voluntary smoking cessation programme (that included transdermal nicotine replacement) while incarcerated gained more weight at the 6-month postcessation follow-up compared with inmates who continued to smoke (on average 4.5 kg more than smokers).³⁰

The majority of studies on obesity in prison were out of Australia, the USA and the UK.²⁶ In our recent publication, we found that Canadian inmates gained a significant amount of weight during incarceration.²⁵ Our findings showed that, on admission, obesity rates were similar to the general Canadian population (~27%), but after at least 6 months of incarceration obesity rates increased to 45% for the inmate population.²⁵ We suspect the observed weight gain was associated with tobacco cessation in Canadian inmates.

To fill this knowledge gap, this study examined, for the first time, how inmates' body weight changed in Canadian federal penitentiaries during incarceration based on a history of tobacco use prior to incarceration. Our aim was to gain insight on the factors related to inmate weight gain by drawing a comparison between the weight gained (from admission to follow-up) in inmates who were in withdrawal from tobacco, or other substances (drugs and/or alcohol), and inmates not battling addictions during incarceration. Because smoking cessation is known to be associated with weight gain,^{31 32} we hypothesised that inmates with a history of tobacco use would

gain more weight during incarceration, in a penitentiary with a total tobacco ban, than inmates not in withdrawal from tobacco. We also hypothesised that inmates withdrawing from other substances (drugs and alcohol) would also gain more weight than inmates not going through withdrawal.

MATERIALS AND METHODS

This study is part of a larger research project that explored multiple determinants related to weight gain during incarceration in Canadian federal penitentiaries. Using the same methodology as described below, we also collected data on food intake³³ and physical activity.³⁴

Participants

Participants for this research project were male and female inmates who volunteered to take part in the study. To participate, they had to be incarcerated for at least 6 months in their current federal institutions in the Ontario or Atlantic region. In the Ontario region, we collected data from inmates housed in five institutions near Kingston (of the seven institutions in the Ontario region).¹⁵ These institutions were selected for geographical feasibility reasons. In the Atlantic region, we collected data from inmates housed in all five institutions in New Brunswick and Nova Scotia.¹⁵ Critically ill inmates admitted to the prison hospital and pregnant inmates were excluded from the study. The capacity of these institutions was approximately 2700 inmates.

Sampling

The sample was based on the National Statistical Service sample size calculator. There were approximately 1630 inmates eligible to participate in the study (they were in their current institution for at least 6 months and had anthropometric measurements taken on admission in their medical chart). Our sample had to be at least 300 inmates.³⁵ The inmate population is heavily male-dominated; ~95% of inmates are male, whereas only ~5% are female. Consequently, we attempted to recruit the most volunteers from the one female institution in Ontario and the one in the Atlantic region. The sampling was stratified to ensure an adequate number of participants from both sexes and from institutions with each feeding system to ensure the best possible comparison. We ended up recruiting far more male participants because many of them wanted to volunteer, and this increased the power of our statistical analysis. For ethical reasons, we accepted all participants who volunteered. A condition of our ethics approval was to accept all eligible volunteers to avoid feelings of rejection.

Data collection

Research assistants (trained registered dietitians) gathered data from 754 inmates who volunteered for a 30 min face-to-face interview from May 2016 until September 2017. They objectively measured participants' height,

weight and waist circumference following a standardised protocol. Then they subtracted current anthropometric data from the measurements recorded in the medical charts of participants (taken at the beginning of incarceration following a similar protocol) to determine anthropometric changes during incarceration. The standardised protocol was guided by a WHO report.³⁶ Participants' height was measured by standing against the wall, and weight measured on a scale. Two measurements were taken, and a third was taken if the first two measurements had a significant difference (≥ 0.5 cm for height and > 0.5 kg for weight). The final recorded measurement was the mean of the two nearest values. The measured data were then used to calculate body mass index (BMI) (kg/m^2).³⁶ The anthropometric measurements taken on admission were taken by healthcare professional staff (registered nurses), using a professional-grade, calibrated equipment and following a standardised protocol from Correctional Service Canada.

Outcomes

The main outcome measures for this study were body weight change (kg), BMI change (kg/m^2), annual weight change (kg/year), BMI (kg/m^2) and waist circumference (cm) at the time of the interview. The waist circumference outcome is a stand-alone indicator since it was not measured on admission, and therefore not available to make a comparison between admission and follow-up. Waist circumference was divided into two categories (high risk and low risk) based on the WHO cut-off points (men > 102 cm and women > 88 cm).³⁷ BMI categories were based on the WHO classification system.³⁸

Exposure

During the interview, we also gathered self-reported data on tobacco and substance use (drugs and alcohol) prior to incarceration. Specifically, inmates were asked the following five questions: (1) 'Incarceration forces many lifestyle changes, were you a smoker before your incarceration?' (response options: yes or no); (2) 'How many cigarettes did you smoke per day prior to your incarceration?' (response: number of cigarettes per day); (3) 'Did you have substance abuse problems before your incarceration?' (response options: yes or no); (4) 'Which substance?' (response options: alcohol or drugs or other with specification); and (5) 'How much alcohol did you consume (per day or per week) prior to your incarceration?' (response: number of drinks per day or number of drinks per week). We gathered this information to verify if our outcome measures changed significantly based on a history of tobacco use or substance (drugs and alcohol) use. We considered that ex-smokers were inmates who responded 'yes' to question 1, we considered an inmate to have substance/drug if they responded 'yes' to question 3, and we considered an inmate to have misused alcohol when they reported drinking five drinks or more on one occasion at least once per month for the past 12 months (WHO definition of a heavy drinker) or if an

inmate responded 'drinking a lot' or reported being an alcoholic to question 5.

Covariates

We adjusted our findings for the following covariates: sex, age, ethnicity, region, language, feeding system and length of incarceration as they were defined by Correctional Service Canada's standard and taken from inmates' chart. For physical activity, we adjusted for the reported time (number of minutes) spent doing moderate to vigorous physical activity per day. For diet, we gathered data from food frequency questionnaires. Then we took the variables that were most strongly associated with weight change (vegetable, fruit and sweetened beverages), and created an indicator to adjust for diet.

Statistical analysis

We performed χ^2 and non-parametric median comparison tests (Wilcoxon and Kruskal-Wallis) to detect statistically significant changes in anthropometric measurements (weight change, BMI change, yearly weight change, BMI at follow-up and waist circumference at follow-up) between inmates with and without a history of tobacco or substance use (exposure). These tests were performed because the data did not have a normal distribution (it was skewed to the right). We performed quantile regression analysis to examine whether associations were present for various quantiles (10th, 25th, 50th, 75th, 90th) of the BMI change distribution adjusted by sex, age, ethnicity, region, language, length of incarceration, substance abuse, physical activity, diet and feeding system. We opted for the conditional quantile regression model^{39–41} instead of the multivariate regression analysis on the mean because the residuals (from the multiple regression model) did not meet the model assumptions (ie, normality, linearity, homoscedasticity). We used the Statistical Analysis Software (SAS) V.9.4, and the level of statistical significance was set at $p < 0.05$ for all analyses.

Ethics approval

Inmates volunteered to participate and provided their consent by signing our consent form. Since most inmates hesitated to sign our forms because of low literacy and/or fear of reprisal, participants could provide verbal consent if they preferred.⁴² The verbal consent was obtained by the research assistants and witnessed by correctional staff. All personal data collected were coded to ensure confidentiality.

Participant involvement

The research team met with the inmate committee members to present the project and to pilot the questionnaire with them. We then got their feedback on how to adapt it to their preferences before starting our data collection. Once the exercise was completed, we drew a random list of inmates and called them to see if they wanted to participate in our study because we planned for a random sample (to reduce selection bias). However, this recruitment strategy yielded a very poor response rate

Table 1 BMI categories for inmates on admission and follow-up (n=754) in comparison with the Canadian adult population in 2015

	BMI categories	Inmates on admission (%)	Inmates at follow-up (%)	P value	Canadians (%)
Underweight	<18.5	1.3	0.1	<0.0001*	2.7
Normal weight	18.5–24.9	32.5	18.0		36.1
Overweight	25.0–29.9	41.6	39.4		34.6
Obesity total	≥30.0	24.5	42.4		26.7
Overweight and obesity	≥25.0	66.2	81.8		61.3
Obesity class I	30.0–34.9	14.7	26.8		17.2
Obesity class II	35.0–39.9	6.4	10.2		6.7
Extreme obesity	≥40.0	3.4	5.4		2.8

*P value is the result of the χ^2 test between the inmates' BMI categories on admission and at follow-up. A p value <0.05 was considered statistically significant for the comparison between admission and follow-up. The average length between admission and follow-up was 5.0±8.3 years.

BMI, body mass index.

because inmates found it stressful to be called on (over loudspeaker) without knowing why. We then reconvened with the inmate committee members to get advice on how to increase participation; we suggested we ask for volunteers to participate instead of using a random list. The convenience sample strategy was much more successful, with participants saying they felt more informed and empowered about why they were being called on. We recruited 754 participants over a 16-month period.

RESULTS

The participation rates were 45% (n=398/883 eligible inmates) for male inmates and 42% (n=45 participants/107 eligible inmates) for female inmates in Ontario. The participation rates were 47% (n=274 participants/583 eligible inmates) for male inmates and 64% (n=37 participants/58 eligible inmates) for female inmates in the Atlantic region.

Table 1 presents the proportion of inmates in each BMI category on admission and follow-up (mean duration of 5.0±8.3 years). It also shows how these proportions compare with the Canadian adult population (≥18 years of age) using data from Statistics Canada.⁴³ The prevalence of obesity for the general Canadian adult population was 26.7% in 2015, similar to our inmate sample on admission to the penitentiaries (24.5%). However, 42.4% of inmates were considered obese at follow-up. This represents a 73% increase in inmates' obesity rates between admission and follow-up. This comparison illustrates how inmates' weight increased much more compared with the general population. Moreover, the observed weight gain is deemed undesirable since it results in an increase in the prevalence of inmate with obesity during incarceration (as opposed to seeing inmates come into the institution underweight and having normal BMI as a result of the weight gain).

Table 2 presents the sociodemographic characteristics (age, region and ethnicity) associated with history of tobacco use and substance misuse (drugs and alcohol). Younger age was associated with more drug misuse. Regional differences were also observed. A higher proportion of inmates from the Atlantic region reported smoking tobacco, were heavier smokers and reported alcohol misuse compared with inmates from the Ontario region. Inmates with Aboriginal backgrounds reported higher rates of smoking and substance misuse (drugs and alcohol). Sex and language were not associated with tobacco use or substance misuse (data not shown in the table).

Table 3 shows the waist circumference and BMI data at follow-up (measured at the time of the interview) for inmates with and without a history of tobacco use and substance misuse. We did not observe a significant difference in waist circumference and BMI between inmates with or without a history of tobacco use. But we observed that the proportion of inmates with high-risk waist circumference increased in a dose–response fashion with the number of cigarettes smoked prior to incarceration. Inmates with a history of tobacco use or drug misuse were also more likely to have a high-risk waist circumference and to be obese than those without a history of tobacco use and substance misuse. In addition, there was a strong positive correlation (r=0.82) between waist circumference and BMI at follow-up (data not shown).

Table 4 presents the data on median weight change, median BMI change and median annual weight change for inmates who had a history of tobacco use or substance misuse (drugs and alcohol) compared with inmates who did not. More than two-thirds (67.5%) of our sample reported tobacco use before incarceration. We found that ex-smokers gained roughly twice the amount of weight compared with non-smokers over time (7.5 kg vs 3.7 kg, respectively). Moreover, weight gain was related to

Table 2 Sociodemographic characteristics (age, region and ethnicity), by history of tobacco use and substance (illicit drugs and alcohol) misuse (n=754)

	Age, n (%)					Region, n (%)					Ethnicity, n (%)				
	All, n (%)	18≤24 years	≥25≤34 years	≥35≤44 years	≥45≤64 years	P value	Atlantic	Ontario	P value	Caucasian	Black	Aboriginal	Other	P value	
		n	n	n	n										n
All, n (%)	754 (100)	63 (8)	221 (29)	176 (23)	249 (33)	45 (6)	311 (41)	443 (59)	470 (62)	124 (16)	106 (14)	54 (7)			
Ex-smoker	509 (68)	45 (71)	151 (68)	116 (66)	173 (69)	24 (53)	232 (75)	277 (63)	326 (69)	71 (57)	82 (77)	30 (56)	0.0019*		
	245 (32)	18 (29)	70 (32)	60 (34)	76 (31)	21 (47)	79 (25)	166 (37)	144 (31)	53 (43)	24 (23)	24 (44)			
Number of cigarettes smoked per day	105 (21)	8 (18)	40 (27)	26 (22)	25 (14)	6 (25)	36 (16)	69 (25)	51 (16)	30 (42)	16 (19)	8 (27)	<0.0001*		
<10	303 (59)	30 (67)	99 (66)	66 (57)	97 (56)	11 (46)	149 (64)	154 (56)	202 (62)	36 (51)	44 (54)	21 (70)			
>10≤25	101 (20)	7 (16)	12 (8)	24 (21)	51 (30)	7 (29)	47 (20)	54 (19)	73 (22)	5 (7)	22 (27)	1 (3)			
>25															
Illicit drug misuse	327 (43)	26 (41)	106 (48)	90 (51)	96 (39)	9 (20)	147 (47)	180 (41)	211 (45)	35 (28)	68 (64)	13 (24)	<0.0001*		
	427 (57)	37 (59)	115 (52)	86 (49)	153 (61)	36 (80)	164 (53)	263 (59)	259 (55)	89 (72)	38 (36)	41 (76)			
Alcohol misuse	150 (20)	10 (16)	34 (15)	38 (22)	55 (22)	13 (29)	81 (26)	69 (16)	105 (22)	8 (6)	35 (33)	2 (4)	<0.0001*		
	604 (80)	53 (84)	187 (85)	138 (78)	194 (78)	32 (71)	230 (74)	374 (84)	365 (78)	116 (94)	71 (67)	52 (96)			

χ² test was used for ex-smoker, illicit drug use and alcohol misuse by region. Wilcoxon test was used in analyses with continuous variables (ex-smoker, illicit drug use and alcohol by age). Kruskal-Wallis test was used in analyses with three or more categories (number of cigarettes smoked per day).

*P value <0.05 was considered statistically significant when comparing data between inmates with a history of substance use (tobacco, drugs and alcohol) with inmates without a history of substance use prior to incarceration.

the number of cigarettes smoked daily before incarceration, with heavy smokers gaining the most (light smokers (≤10 cigarettes/day) gained 5.6kg vs 10.2kg for heavy smokers (>25 cigarettes/day)). Approximately 50% of inmates reported a history of substance misuse prior to incarceration. These inmates gained 64% more weight, with a median weight gain of 7.4kg, compared with 4.5kg for inmates not battling an addiction to substances (drugs and/or alcohol) during incarceration. The type of substance was also associated with the amount of weight gained. The median weight gain for inmates with a history of drug misuse was three times higher than the weight gain of inmates with a history of alcohol misuse (8.4kg vs 2.6kg, respectively). Globally, BMI change and annual weight change followed a pattern similar to weight change.

Table 5 presents the results of a quantile regression coefficients analysis that confirms the association between BMI change and a history of smoking. For inmates from the groups with the highest weight change (75th and 90th percentiles), non-smokers had, respectively, 1.64 and 2.3 lower BMI points than ex-smokers. These findings also show similar findings for alcohol misuse. Moreover, BMI gain was significantly higher for inmates below the age of 45, for inmates of Aboriginal descent and inmates who were incarcerated the longest (length of incarceration >5 years). These findings were adjusted for sociodemographic factors (sex, age, region, language and ethnicity) as well as for other factors (length of incarceration, physical activity, feeding system and diet). Once findings were adjusted for confounders, the weight gain by number of cigarettes disappeared, suggesting the relationship was more influenced by another factor.

DISCUSSION

The most important finding of this study is that ex-smokers who were forced to quit smoking during incarceration gained more weight, and at a faster rate, than non-smokers did (1.6kg/year and 2.4 BMI increase for ex-smokers vs 0.9kg/year and 1.2 BMI increase for non-smokers). This represents an overall gain of roughly twice the weight than non-smokers did (7.5kg vs 3.7kg for ex-smokers and non-smokers, respectively). This weight gain was deemed unhealthy since most inmates had a normal or overweight BMI on admission (33% had normal BMI and 42% had overweight BMI), then weight gain in prison (7.5kg for ex-smokers) put a significant proportion of our sample in the obese range (BMI ≥30kg/m²). Our findings revealed that obesity rates went from 25% on admission to 42% at follow-up (or time of the study), representing a 68% increase in obesity rates. Moreover, since most ex-smokers will likely resume smoking once released from prison,^{7 17 44} they may end up with two compounding risk factors for developing chronic diseases. Many inmates are already vulnerable to unhealthy weight gain by being incarcerated,²⁶ and the added stress of involuntary tobacco cessation puts smokers at an even higher risk of becoming

Table 3 Waist circumference and BMI at follow-up by tobacco use and substance misuse (drugs and alcohol)

		All, n (%)	Waist circumference, n (%)		P value	BMI, n (%)			P value
			Low risk (men ≤102 cm and women ≤88 cm)	High risk (men >102 cm and women >88 cm)		Normal (18.5–24.9 kg/m ²)	Overweight (25.0–29.9 kg/m ²)	Obese (≥30 kg/m ²)	
All		754 (100)	364 (48.3)	390 (51.7)		137 (18.2)	297 (39.4)	320 (42.4)	
Ex-smoker	Yes	509 (67.5)	240 (47.2)	269 (52.8)	0.3731	87 (17.1)	193 (37.9)	229 (45.0)	0.0786
	No	245 (32.5)	124 (50.6)	121 (49.4)		50 (20.4)	104 (42.4)	91 (37.1)	
Number of cigarettes smoked per day	≤10	105 (13.9)	57 (54.3)	48 (45.7)	0.0200*	22 (21.0)	40 (38.1)	43 (41.0)	0.1659
	>10≤25	301 (40.1)	149 (49.2)	154 (50.8)		51 (16.9)	117 (38.9)	135 (44.9)	
	>25	101 (13.4)	34 (33.7)	67 (66.4)		14 (13.9)	36 (35.6)	51 (50.5)	
Illicit drug misuse	Yes	327 (43.4)	143 (43.7)	184 (56.2)	0.0288*	43 (13.1)	134 (41.0)	150 (45.9)	0.0150*
	No	427 (56.6)	221 (51.8)	206 (48.2)		94 (22.0)	163 (38.2)	170 (39.8)	
Alcohol misuse	Yes	242 (32.1)	111 (45.9)	131 (54.1)	0.0447*	42 (17.4)	95 (39.3)	105 (43.4)	0.1911
	No	512 (67.9)	253 (49.4)	259 (50.6)		95 (18.6)	202 (39.5)	215 (42.0)	

Alcohol misuse is defined as participants who drank an amount of alcohol ≥5 drinks on one occasion at least once a month for the past 12 months (WHO definition of a heavy drinker) or participants who responded 'drinking a lot' or being an alcoholic. Wilcoxon test was used in analyses with two categories (ex-smoker, illicit drug misuse and alcohol misuse) in comparison with inmates who reported that they did not use those substances. Kruskal-Wallis test was used in analyses with three categories (number of cigarettes smoked per day).

*P value <0.05 was considered statistically significant. The average length between admission and follow-up was 5.0±8.3 years. BMI, body mass index.

obese. This is important because a high proportion of inmates were smokers (67.5% of our sample) before incarceration, and it illustrates a need for more support for inmates withdrawing from tobacco during incarceration in Canadian penitentiaries.

Our findings are consistent with other studies on inmate addiction that found the prevalence for tobacco use and drug misuse to be three to four times higher in the inmate population (prior to incarceration) than in the general Canadian population.^{18 45 46} In our study, 67.5% of inmates reported a history of tobacco use, 43.4% of inmates reported illicit drug misuse, and 32.1% of inmates reported heavy alcohol use prior to incarceration, whereas in 2016, 16.9% of Canadians used tobacco,⁴⁷ 13% used illicit drugs,⁴⁸ and 17.9% misused alcohol or were considered 'heavy drinkers' by WHO standards (ie, more than five drinks on one occasion at least once a month for the past 12 months).⁴⁹ Overall, our findings showed that most inmates suffering from addictions (ie, tobacco and/or drugs) gained more weight during incarceration. Given the higher prevalence of tobacco and substance misuse, this puts a large proportion of inmates at increased risk of becoming obese and developing obesity-related illness.

It has been hypothesised by other authors that the rapid weight gain in the beginning of incarceration may be because inmates were withdrawing from alcohol, drugs and/or tobacco.^{28 50} In support of this hypothesis, studies from penitentiaries where tobacco was still permitted reported a modest weight gain (0.7–0.96 kg weight gain over 1–2 years).^{23 26 27 51 52} Contrary to Canadian data on inmate weight gain,²⁵ these studies found that inmates were less likely to be obese than the general

population,^{23 26 27 51 52} possibly in part because they were incarcerated in penitentiaries that still allowed smoking.

In prison, tobacco serves a range of functions, including being a surrogate currency, a means of social control, a symbol of freedom in a group with few rights and privileges, a stress reliever, and a social lubricant.⁴⁵³ Therefore, the importance of tobacco in the prison environment goes beyond what would be expected in the general population. These added functions of tobacco in prison should be taken into consideration when developing smoking cessation interventions. Furthermore, since before the ban tobacco and cigarettes were the main source of currency, now there are reports that inmates use junk food (chips, chocolate bars and soda drinks) as currency, to exchange services and to gamble.^{54 55} This new phenomenon may provide insight into the obesogenic effect of the tobacco ban. It may also go beyond smokers in prison, since it can potentially influence the obesogenic environment for everyone living in this environment. Now that junk food has become the new currency, it has become omnipresent in prison and therefore possibly consumed more frequently by all inmates.

The inclusion of tobacco cessation counselling and the use of cessation aids (such as nicotine replacement therapy) are deemed essential to long-term smoking cessation.^{13 30 56 57} In Canadian federal penitentiaries, these aids were available for inmates to purchase at the commissary store (or 'canteen'). This means inmates are responsible for purchasing these items themselves (with their own funds). However, there are reports that inmates cannot afford these expensive cessation aids because of very low income during incarceration (daily salary ~\$6 per day).⁵⁸ This could, in part, explain why inmates gained

Table 4 Median weight change, BMI change and annual weight change between admission and follow-up by tobacco use and substance misuse (drug and alcohol)

	All, n (%)	Median weight change, kg (95% CI)		Median BMI change, kg/m ² (95% CI)		Annual weight change, kg/year (95% CI)		P value
		Median weight change, kg (95% CI)	P value	Median BMI change, kg/m ² (95% CI)	P value	Annual weight change, kg/year (95% CI)	P value	
All	754 (100)	+5.6 (4.8 to 6.4)	<0.0001*	+1.8 (1.5 to 2.1)	<0.0001*	+1.4 (1.0 to 1.8)	0.0061*	
Ex-smoker	509 (67.5)	+7.5 (4.3 to 8.6)	<0.0001*	+2.4 (2.0 to 2.8)	<0.0001*	+1.6 (1.1 to 2.1)	0.0061*	
	245 (32.5)	+3.7 (2.5 to 4.9)		+1.2 (0.8 to 1.6)		+0.9 (0.2 to 1.5)		
Number of cigarettes smoked per day (n=509)	≤10	+5.6 (3.4 to 7.8)	<0.0001*	+1.8 (1.1 to 2.5)	<0.0001*	+1.3 (0.3 to 2.2)	0.0288*	
	>10≤25	+7.5 (6.1 to 8.9)		+2.4 (2.0 to 2.8)		+1.6 (0.9 to 2.3)		
	>25	+10.2 (7.4 to 13.0)		+3.7 (2.8 to 4.6)		+1.4 (0.6 to 2.1)		
Substance misuse	Yes	+7.4 (6.1 to 8.7)	0.0056*	+2.3 (1.9 to 2.7)	0.0047*	+1.4 (0.8 to 2.8)	0.0885	
	No	+4.5 (3.4 to 5.6)		+1.5 (1.2 to 1.8)		+1.3 (0.8 to 1.7)		
Substance type (n=379)	Alcohol	+2.6 (-1.1 to 6.3)	0.0013*	+0.8 (-0.4 to 2.8)	0.0013*	+0.3 (-0.6 to 1.2)	<0.0001*	
	Drugs	+8.4 (6.9 to 9.9)		+2.6 (2.1 to 3.11)		+2.6 (1.6 to 3.5)		
	Both	+6.8 (4.1 to 9.5)		+2.1 (1.2 to 3.0)		+0.8 (0.1 to 1.5)		
Illicit drug misuse	Yes	+8.0 (6.3 to 9.7)	0.0004*	+2.4 (2.0 to 2.8)	0.0003*	+1.7 (1.0 to 2.4)	0.0009*	
	No	+4.5 (3.4 to 5.6)		+1.4 (1.1 to 1.7)		+1.1 (0.7 to 1.5)		
Alcohol misuse	Yes	+5.5 (3.8 to 7.2)	0.4147	+1.8 (1.1 to 2.5)	0.5435	+1.4 (1.0 to 1.8)	0.8075	
	No	+5.8 (4.3 to 7.5)		+1.9 (1.6 to 2.2)		+1.3 (0.5 to 2.1)		

Wilcoxon test was used in analyses with two categories (ex-smoker, substance misuse, illicit drug misuse and alcohol misuse). Kruskal-Wallis test was used in analyses with three or more categories (number of cigarettes smoked per day, substance type).

*P value <0.05 was considered statistically significant. The average length between admission and follow-up was 5.0±8.3 years. BMI, body mass index.

Table 5 Quantile regression coefficients analysis for estimated BMI change based on history of smoking, alcohol misuse and sociodemographic factors and length of incarceration

Variables	10th percentile (CI)	25th percentile (CI)	50th percentile (CI)	75th percentile (CI)	90th percentile (CI)	
Ex-smoker	Yes	0 (reference)	0 (reference)	0 (reference)	0 (reference)	0 (reference)
	No	-0.94 (-1.96 to 0.52)	-0.6 (-1.87 to 0.1)	-0.61 (-1.81 to 0.20)	-1.64* (-2.72 to -0.60)	-2.3* (-4.92 to -0.83)
Number of cigarettes smoked per day	≤10	0 (reference)	0 (reference)	0 (reference)	0 (reference)	0 (reference)
	>10≤25	0.2 (-0.9 to 1.1)	0.3 (-0.8 to 0.9)	0.8 (-0.2 to 1.2)	0.2 (-1.5 to 1.0)	-0.4 (-2.5 to 1.1)
	>25	2.4 (-1.3 to 1.4)	0.5 (-1.0 to 1.9)	1.2 (-0.8 to 2.8)	0.4 (-0.8 to 1.7)	-0.25 (-3.1 to 2.2)
Alcohol misuse	Yes	0 (reference)	0 (reference)	0 (reference)	0 (reference)	0 (reference)
	No	0.7 (-0.0 to 2.0)	0.9* (0.12 to 1.65)	1.17* (0.24 to 1.90)	1.32* (0.42 to 2.05)	1.65 (-0.75 to 3.07)
Sex	Male	0 (reference)	0 (reference)	0 (reference)	0 (reference)	0 (reference)
	Female	-1.7* (-3.0 to -0.6)	-0.7 (-2.1 to 0.7)	-0.14 (-0.68 to 0.58)	1.44 (-0.80 to 3.05)	2.88* (1.29 to 7.14)
Age (years)	18≤24	0.7* (0.0 to 2.9)	-0.3 (-2.3 to 2.5)	-2.39 (-4.16 to 0.22)	-2.41* (-5.91 to -0.69)	-2.38 (-5.47 to 0.97)
	≥25≤34	0.4 (-0.3 to 6.9)	-0.7 (-2.5 to 2.4)	-1.89 (-3.36 to 0.40)	-2.2* (-5.06 to -0.44)	-2.93* (-5.58 to -0.32)
	≥35≤44	0.8* (0.2 to 7.4)	-0.2 (-2.2 to 2.7)	-1.7 (-3.22 to 0.77)	-2.31* (-5.31 to -0.40)	-1.6 (-4.49 to 0.96)
	≥45≤64	1.0 (-0.2 to 7.4)	-0.6 (-2.3 to 2.3)	-1.04 (-2.50 to 1.56)	-0.79 (-3.43 to 0.66)	-0.9 (-3.27 to 1.40)
	≥65	0 (reference)	0 (reference)	0 (reference)	0 (reference)	0 (reference)
Ethnicity	Caucasian	0 (reference)	0 (reference)	0 (reference)	0 (reference)	0 (reference)
	Black	0.2 (-1.3 to 1.4)	0.3 (-0.6 to 1.5)	0.36 (-0.34 to 0.96)	-0.04 (-0.90 to 1.26)	-0.15 (-1.78 to 2.11)
	Aboriginal	-0.4 (-2.2 to 1.4)	0.8 (-0.4 to 1.7)	1.21 (-0.50 to 2.06)	1.32* (0.57 to 2.32)	0.88 (-0.56 to 2.54)
	Other	-0.2 (-2.5 to 0.5)	0.1 (-1.6 to 0.7)	-0.46 (-1.28 to 0.43)	-1.07* (-1.54 to -0.03)	-1.98 (-3.19 to 0.69)
Length of incarceration	≤18 months	0 (reference)	0 (reference)	0 (reference)	0 (reference)	0 (reference)
	>18 months ≤5 years	-0.3 (-0.8 to 0.5)	-0.1 (-0.9 to 0.8)	-0.34 (-0.92 to 0.32)	-0.22 (-0.70 to 0.46)	-0.28 (-1.52 to 0.55)
	>5 years	-0.9 (-1.5 to 0.0)	0.2 (-0.8 to 1.2)	0.64 (-0.26 to 1.64)	1.57* (0.56 to 2.60)	1.93* (0.70 to 3.68)

The results presented were adjusted for the factors seen in the table and other factors (language, feeding system, physical activity and diet) (data not shown in the table).

* $p < 0.05$ was considered statistically significant.

BMI, body mass index.

more weight when in withdrawal from tobacco during incarceration, since they have limited access to tools that may help deal with cravings.¹⁷ Furthermore, without these tools, they may turn to food to manage tobacco withdrawal symptoms. This coping strategy appears to be permanent since weight gain is sustained over time. As such, inmates who are incarcerated longer (>5 years) gain significantly more weight than inmates with shorter sentences.

The tobacco ban in prison appears to be insufficient in obtaining long-term tobacco cessation.^{44 59} Most studies on the subject reveal that the vast majority of inmates (up to 97%) resume smoking within 6 months of being released back into the community.^{7 17} Consequently, once released inmates who smoke may end up with two compounding risk factors (tobacco and obesity), which put them at increased risk for health problems. The tobacco ban policy, intended to improve the prison health environment by improving air quality,⁶⁰ has been successful at achieving this goal and also at reducing tobacco-related diseases.¹⁴ The risk of weight gain would unquestionably be offset by the benefits of long-term smoking cessation.^{61 62} However, this may not be the case for Canadian inmates who will likely resume smoking after incarceration, since evidence indicated most inmates resume smoking once released from prison.⁷ In light of this reality, there are programmes aimed at offering support to inmates with continued tobacco abstinence once released from prison. For example, WISE (Working Inside for Smoking Elimination) is a programme based on motivational interviewing and behavioural therapy out of the USA that has been successful at maintaining continued tobacco cessation postrelease from institutions where tobacco is forbidden.^{17 63} This type of programme could be helpful in Canada for inmates looking to achieve long-term smoking cessation. When planning for smoking cessation programmes for inmates, it is helpful to note that many inmates reported wanting to achieve something positive while in prison, and they say quitting smoking while in prison would be a great accomplishment.⁶⁴ From this perspective, smoking cessation in prison could be viewed as a unique opportunity to help a population typically resistant to mainstream smoking cessation strategies.⁶⁴ A WHO paper on tobacco bans in prison reported that inmates saw incarceration as an opportunity for smoking cessation and identified physical activity as a substitute for smoking.⁶⁴ From a policy perspective, this means that including physical activity in a smoking cessation programme in prison could help inmates to quit smoking successfully and could also help with the unintended weight gain from smoking abstinence during incarceration. Moreover, physical activity could also potentially replace other above-mentioned functions related to tobacco in prison, such as acting as a stress reliever and a social lubricant.

In comparison with inmates who smoked, inmates suffering from drug withdrawal also gained more weight than inmates not going through withdrawal. They gained

8.0 kg compared with inmates without a history of drug use, who gained 4.5 kg, that is, a difference of 78% between these two groups. At follow-up, 87% of inmates with a history of illicit drug misuse were overweight or obese (BMI ≥ 25 kg/m²). This suggests the median 8 kg weight gain in those inmates did not help most of them go from underweight (since only 1.3% of our sample was underweight on admission) to a normal weight, but rather from a normal weight to overweight or obese. Prison staff often share the opinion that drug users enter prison underweight and the observed weight gain is deemed healthy, but our findings did not support this opinion. However, inmates withdrawing from alcohol misuse did not gain significantly more weight than inmates without a history of alcohol misuse, whereas the weight gain seen in inmates with a history of tobacco use or drug misuse was similar during incarceration.

Limitations

This study should be interpreted in light of the following limitations. First, the observational nature of the data precludes inferences about causality. Second, the data collected on tobacco and substance (alcohol and drug) misuse (exposure) were self-reported by participants, and therefore subject to recall and social desirability biases.⁶⁵ Third, residual confounding by unmeasured variables (ie, duration of tobacco use and previous quit attempts) is a possibility. Fourth, the measurements on admission were taken retrospectively from the medical charts. Consequently, these measurements were taken by healthcare staff using equipment different from ours for the study. Finally, our convenience sample may be subject to selection bias.

CONCLUSION

In conclusion, inmates are vulnerable to weight gain during incarceration in part because of withdrawal from tobacco and drugs in Canadian penitentiaries. Although the decision to ban tobacco from penitentiaries contributes to a healthier environment in prison, the ban was suspected to have unintended consequences, and our findings have identified weight gain as one of those unintended consequences. Our findings suggest that tobacco ban in prisons could partly explain the large variation in weight gain seen in certain penitentiaries. For further research, a large-scale analysis examining weight gain data from penitentiaries where tobacco is banned, compared with penitentiaries where smoking is still permitted, could confirm our suspicion. Since many inmates view incarceration as an opportunity for smoking cessation, a carefully planned intervention programme (with postrelease support) could help empower inmates to abstain from tobacco long term. A follow-up study post-release from prison to assess weight changes and smoking status could provide information on how to help inmates manage their addictions and their weight over time.

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