Correctional institutions as obesogenic environments: a multi-level exploration of determinants that influence inmates' weight outcomes during incarceration in Canadian federal penitentiaries

by

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Abstract

Background: Since inmates in Canada are excluded from household statistics, very little information is known about obesity prevalence or associated risks in this vulnerable population. This is a problem since obesity rates are high in Canada, and obesity is considered a public health crisis. Furthermore, the burden of obesity is disproportionately carried by low-income, vulnerable and marginalized populations (such as inmates). The goal of this study was to determine weight changes during incarceration in Canadian federal penitentiaries, and to determine which factors were influential at the socio-demographic, behavioral, institutional and policy level.

Methods: This study was a retrospective cohort study that used a quantitative approach. The setting for this study was 12 correctional institutions in Ontario, New Brunswick and Nova Scotia (or the "Atlantic region"). Administrative data were collected from 1420 inmates, with 754 of these participants also participating in a face to face interview to gather additional data on self-reported behavioral determinants and measured anthropometric data. Eligibility criteria for inmates to participate were: a recorded admission weight in their medical chart, housed in their current institution for at least 6 months, not acutely or terminally ill (and requiring hospitalization), and not pregnant or in a wheelchair.

Results: We found that almost three quarters of inmates (73%) gained weight during incarceration. Obesity rates increased by 71%, going from 26.6% to 45.4%. The observed weight gain was associated with the tobacco ban (macrosystem level), the use of commissary store (or "canteen") (at the microsystem level), and many determinants at the individual level (physical activity, diet, smoking status). The observed weight gain was also significantly associated with age, ethnicity, length of incarceration, duration of total sentence and region. It was however not associated with the national menu, food service/feeding system, sleep, screen time, mental health status or psychotropic medication use. Some inmates who gained excessive weight also developed obesity related illnesses.

Interpretation: The observed weight gain was deemed to be unhealthy, since obesity rates increased significantly (and the proportion of inmates with normal weight decreased). These findings have potential repercussions on inmate health, since the observed weight gain was associated with the development of obesity related illnesses. Lastly, many of the factors associated with the observed weight gain were modifiable, which means it is possible to intervene to manage weight gain during incarceration.

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1. Introduction

My work as a Registered Dietitian with Correctional Service Canada is the inspiration behind this study. While working with incarcerated inmates in federal penitentiaries, I noticed many inmates gained weight during incarceration, and heard multiple comments from inmates and staff supporting this observation. Upon reviewing the available data, it became clear that this is a poorly researched topic and there is very little data available on weight outcomes for Canadian federal inmates during incarceration.

1.1 Problem statement

Canada's combined overweight and obesity measured rates were 61.3% in 2015, as stated in the Canadian Community Health Survey (1). It is well established that obesity increases the risk of developing non-communicable diseases, such as type 2 diabetes, cardiovascular disease (CVD), certain types of cancer, and all-cause mortality (2). These health problems are increasingly seen as a global public health crisis. The burden of obesity is disproportionately carried by low-income, vulnerable and marginalized groups, such as ethnic minorities, the Aboriginal population and inmates (3). However, little is known about the overweight and obesity problem in the Canadian inmate population, as most of the research done on inmate health focuses on infectious disease and mental health (4, 5). By comparison, there is still little information on Canadian inmates' bodyweight, BMI, weight change and body composition during incarceration (6). This is an important knowledge gap as the inmate population is not exempt from the impact of obesity. Inmates who have overweight or obesity are at increased risk of many diseases and health

conditions. Many correctional physicians anecdotally report weight gain as a major problem for inmates, but lack the data to back up these claims (7).

During incarceration, federal inmates receive most of their health care from institutional Health Services or the prison "hospital", but if they become too ill they are referred to their community hospital. That means, during incarceration the healthcare costs are shared between the Public Safety budget and the provincial Health Care budget. However, once they are released into the community, the burden of care is transferred entirely to the provincial level because, once released, the inmate resumes regular citizen status. Therefore, if an inmate becomes obese while incarcerated, the burden of care related to obesity-related chronic diseases may be increased, and the associated costs will eventually be transferred at the provincial and community level.

Obesogenic environments are defined as "the sum of influences that the surroundings, opportunities or conditions of life have on promoting obesity in individuals or populations" (8, 9). There is an increasing recognition that the physical, social, political and cultural environment can play an important role in shaping health behaviours, such as eating habits and food intake, that ultimately influence bodyweight and BMI (9). Since the prison environment is all encompassing to inmates, providing a social, cultural and physical environment, it may in fact have a major influence on their bodyweight and BMI. However, the emerging field of study of obesogenic environments is still poorly understood due to the complex nature of studying the environment as a health determinant. In any given environment, there is a multitude of influences and interactions working together to shape

health behaviours. Since the prison setting is a relatively controlled environment, it could lend itself well to obesogenic research and could potentially contribute to extrapolate certain findings into the larger community setting. However, it is clear that some of the findings will only apply to the unique prison environment.

To address this complex issue, the goal of this study was to examine the prison setting to first determine if it is an obesogenic environment. To reach this goal, we proposed to assess weight outcomes such as BMI (kg/m^2), waist circumference (cm), weight change (kg), BMI change (kg/m^2) and annual weight change (kg/year) in the inmate population of the Ontario and Atlantic federal correctional institutions. Then, we proposed to situate this examination within a broader context of socio-demographic, behavioral, institutional and policy determinants.

1.2 Background on inmate health

Inmates are an extremely vulnerable population with a web of negative health determinants and poor health profiles. Prior to incarceration, they are more likely to be underemployed, have unstable living conditions and poor social networks. Often, they have little education and are also less likely to be married (3). Furthermore, they are known to have higher rates of smoking, alcoholism and substance abuse (7). They also have higher rates of chronic diseases (diabetes, CVD), injury and death compared to the general population (6, 10, 11). It remains unclear if the higher rates of chronic disease are because of the above-mentioned unhealthy behaviours or because of weight gain and higher obesity rates (or both) in the prison population. This project is important as the prison population is excluded from most

governmental household statistics, and therefore, there is a lack of Canadian data on this population group. In 2016, the total adult inmate population in Canada, including inmates in federal or provincial prisons, was approximately 40 000 individuals (12). Worldwide, the inmate population represents 10.3 million people at any given time (13).

The current situation is described as dire in the correctional ombudsman report, which states that prison-based health care is an increasingly expensive endeavor. The total annual health services expenditure for federal correctional institutions exceeded $216 million per year in 2014 in Canada (14). On a per capita basis, the average annual physical health care cost, per inmate, was $9 700 for male inmates and $26 200 for female inmates (14). Inmate health care costs are high and rising, since the costs are compounded by the needs of a population that is growing older and sicker behind bars (14). These costs are higher for inmates than the average cost of health care for Canadians in the community, which is approximately $6 367 in Ontario and $6 913 in the Atlantic region (15). Our study was developed to provide insight into the problem of obesity in prison, that could potentially lead to solutions to help curb these soaring health care costs related to obesity and associated health problems. These cost savings will go beyond Correctional Service Canada's budget. During incarceration, the cost of health care provided to inmates is shared between the institution (Public safety budget) and the community hospital (various provincial healthcare budgets). However, all of the healthcare costs are transferred to the provincial health care level once the inmate is released. A sick inmate becomes a sick citizen once released (16).

2. Literature Review

This section is an overview of the literature on the topic of inmate obesity. The first part describes overweight and obesity in Canada (section 2.1), followed by an overview of the available literature specific to inmate obesity (section 2.2). Then, we discuss risk factors for obesity (section 2.3), obesogenic environments (section 2.4) and the context at Correctional Service Canada (section 2.5). Each section ends with a sub-section on the knowledge gap that will be addressed by our study.

This literature review was conducted by doing a search on PubMed/Medline and Psych Info on the University of Ottawa library website. The search for articles was done by using the Medical Subject Headings terms: prison OR inmate OR incarceration OR jail OR prisoner OR offenders AND weight gain OR weight loss OR obes* OR overweight* OR BMI* OR AND adults. The search yielded over 209 articles, which were reviewed. Only 62 articles referred to studies that were specifically done on obesity in the prison population. For example, many articles came up for hernias and obesity, because "incarceration" is a term often used to describe hernias. Also, the term "offenders" yielded many articles that examined about "offending" patients while talking about obesity or "offending" drug when discussing drugs that cause weight gain or other health problems. Furthermore, many articles pertained to prisoners of war, which was not in the scope to our research topic. Of the articles found, many had pertinent references that did not come up during the initial search. Several of these references were independently investigated by title or author or directly in the published journal. The time period was not specified because there is little literature on inmate obesity and it does not seem useful to limit the

search at this point. There were no new references added after September 1, 2018. The inclusion criteria for the population were inmates, adults, prison population, men and women. The exclusion criteria were concentration camps, non-penal institutions, previous inmates, specific subgroups and young offenders. The inclusion criteria for outcomes were bodyweight, BMI, weight change, weight gain, weight loss and waist circumference.

2.1 Overweight and obesity in Canada

Overweight and obesity rates have doubled in the Canadian population during the last 30 years, which has brought much attention to obesity research in Canada (17). Table 1, below, presents the results from the 2015 Canadian Community Health Survey that measured overweight and obesity rates in adults, 18 years and older for the general Canadian population.

Table 1: Measured overweight and obesity rates for the general Canadian population in 2015

	BMI (kg/m²)	**Obesity class**	**Number (N) and Proportion (%) of Canadians**
			N=27 643 000 (100)
Underweight	<18.5		736 800 (2.7)
Normal	≥ 18.5 ≤24.9		9 977 500 (36.1)
Overweight	25.0–29.9		9 553 700 (34.6)
Obesity total	≥30.0	All classes	7 375 000 (26.7)
Overweight and obesity	≥25		16 928 700 (61.2)
Obesity	30.0–34.9	I	4 751 600 (1ntytunj 7.2)
Obesity	35.0-39.9	II	1 840 900 (6.7)
Extreme obesity	≥40.0	III	782 500 (2.8)

Source: Statistics Canada website: http://www5.statcan.gc.ca/cansim/a47

Table 2 shows that overweight and obesity rates are higher in the Atlantic region, for both sexes, in comparison to the national average. By contrast, the rates in Ontario are below the national rates. There are important discrepancies between male and female overweight and obesity rates. In every region across Canada, a BMI of 25 and over is consistently higher for males than for females. When combining both sexes in 2015, 61% of males and females between ages 18-79 years had a BMI of 25 or over (1).

Table 2: Measured overweight and obesity rates in the regions across Canada in 2015

Region	Males with BMI 25 and over (%)	Females with BMI 25 and over (%)
Atlantic (NB, NS, PEI, NL)	80.2%	66.2%
Quebec	66.2%	53.2%
Ontario	64.3%	52.2%
Prairies (MB, SK, AB)	77.7%	61.3%
Pacific (BC)	64.5%	53.6%
Canada	68.1%	54.4%

Source: Statistics Canada website: http://www5.statcan.gc.ca/cansim/a47

In 2015, 29% of males and 41% of females had a waist circumference above target (men >102 cm and women >88 cm) (1). Waist circumference is an important measure as it determines the location of body fat distribution, which is helpful to predict adverse metabolic and cardiovascular risk factors (18). It complements BMI well, which determines if an individual's weight is higher in relation to their height. Both measures combined are ideal at assessing obesity and related risks.

Longitudinal studies have demonstrated that, in general, adults gain bodyweight as they age (19). However, these changes are not linear, as bodyweight changes are considered a dynamic process. As such, trends can be difficult to determine as people will gain weight and then lose weight over different periods of time. A Canadian study found that roughly half the adults, below 60 years old, will gain weight over time; on average those who gain bodyweight will gain 0.74 kg/year for men and 0.57 kg/year for women. This study assessed weight gain over an eight year period, and the authors found that men (who gained weight) gained an average of 4 kg, and the women (who gained weight) gained 3.4 kg (19).

This represents an annual weight gain of 0.5 kg per year for men (who gained weight) and a 0.43 kg per year for women (who gained weight).

2.2 Inmate obesity

A recent pan-Canadian study, done by the Correctional Service Canada research branch, indicated that, in 2012, 64.5% of federal male inmates in Canada were overweight or obese on admission (from measured weight and height data) (4). Those findings are higher than the combined overweight and obesity prevalence for the general Canadian population that was 61.2% in 2015 (1). However, it remains largely unknown what transpires with regards to federal inmates' weight outcomes (BMI, waist circumference, weight change, BMI change and annual weight change) during incarceration in Canada.

The Lancet published a systematic review in 2012 called *Prevalence of risk factors for non-communicable disease in prison populations worldwide: a systematic review* (3). The review reveals that male prisoners are less likely to be obese than males in the general population. However, Canada was not part of that review. The review estimated inmates' weight to be lower than the general population, but this result is not consistent with the Stewart et al.'s paper (4) or the different reports and observations on weight gain in the prison setting in the US and in Canada (7). Also, from this review, it is not known if the data were collected upon admission or after incarceration; nor is it known if there was a change in inmates' bodyweight during incarceration.

In 2017, Obesity Reviews published a systematic review on weight change during incarceration (20). Of the 16 studies included in the review, 11 studies used measured weights to assess bodyweight change, 7 studies dealt with female inmates only, 1 study dealt with male inmates only, and 2 studies included adults from both sexes. The findings revealed that most inmates gained bodyweight during incarceration, with weight gain ranging from 0.17 kg to 0.50 kg per week (7, 21). In most studies, the proportion of participants in the overweight or obese category increased during incarceration. Furthermore, 50 to 80% of participants gained bodyweight during incarceration, whereas only 20 to 33% of participants lost bodyweight (22). The assessment period for the bodyweight change varied greatly, from 2 weeks (7) to a mean of 5.8 years (23). The methods used to assess the bodyweight changes were average change in weight, subsequent change in BMI, proportion of inmates who gained, lost or kept a stable bodyweight, as well as the proportion of participants in each BMI category (22). These studies were mostly out of the United States, one from England, one from Australia and one from Japan. Canada was not part of the review since there was no Canadian data available on weight change during incarceration at the time of the review. Many of the studies were unable to demonstrate statistically significant weight change because of small samples size and low bodyweight gain (22). It should be noted that most of institutions where reported weight gain was low were institutions that still allowed inmates to smoke tobacco (fact verified by correspondences with the authors of the studies), as opposed to Canadian institutions where tobacco has been prohibited since 2008 (24). These findings are consistent with another recent systematic review published in the United Kingdom (25).

In the Lancet review from 2012 (mentioned earlier), female prisoners were found more likely to be obese than non-imprisoned women (3). One of the studies from the review indicated that 70% of incarcerated females were overweight or obese in the United States (US) between January 2004 and June 2005 (26). This was deemed higher than non-imprisoned women of similar age whose overweight and obesity rates were around 60% in the US (3) and around 54% in Canada (1). Furthermore, a study at the Rhode Island Adult Correctional Institutions found anecdotal evidence from correctional physicians and health care staff reporting that obesity and weight gain were major problems in the female prison population (7). This American study indicated that 71% of the incarcerated women gained on average 1.1 pounds per week, which would represent more than 50 pounds per year. But, this same study also found that women who were newly incarcerated tended to gain more weight than those who had been incarcerated longer (7). The authors suggested that at the beginning of their sentence, women are often withdrawing from drugs, alcohol and tobacco as well as coping with the stress of their incarceration. All of these issues are likely to affect weight (7). This observation is important, because in Canada, drugs, alcohol and tobacco are banned from federal institutions; therefore, female inmates may gain more bodyweight at the beginning of their sentences because of withdrawal from these substances (27). In Canada, 80% of female inmates reported dependence to at least one substance before incarceration (28). There could be other explanations for the observed weight gain early during the sentence, such as stress, emotional eating, changes in eating patterns and access to more food in prison than in the community.

Although both systematic reviews (3, 22) are very informative, they have some limitations. First, many of the studies reported in the reviews relied on self-reported weight, which can be problematic since most self-reported data tend to underestimate obesity when compared to measured data (17, 29). The difference between self-reported weight and measured weight could reach 10% (17). Second, the review reported findings from Australia, Bangladesh, Cambodia, Nigeria, the United Kingdom, Japan and the US, but did not include Canadian inmates. We know of only one study on inmates' bodyweight upon admission to their penitentiaries in Canada (4). However, we did not know about bodyweight and BMI changes in prison settings in Canada. To our knowledge, there are no studies that measured bodyweight and BMI changes in prison settings in Canada.

2.3 Risk factors for obesity

Few studies have explored the potential factors associated to bodyweight change during incarceration (25). In most studies, bodyweight gain was higher in female inmates and therefore, associated with sex (22). Duration of incarceration, length of sentence, hypertension, tobacco and substance use were sometimes found to be associated with weight gain (21, 22), but found to be unrelated in other studies (22, 30, 31).

At the population level in Canada, many obesity determinants have been identified. The report *Obesity in Canada* summarized these findings (Figure 1) (17).

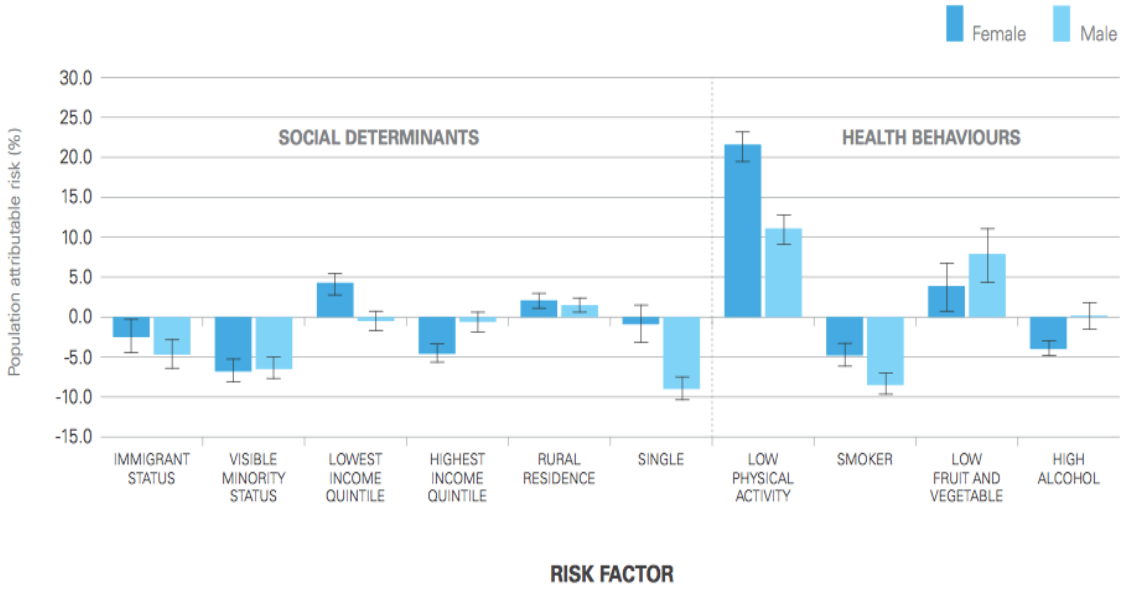

Figure 1: Population attributable risk of self-reported obesity, by risk factor and sex, ages 18 years and older, Canada (17)

Socio-economic status: As a general rule, poor diet quality, lack of exercise and obesity are associated with lower socio-economic status (32). Figure 1 supports these findings for women. However, the trends are not as obvious in men. Furthermore, individuals with lower socio-economic status are overrepresented in the prison population (3).

Ethnicity: Ethnicity, immigrant status and visible minority status are known to have an influence obesity rates. Typically, there is a protective effect against obesity for recent immigrants to Canada. Many studies have tackled the complex issue of ethnicity and obesity. This is relevant to the prison population, since 41% of Canadian inmates are not Caucasian (12). Typically, the probability of being overweight or obese is lower for immigrants on arrival to Canada (35% for new immigrants versus 60% for Canadians), but after approximately 25 years in Canada, these indicators of unhealthy weight match native-born Canadians (33). This weight gain can be tempered when immigrants are in the

presence of ethnic social networks or in a neighborhood with a large ethnic community (33). Since the prison setting will influence inmates' social network and their ethnic community, it is relevant to examine the relationship between ethnicity and social network in relation to bodyweight and BMI changes in the prison population. In addition, studying the association with weight and ethnicity in the prison setting could shed some light on the genetic versus the environmental influence, since the environment is the same for all inmates regardless of ethnicity.

Minority spoken language: New figures show the number of visible minorities in Canadian prisons has increased by 75% in the past decade (34), which means there is an increased number of inmates who may not speak either of the official languages. It is already known that when a French-speaking individual lives as a linguistic minority in Canada, it can have detrimental effect on their health status (35). A recent study found that in Ontario, French-speaking individuals are more likely to be overweight or obese and less likely to eat the recommended servings of fruits and vegetables than the general population (36, 37). The language issue is relevant in the Atlantic and Ontario regions where many French-speaking inmates are incarcerated in institutions where most inmates and staff speak English. The two regions targeted in this study housed the highest proportion of minority speaking francophones in Canada (35). Spoken language was therefore assessed as a variable that may influence BMI changes in the inmate population.

Aboriginal status: Aboriginal status is an important part of ethnicity, since obesity rates remain higher in Aboriginal populations compared with non-Aboriginal populations (17).

The proportion of Aboriginal inmates has increased from 8% to 20% in the past 20 years. This is a significant issue, because Aboriginals are over-represented in prisons; constituting approximately 4% of the Canadian population, yet they account for 23% of the prison population (12). This over-representation of Aboriginals in prison is far worse for women, where 33% of incarcerated women are Aboriginal (12). This makes Aboriginal incarcerated women particularly vulnerable to weight gain, as they are at a higher risk for being overweight or obese because of their Aboriginal ancestry, in addition to the increased risk associated with incarceration (17).

Sex: Sex is an important health determinant known to affect BMI and body composition (17). Most research done on the prison population separate inmates by sex when analyzing health related factors (7, 31). Furthermore, the institutional environment for male and for female inmates is different, because they are incarcerated in sexually segregated institutions (38).

Diet: It is well established that poor diet quality contributes to obesity. The usual culprits are high caloric processed foods (that are high in energy but have little nutritional value), low consumption of fruits and vegetables, and high consumption of sodium, fat, carbohydrate and sweetened beverages (32, 39). These latter junk foods are available to inmates through commissary store (or "canteen") in Canadian penitentiaries, where inmates may use their earnings to purchase these foods. Moreover, in the penitentiaries, food is often used as currency (40). Inmates typically trade chocolate bars, chips and pop for goods and services inside the prison. Each item has a one-dollar value, so it is common to see inmates use a stack of chocolate bars in exchange for a service or for card-game

gambling (41). In addition to this peculiar food environment, eating habits such as eating quickly, skipping breakfast, irregular meal intake and eating large portion sizes influence bodyweight (42). Very little was known about inmates' food intake and eating habits, while incarcerated (6).

Physical Activity: Low physical activity and sedentary lifestyle are major risk factors for obesity. The Lancet systematic review discussed earlier indicated that six out of seven studies found that both male and female inmates were meeting the international guideline of 150 minutes or more of moderate to vigorous physical activity per week (3). The data indicated that inmates from the United Kingdom were less active than the ones from Australia; but, as mentioned before, Canadian data were not part of the review (3). We do, however, know that in the community, only 15% of Canadians meet the weekly recommended time for physical activity (when physical activity is measured) (43). However, when the data are self-reported, studies found that 51.6% of non-incarcerated Canadians meet recommendations for physical activity (44). It is also well established that individuals who are considered very physically active (who exercise at least 60 minutes a day) are far less likely to be obese or more likely to maintain weight loss (45). In Canada, inmates have the opportunity to exercise while incarcerated; however, use of the gym and the yard depends on inmates' choice to exercise, but may also be restricted because of security concerns. This is generally the case in prisons worldwide (46). Because of these extra barriers to physical activity unique to the prison environment, it was important to measure physical activity in the prison setting.

Sedentary behaviors: Sedentary behaviors are a well-known contributor to obesity. It is strongly related to lower income in every race and ethnic group and in both sexes (32). Sedentary behaviors are defined as "any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting or reclining position" (47). In recent population-based surveys, sedentary behaviors such as watching television, using a computer or playing video games, were assessed separately from physical activity. The term *screen time* typically encompasses the use of all types of screens. Screen time studies usually target children and rarely include information on adults. Two Canadian studies did, however, find a positive association between television watching and weight gain in adults (48, 49). These behaviours are relevant to the prison setting since many inmates are known to be sedentary during incarceration (50). Furthermore, they often have a television in their cells, and consequently may engage in significant screen time.

Sleep: There is a growing body of research that suggests an association between chronic sleep deprivation and weight gain. Adults who have short sleep patterns, usually less than 7 hours per night, tend to weigh more than those who get enough sleep (51-53). The recommendation for adequate sleep for adults, aged 18 to 64 years, is between 7-9 hours, and between 8-9 hours for older adults, aged 65 years and older (54). In Canada, the sleep and health connection is pertinent since one-third of adult Canadians reported sleeping less than the recommended 7 hours per night (55). Furthermore, two-thirds of adults reported getting the recommended hours of sleep; whereas only 3.3% of participants reported sleeping more than 9 hours (55). In addition, poor sleep is associated with lower socio-economic status, low education and low income, for both sexes (55). The sleep question is

relevant to inmates in Canada because many of them report poor sleeping while incarcerated (6). In support of that statement, a study out of Switzerland found that insomnia was inmates' most commonly health related complaint during incarceration (56).

Smoking: There is convincing evidence for the association between smoking cessation and weight gain (17, 57). Typically, weight gain occurs because of increased energy intake and decreased resting metabolic rate. There is variability in the amount of weight gained among individuals who stop smoking. Younger age, lower socio-economic status and heavier smoking are predictors of higher weight gain (17, 58). This point is particularly relevant to the inmate population, since 75% of inmates smoked prior to incarceration (59-61). Those rates are three to four times the smoking rate of the general Canadian population (62). Before the institutional tobacco ban in 2008, more than 50% of inmates reported spending most of their money on cigarettes (6). Since then, there was anecdotal evidence that inmates now spend their money on junk food, potentially affecting food intake, bodyweight and BMI (40). As such, smoking status prior to incarceration is relevant as a potential contributor to weight gain. The ban on tobacco does not guarantee that inmates will not smoke, since there are reports that contraband cigarettes make their way into the prison. However, inmates smoke less since the ban and they do not have a regular supply of tobacco as they did prior to the tobacco ban.

Psychotropic medication use: Mental illness is associated with obesity and a higher proportion of obese individuals suffer from mental illness (63). In addition, the prevalence of mental health disorders is several times higher with inmates as compared to the Canadian

population. In a study done in 2004, inmates were twice as likely as the rest of the population to have suffered from a mental disorder during their lifetime. Male inmates were three times more likely to develop schizophrenia, while female inmates were twenty times more likely. Moreover, inmates were four times more likely to have a mood disorder (6). A recent study conducted by the Correctional Service Canada research branch found that 70% of male inmates met at least one criterion for mental illness, whereas in Canada the national rate is 12% (5). In another study by the Correctional Service Canada research branch, the authors identified a sample where 94% of female inmates had experienced symptoms consistent with a lifetime diagnosis of a psychiatric disorder. In addition, 85% of the sample had experienced diagnostic symptoms of more than one disorder (28). Furthermore, mental health issues are usually treated with psychotropic medications, many of which increase appetite and reduce metabolism; which increases bodyweight and BMI (63). Given that inmates are more likely to suffer from mental illness, this condition can potentially provide insight into a cause for weight gain in prison.

2.4 Obesogenic environments

In past decades, interventions to reduce obesity have typically focused on behaviors at the individual level; but little success has come from these efforts (42, 64). Therefore, the attention has recently shifted towards environmental, social, economic and cultural determinants to explain energy-imbalance behaviors (65). The general idea is to identify and differentiate between elements of the environment in an attempt to understand their influence on health behaviors that will ultimately influence bodyweight and BMI changes. Given the complex nature (microsystem and macrosystem) of studying the environment in

relation to obesity, it is often deemed unrealistic to undergo intervention research. In view of this reality, the prison setting, as a potential obesogenic environment, is relatively easier to study than the community at large. Some of these findings may offer insight into obesogenic environments outside the prison walls.

Obesogenic environments are defined as "the sum of influences that the surroundings, opportunities or conditions or life have on promoting obesity in individuals or populations" (8, 9). To determine if an environment is obesogenic, it is important to assess the types of foods that are available as part of the food environment (42). For example, non-nutritious, energy dense foods are present in Canadian federal institutions and inmates are allowed to purchase these foods from the commissary store (or "canteens"). Conversely, more nutritious foods are available through correctional Food Services. Dining practices and the environment where food is eaten can also influence eating habits and food intake, meaning that food intake may vary depending on if a person dines alone or with his or her peers. Food intake can also be affected by the subjective norm found in the prison environment (66). For example, if healthy eating is common and considered normal, then individuals in that environment will probably tend to eat more healthily than in an environment where big food portions or non-nutritious food is considered the norm (67). Typically, in an obesogenic environment, non-nutritious foods are readily available and eating them is part of daily life. In the correctional setting, subjective norm applies to eating and it also applies to the physical body. For male inmates, a large stature is considered a good feature. Therefore, some inmates may try to purposefully gain weight in an effort to have an intimidating physical appearance (25).

2.5 Food service systems at Correctional Service Canada

There are three different types of food service feeding systems that influence dining practices in Canadian federal correctional institutions. The first system is a central food production system with in-room delivery; typically, in these maximum-security institutions, inmates eat alone in their cells. The second system is a central food production system with cafeteria delivery; typically, inmates eat together in the dining area. This style of feeding allows for a bit more flexibility as inmates can negotiate food choices on the cafeteria line and trade food with other inmates in the dining hall. As mentioned previously, food is also commonly used as currency in prison since the tobacco ban. The third system is a system called "small group meal plan" where inmates are given a food budget and they purchase their food from the main food services. This feeding system allows inmates to choose their food (from a standardised grocery list from Correctional Service Canada) and prepare it themselves in prison kitchenettes (68).

3. Theoretical and conceptual framework

3.1 General Concept

Two conceptual framworks provided the theory that guided our study on obesogenic environements in federal institutions. They inspired the model (Figure 2) developed specifically for the unique correctional setting addressed in this study which we present in section 3.2 of this thesis.

First, Carpiano and Daley's model (Appendix A, Figure A1) illustrates the notion that social environments provide different community resources that influence health behaviors which affect health outcomes (69). The second influence was "*An ecological perspective: levels of influence"* from the National Cancer Institute (Appendix A, Figure A2), which offers insight into how various levels of influence can impact health behaviors and health outcomes (67). The terminology used for this model was based on Bronfenbrenner's ecological systems theory (70). As such, for this study, the different levels are called individual level (socio-demographic and behavioral determinants), microsystem (institutional determinants) and macrosystem (policy determinants). The institutional factors, or the microsystem level, are very pertinent to the prison setting as the rules, regulations and policies within the correctional institutions influence the social environment that could in turn influence inmates' behaviors.

3.2 A proposed model: socio-ecological model of obesity in prison

A socio-ecological model of obesity in prison was proposed (Figure 2) to examine factors in the prison environment, which could influence weight outcomes and obesity related illness or comorbidities of inmates while incarcerated.

The macrosystem level of the proposed model (e.g., policy determinants) are the policies that are approved at Correctional Service Canada's National Headquarters in Ottawa. The national policies are promulgated to the five regions across Canada, and ideally, they would be implemented in a standardized manner. However, in practice, the same policy may be applied differently depending on the region. For this study, we wanted to compare the

Atlantic region where inmates' health care costs and obesity rates are the highest, to the Ontario region where inmates' health care costs are the lowest in the country and the obesity rates are lower than the national average (1, 71). Policies at the macrosystem level are heavily influenced by the federal government's vision and priorities. For budgetary direction, Correctional Service Canada relies entirely on the federal budget from the federal government. It is relevant to this thesis, since in 2012, as part of the deficit reduction action plan, the budget was reduced by 15% and this caused many cost saving projects to be implemented. Specifically, food service modernization projects were proposed as cost saving measures. That meant creating food production centers in each region to centralize food production and CSC implemented a standardized national menu where each institution across Canada served the same meals (72). The political context is important since it influenced the policies and decisions at the macrosystem level.

The microsystem level of the proposed model (e.g., institutional determinants) focuses on the policies, procedures and rules that vary from one institution to another. For example, the three different food service feeding systems, described earlier in section 2.5, may impact inmates' eating habits. Finally, the individual level of the proposed model focuses on how socio-demographic and behavioral determinants influence weight outcomes. This also includes a section on health indicators that focuses on mental health status and psychotropic medication use.

The individual level focuses on how socio-demographic and behavioral determinants influence our weight outcomes. We also included a section on health indicators that focuses

on mental health status and psychotropic medication use.

In addition to our weight outcomes, we also assessed how weight gain influenced obesity related illness. We called that outcome “comorbidities” in our model below.

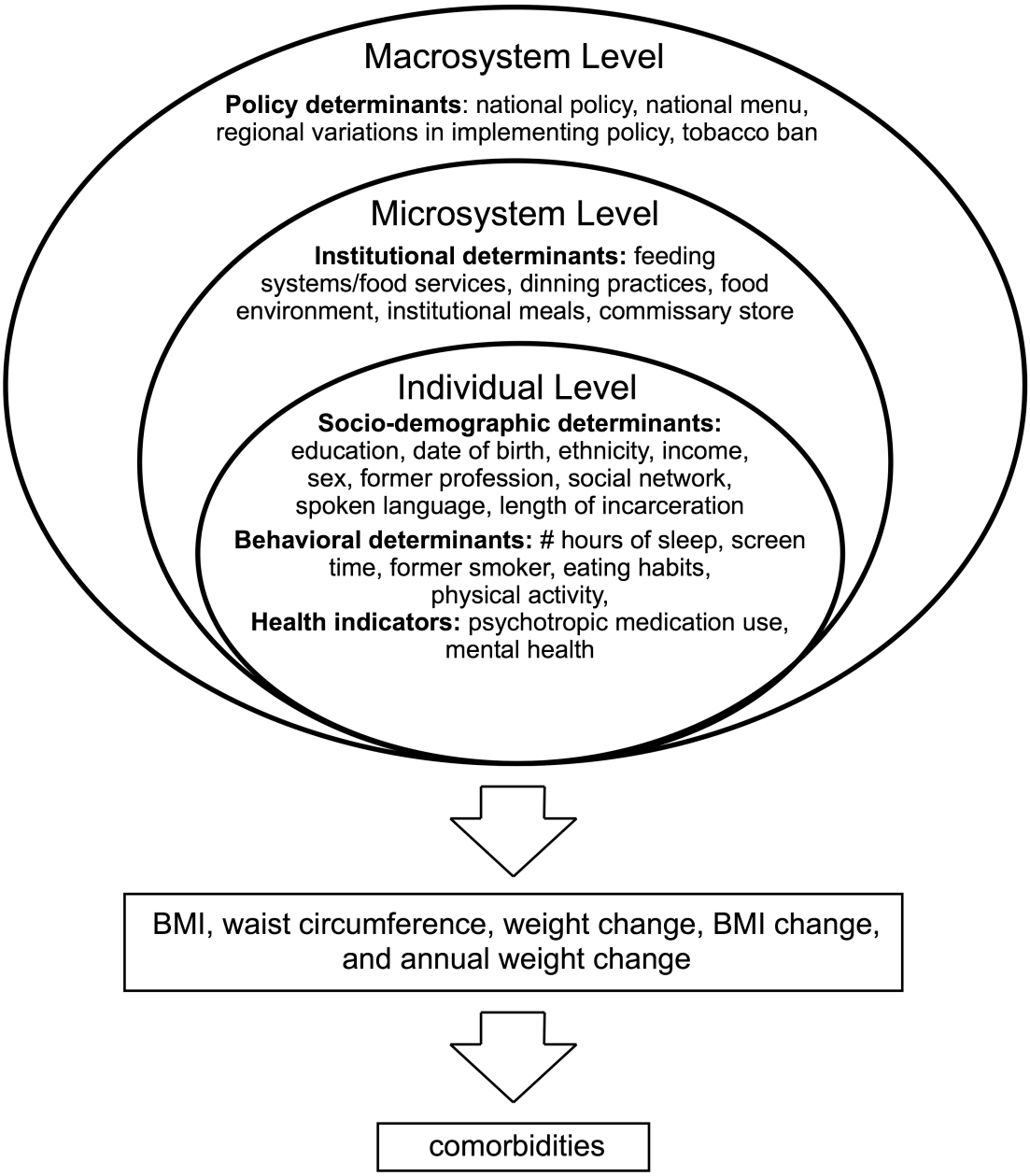

Figure 2: A proposed model: socio-ecological levels of influence on inmates' weight outcomes: BMI, waist circumference, weigh change, BMI change and annual weight change.

4. Research objectives and hypotheses

The principal objective of this paper-based thesis was to determine if federal penitentiaries in Canada were obesogenic by examining weight change in inmates during incarceration, and to identify the main factors at the macrosystem level, microsystem level and individual level that were associated to inmate weight gain during incarceration in the federal prison setting. We proposed four secondary objectives for this study and the results, presented by papers, will allow to communicate our findings and to inform policy makers on where to focus interventions to diminish the burden of obesity, and related chronic diseases, due to a sojourn in prison. We plan on running focus groups with various shareholders to communicate our findings.

Objective 1 was to determine if Canadian federal penitentiaries were obesogenic, by comparing the inmates' bodyweight and BMI at admission to their bodyweight and BMI at the time of the interview. Our main weight outcomes were: BMI (kg/m^2) and waist circumference (cm) at the time of interview (or follow-up). Our weight change outcomes were: weight change (kg), BMI change (kg/m^2) and yearly weight change (kg/year) between admission and the time of the interview. Objective 2 was to identify the main social, demographic and behavioral determinants that influenced weight outcomes (BMI, waist circumference, weight change, BMI changes and annual weight change) in male and female inmates during incarceration. At the microsystem level, Objective 3 was to explore the influence of the food environment on inmates' weight outcomes (BMI, waist circumference, weight change, BMI changes and annual weight change) incarcerated in penitentiaries with different types of feeding systems: 1) in-room tray delivery, 2) cafeteria

delivery, or 3) small group meal plan. Objective 4 was to examine how the weight outcomes (BMI, waist circumference, weight change, BMI changes and annual weight change) were related to chronic health conditions (i.e., certain types of cancer, CVD, type 2 diabetes, reflux, hypertension, osteoarthritis and sleep apnea) in the inmate population during incarceration in Canadian federal penitentiaries.

We hypothesized that inmates would gain weight during incarceration, and obesity rates would significantly increase during incarceration in Canadian penitentiaries. We also hypothesized the observed weight outcomes would be higher for inmates who were forced to quit smoking, who were physically inactive and were eating poorly (either by not meeting the Canadian food guidelines or consuming excessive calories) during their incarceration. This would ultimately lead to a disproportionate increase in obesity related chronic diseases in the inmate population in Canada.

5. Methodology

This study was a retrospective cohort study that used a quantitative approach. The study provided statistical data on inmate obesity in Canada, as well as explored the relationship between various factors. This type of study lends itself well to a quantitative approach and survey design (73). The study examined if correctional institutions were indeed obesogenic environments by comparing current bodyweight and BMI to bodyweight and BMI on admission, to determine subsequent BMI change. Our main outcomes were BMI and waist circumference (at the time of interview), weight change (kg), BMI change (kg/m^2) and annual weight change (kg/year).

The setting for this study was 12 correctional institutions in Ontario, New Brunswick and Nova Scotia (or the "Atlantic region"). In Ontario, 7 institutions participated; one is a maximum-security level institution with an in-room delivery feeding system, 3 are medium-security with a cafeteria delivery feeding system, 2 are minimum-security with a small group meal plan and 1 are multi-level with various feeding systems (38, 68). In the Atlantic region, 5 institutions participated in the study; one of which is a maximum-level institution with an in-room tray delivery feeding system, 2 are medium-security with a cafeteria delivery feeding system, 1 is a minimum-security with small group meal plan and 1 is a multi-level female institution with all three feeding systems (38, 68).

5.1 Participants

Participants for this study were male and female inmates incarcerated in federal institutions in the Ontario and the Atlantic regions. Eligibility criteria for inmates to participate were: a recorded admission weight in their medical chart, housed in their current institution for at least 6 months, not acutely or terminally ill (and requiring hospitalization), not pregnant or in a wheelchair. In Ontario, male participants were recruited from the 5 institutions near Kingston, since all the feeding systems of interest were represented and accessible for data collection. Due to the small size of the female inmate population, a large proportion was recruited as participants, to enable the best possible comparison with the male inmate population. Although the location of the female institution, in the Kitchener-Waterloo area, is outside the Kingston area, this institution was included as the female population was essential to provide insight on the differences between men and women with regards to

weight outcomes while incarcerated. In the Atlantic region, participants were recruited from all 5 sites. Recruitment of participants was conducted by offering information sessions with the inmate committee in each of the institutions where we were collecting data to encourage inmates to volunteer. In addition, there were advertisements about the study posted on the prison telecommunication service. Inmates were asked to submit their name to a designated staff member in the penitentiary.

The federal inmate population for these two regions totals approximately 3650 inmates: 3480 males and 170 females (38). They are housed in 7 institutions. Male participants were recruited from the 6 institutions near Kingston (Ontario), since all the feeding systems of interest were represented and accessible for data collection. Due to the small size of the female inmate population, a large proportion was recruited as participants, to enable the best possible comparison with the male inmate population. Although the location of the female institution, in the Kitchener-Waterloo area, is outside the Kingston area, this institution was included as the female population was essential to provide insight on the differences between men and women with regards to weight outcomes (BMI, waist circumference, weight change, BMI change and annual weight change) while incarcerated.

In the Atlantic region, the inmate population is approximately 1300 inmates: 1215 male inmates and 85 female inmates (38). They are housed in 5 institutions in New Brunswick and in Nova Scotia, one of which is a maximum-level institution with an in-room tray delivery feeding system, 2 are medium-security with a cafeteria delivery feeding system, 1

is minimum-security with small group meal plan and 1 was a multi-level female institution with all three feeding systems (38). Participants were recruited from all 5 sites.

5.2 Sampling

The sample was based on the National Statistical Service sample size calculator. For an adequate sample (with a significance level of 0.05 and confidence level of 95%) of the inmate population in both regions; we needed a sample of at least 325 males and 100 females for the Ontario, and at least 275 males and 70 females for the Atlantic Region (74). Since the inmate population is heavily male dominated, ~95% of inmates are male, whereas only ~5% are female. The entire female sample was recruited 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 to increase the power of our analysis. Once we excluded all participants who could not participate, we ended up with ~1600 inmates. From that segment of the population, our sample only had to be at least 300 inmates to have an adequate sample (74).

The response rate for our study was 87% for the chart review and 46% for the face to face interview. At the time of the data collection, there were approximately 3000 inmates living in the institutions who participated in the study. From that population, approximately 1600 were eligible to participate (they had been in their current institution for at least 6 months and their weight was recorded on admission). Overall, roughly 50% of eligible inmates volunteered to participate for the interview. In the Ontario region, there were 883 male and

107 female inmates eligible to participate in the study. In the Atlantic region, 583 male and 49 female inmates were eligible to participate in the study. The response rate for the chart review and face-to-face interview was 92% (814 participants/883 eligible inmates) for male inmates and 80% (86 participants/107 eligible inmates) for female inmates in the Ontario region. Whereas, the response rate for the Atlantic region was 79% (462 participants/583 eligible inmates) for male inmates and 100% (58 participants/58 eligible inmates) for female inmates. The response rates for the face-to-face interview participants were 51% (398/883 eligible inmates) for male inmates and 42% (45 participants/107 eligible inmates) for female inmates in Ontario. Whereas the response rates were 50% (274 participants/583 eligible inmates) for male inmates and 64% (37 participants/58 eligible inmates) for female inmates in the Atlantic region.

Inmates volunteered to participate and provided their consent by singing 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. The verbal consent was obtained by the research assistants and witnessed by correctional staff. All personal data collected were coded to ensure confidentiality. We clearly described the expected participant involvement during the information session at each participating penitentiary.

5.3 Data collection

The data collection was done in two parts. The first part was with 754 volunteers who participated in a face-to-face interview, where two research assistants (all registered dietitians) collected self-reported data on smoking status, substance use, physical activity,

eating habits, education level, employment before and during incarceration, body image, social network and language (see questionnaire completed by the interviewer in Appendix B2). The second part of the data collection was a chart review, where I pulled data from 666 participants' medical and administrative charts (see questionnaire for chart review in Appendix B3).

During the interview, the research assistants (registered dietitians) measured the height, weight and waist circumference, following a standardized protocol (they were provided training on how to follow the protocol), then conducted a 30-minute interview with each individual participant. The standardized protocol was taken from a World Health Organization report; the height was taken with the participant's back against the wall (or using a stadiometer when available) with a ruler placed on the uppermost point on the head. Participants were barefoot or wearing thin socks, and standing on a flat surface with weight distributed evenly on both feet, heels together, and the head positioned so that the line of vision is perpendicular to the body. The arms of the participant were hanging freely by their sides. The head, back, buttocks and heels were in contact with the wall. Participants were asked to maintain a fully erect position during the measurement. The participants' height was recorded to the nearest 0.1 cm twice, with a third measurement taken if the difference between the first two measurements was ≥ 0.5 cm. The final height was the mean of the two nearest values (75). For weight, all participants were weighed using the same levelled platform scale, where they stood in the center of the platform with the bodyweight evenly distributed between both feet. Participants were all wearing prison issued clothing (jeans, t-shirt), all other clothing including shoes were removed. Weight was recorded at

the nearest 0.5 kg. Two measurements were taken, with a third weight measured if the difference between the two first measurements was > 0.5 kg. Lastly, the mean of the two nearest values was recorded (75). For the waist circumference measurement, participants were asked to stand comfortably with weight evenly distributed on both feet, and with feet about ~25 cm apart. The waist circumference measurement was taken midway between the inferior margin of the last rib and the crest of the ilium (in a horizontal plane). The described landmarks should be palpated to determine the midpoint. Then the research assistant took a tape measure and snugly compressed the underlying tissue, to measure the value to the nearest 0.1 cm. Two measurements were taken, a third measurement was taken if the difference between the two first measurements was ≥ 0.5 cm. Lastly, the mean of the two nearest values was recorded (75).

The interview questions were based on the Canadian Health Measures Survey (Cycle 3-household questionnaire: Statistics Canada-Cycle 3), with slight modifications to fit the prison setting and to make the questions easier for inmates to answer. As a first step, we omitted questions that were not relevant to the prison setting. Questions such as: "how often to you walk to the grocery store" for example. The second step was to pilot the interview questions with a group of 10 inmates, to which they provided valuable feedback and requested we adjust certain questions. For example, they suggested we avoid asking how often they spoke to friends or family on the phone; and instead simply ask how many phone calls the participant made per month. The adjustments were to avoid painful topics when possible. The results and analysis are presented below in Manuscripts 2, 3 and 4 in section 6 of this thesis.

The rest of the data, for the remaining 666 participants, was considered secondary data since it was collected from the electronic medical chart (OSCAR) and the offender management system (RADAR). That means we have more data from the participants who participated in the face to face interview, so some analyses were only done with the 754 participant sample, whereas other analyses were done using the whole 1420 participant sample.

See flow chart below that illustrates how the data were collected for the different samples.

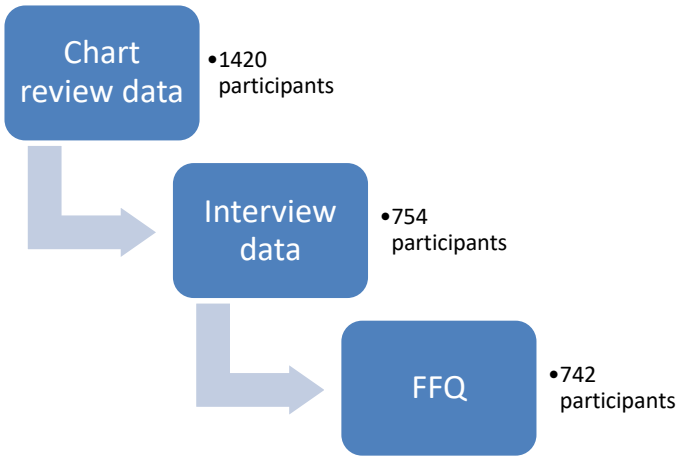

Figure 3: Flow chart of data collection for each sample of participants

5.4 Data entry

Data entry was done simultaneously throughout the duration of the study by a research assistant (a trained dietitian) at the University of Ottawa. She entered all the data into excel while double checking all questionable entries (data that was very high or very low). In addition, to validate our data entry, we double-checked 10% (n=142) of questionnaires and

found only 0.02% error. We also compared height measurements taken by our research assistants at the time of interview to the height measurements taken by health care staff on admission to the institution, and only found 0.7% difference.

5.5 Statistical Analysis

We performed chi-square and nonparametric median comparison tests (Wilcoxon and Kruskal-Wallis) to detect statistically significant differences in anthropometric measurements on weight outcomes (BMI, waist circumference, weight change, BMI changes and annual weight change) between inmates with and without the variable of interest (exposure). These tests were performed because the data did not satisfy the assumptions required for applying parametric methods (i.e., we observed: lack of normality, heterogeneity of variances, platykurtic distributions and skewed Box-Cox transformed distributions). In cases such as these, using nonparametric analysis is a valid option.

We performed multivariate regression analyses for BMI and waist circumference at interview to adjust for covariates (sex, age, ethnicity, sleep, length of incarceration and diet). The multivariate regression could only be performed on BMI and waist circumference at the time of interview, because the data met the conditions for analysis using the mean. Our data for our weight *change* outcomes could not use the mean for a regression analysis because they were not normally distributed. We performed quantile regression analysis to examine whether associations were different for various percentiles by modelling the 0.5 (the median), 0.75 and 0.90 quantiles of the weight change outcomes change distribution adjusted by sex, ethnicity, region, length of incarceration, substance abuse, physical activity, diet and feeding system. We opted for the conditional quantile

regression model instead of the multivariate regression analysis on the mean, because the residuals (from the multiple *regression* model) did not meet the model assumptions (i.e., normality, linearity, homoscedasticity). Statistical analyses were performed using the Statistical Analysis Software (SAS) version 9.4. The level of statistical significance was set at $p<0.05$ for all analyses.

5.6 Ethical considerations

As per University of Ottawa policy, this study needed full ethics approval from the Research Ethics Board (REB) prior to the start of data collection since it involved human participants. In addition to the REB approval, this study also required approval from the Correctional Service Canada (CSC) research branch. The inmate population is a vulnerable one as they are a captive population and have historically been exploited by researchers (76). This implies that since they do not have the freedom to leave the institution and their choices are limited, their participation might be the result of manipulation or coercion (77). Therefore, conducting research in the prison setting has many ethical considerations. It is important for the inmates to understand our study's objectives when agreeing to participate. It was our responsibility to communicate the information appropriately given the low literacy levels. Participants were asked to provide verbal consent, as they are typically wary of providing their signature. We clearly described the expected participant involvement during the information session at each participating penitentiary. Furthermore, during the data collection we reminded each participant that they always had the option to withdraw participation at any time (73). Dealing with confidentiality is typically challenging in the prison setting since everyone sees who moves where and it is easy to identify the

participants in a study (76, 77). Therefore, ensuring confidentiality of participation was difficult. However, the results of the data collection remained anonymous (and coded to ensure confidentiality) as the study dealt with sensitive medical information. Since I played multiple roles at Correctional Service Canada (i.e., Registered Dietitian, coordinator of the nutrition management program, and researcher), it was important to clearly disclose the purpose of my actions, at all times, to avoid confusion. In addition, it was essential to respect my professional code of ethics as a member of the College of Dietitians of Ontario. The ethical considerations changed depending on the phase of the study. During the participant recruitment phase, it was important not to pressure participants to provide consent. During the data collection, we did not deceive or exploit participants, and we were mindful of the potential for power imbalance (77). During the data analysis, we disclosed all findings and not only the results that supported our hypothesis. Lastly, in sharing the information, we were truthful about authorship, evidence, data, findings and conclusions (73).

6. Results

The results section below contains 4 manuscripts and 2 sections of other results that are not part of a manuscript yet. Of the 4 manuscripts below, 3 are published and 1 has been resubmitted with revisions. The first manuscript assessed inmate weight gain during incarceration to determine if the prison environment was obesogenic. It is published in the Canadian Medical Association Journal (CMAJ)-Open. The second manuscript assessed inmate weight gain by smoking status. This manuscript has been resubmitted with revisions to the British Medical Journal (BMJ)-Open. We are currently waiting on a final decision

from the journal. The third manuscript assessed inmate weight gain by daily movement behaviors (physical activity, screen time and sleep). It is published in the Canadian Journal of Public Health (CJPH). The fourth manuscript is an exploration of food intake among inmates who gained weight during incarceration. It is published in PLoS ONE. The 3 published articles have been through the peer-review process.

The last two sections are not presented in a manuscript format yet, but the data will be used to write 2 manuscripts within the next year. The section 6.5 assesses the influence of mental health status and psychotropic medication use on weight gain during incarceration. Lastly, section 6.6 assesses obesity related comorbidities as a health outcome in inmates who gained weight during incarceration. The last section is different from the other results, since it assesses obesity related comorbidities as a result of weight gain; whereas the rest of the results examined factors that can potentially influence weight gain. The last section (section 6.6 of this thesis) corresponds to the bottom arrow ("comorbidities") in figure 2 of our model (section 3.2 of this thesis).

6.1 Manuscript 1- Canadian federal penitentiaries as obesogenic environments: a retrospective cohort study

This manuscript has been written and formatted following the publication guidelines from the peer reviewed journal Canadian Medical Association Journal-Open (CMAJ-Open). Available online: http://cmajopen.ca/content/6/3/E347.full

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Research

Canadian federal penitentiaries as obesogenic environments: a retrospective cohort study

Claire Johnson RD, Jean-Philippe Chaput PhD, Maikol Diasparra PhD, Catherine Richard RD, Lise Dubois PhD

Abstract

Background: Very little is known about how incarceration influences a person's weight in Canada. We sought to determine how inmates' weights change during their incarceration in Canadian federal penitentiaries.

Methods: We performed a retrospective, longitudinal cohort study to examine weight change in Canadian federal penitentiaries. To participate, inmates had to have been incarcerated for at least 6 months at the time of the study. Current anthropometric data were measured or taken from medical records, then compared with anthropometric data from the beginning of incarceration (mean follow-up of 5.0 ± 8.3 yr). We examined 3 outcomes: change in weight (kg), change in body mass index (BMI) and rate of weight change (kg/yr) during incarceration.

Results: A total of 1420 inmates participated in this study. Almost three-quarters (73.0%, *n* = 1037)) of participants gained weight during incarceration. Inmates gained a median of 6.2 (95% confidence interval [CI] 5.6–6.9) kg, and BMI increased by 2.0 (95% CI 1.8–2.2). Obesity rates increased by 71%, from 26.6% of participants (*n* = 378) on admission to 45.4% of participants at follow-up (*n* = 645). The proportion of inmates with a BMI in the normal range (18.5–24.9) decreased by 52%. Weight gain was found to be associated with older age, region (Ontario v. Atlantic), ethnicity (Aboriginal inmates showed the highest weight gain), longer incarceration, and longer total sentence. However, weight gain was not associated with sex, feeding system or spoken language.

Interpretation: The Canadian correctional environment can be considered obesogenic, with most inmates experiencing undesirable and rapid weight gain during their incarceration. Rates of obesity increased dramatically during incarceration, and could put inmates at increased risk of obesity-related health problems.

It is well-established that obesity increases the risk of developing noncommunicable diseases such as type 2 diabetes mellitus, cardiovascular disease and certain types of cancer, as well as all-cause mortality.[1] Marginalized groups, such as inmates, carry a disproportionately high burden of obesity, because they are often from vulnerable segments of the population with low socioeconomic status.[2–4] In 2015, a Canadian study found that 64.5% of inmates were overweight or obese at the beginning of their sentence.[5] This prevalence is higher than 61.3% for the general Canadian adult population, as measured by the Canadian Community Health Survey in 2015.[6] Research done in other countries has identified correctional institutions as obesogenic environments, with most inmates gaining weight during incarceration.[7] However, very little is known on weight changes among Canadian inmates. This is an important knowledge gap, because there are more than 40 000 adults in custody across Canada.[8] Many correctional physicians anecdotally report weight gain as a substantial problem for inmates, but lack the data to support these claims.[9] Physicians across Canada are called upon to care for this unique population, because inmates get transferred to community hospitals when their medical condition warrants it. In the event that an inmate gains weight excessively while incarcerated, the burden of care and associated costs will be increased and assumed by Correctional Service Canada. Once released, after less than 5 years for most inmates,[10] the care and associated costs are covered through provincial health care budgets.[11]

Obesogenic environments are defined as "the sum of influences that the surroundings, opportunities or conditions of life have on promoting obesity in individuals or populations."[12,13] There is increasing recognition that the environment plays an important role in shaping health behaviours, such as eating habits and physical activities.[14] For inmates,

Competing interests: Claire Johnson currently works as coordinator of the Nutrition Management Program for Correctional Service Canada. The data and their interpretation are fully represented in the paper, and no censorship has occurred.

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everything about the prison environment is controlled, including their opportunities to eat and to exercise.[4] The prison food environment is more controlled than most food environments because inmates eat from the same food service within the penitentiary. In many cases, the kitchen provides a standardized menu to all inmates. The controlled nature of prison provides a unique opportunity to examine weight changes in a homogeneous environment.

The objective of this study was to examine how incarceration influences inmates' weight in Canadian correctional institutions. We hypothesized that inmates would gain weight during incarceration in federal penitentiaries.

Methods

Study design and study population

We performed a retrospective, longitudinal cohort study to investigate whether correctional institutions are obesogenic environments. In 2016 and 2017, we collected data from 1420 inmates who volunteered and who had been incarcerated, for at least 6 months, in institutions in Atlantic Canada and Ontario. We used a convenience sample and offered information sessions with the inmate committee in each of the institutions where we were collecting data to encourage volunteers. In addition, we advertised the study on the prisons' telecommunication services. Inmates were asked to submit their names to a designated staff member in each penitentiary.

We initially drew a random list of inmates who we called down to the office to ask whether they wanted to participate. We had a very low response rate with this approach, because inmates found it stressful to be called to the office without knowing why. Most of the inmates contacted in this way refused to participate. We were more successful when we asked for volunteers. In addition, asking inmates to submit their names to a staff member increased their confidence in the study. We did not keep track of who volunteered and who did not. For ethical reasons, we could not gather data on inmates who did not volunteer to participate because we did not have their consent to access their administrative files. We collected data from 88% of the eligible inmates. Participants were recruited from 5 federal penitentiaries (4 male institutions and 1 female institution) near Kingston,[15] chosen for reasons of geographical feasibility, and from all 5 federal penitentiaries (4 male institutions and 1 female institution) in New Brunswick and Nova Scotia.[15] We excluded provincial institutions from our data collection because they are part of a different governance system and only house inmates for short-term sentences (< 2 yr). Inmates with critical illnesses who were admitted to the prison hospital and inmates who were pregnant were excluded from the study.

We used a standardized protocol to collect anthropometric measurements at follow-up for half of our data. The protocol was performed by trained research assistants as part of a face-to-face interview and was guided by a report from the World Health Organization.[16] Participants' heights were measured while they were standing against a wall, and weights were measured on a scale. Two measurements were taken; a third was taken if the first 2 measurements showed a significant difference (≥ 0.5 cm for height and > 0.5 kg for weight). The final recorded measurement was the mean of the 2 nearest values.[16] The rest of the anthropometric measurements (at follow-up and at admission) were objectively measured by a health care professional (i.e., a nurse or dietitian) using a similar protocol. Historical data, such as weight and height on admission to the penitentiary, were drawn from participants' electronic medical records. Sociodemographic data (i.e., sex, age, region, language, ethnicity), information about the institution (i.e., feeding system, security level) and details of the inmates' sentences (i.e., length of incarceration, length of total sentence) were drawn from the electronic Offender Management System.

The 3 main outcomes of the study were change in weight (difference between weight at admission and at follow-up), change in body mass index (BMI; difference between BMI at admission and at follow-up), and annual change in weight during incarceration (kg/yr; weight change during incarceration divided by the number of years of incarceration at the time of study). In addition, data on weight and BMI were compared with similar data from Statistics Canada's Canadian Community Health Survey of the general Canadian adult population in 2015[6] to contextualize our findings.

Statistical analysis

We performed χ^2 and nonparametric median comparison tests (Wilcoxon and Kruskal–Wallis) to detect significant changes in anthropometric data. We used these tests because the data did not have a normal distribution. Statistical analyses were performed using SAS version 9.4, with significance set at $p < 0.05$ for all analyses.

Ethics approval

Our study was approved by the Research Ethics Board at the University of Ottawa and the research branch at Correctional Service Canada. Inmates volunteered to participate and provided their consent. Because many inmates hesitate to sign documents or forms owing to low literacy or fear of reprisal, participants were able to provide verbal consent if they so preferred.[17] All personal data collected were coded to ensure confidentiality.

Results

Table 1 describes our participants, and Table 2 presents the proportion of inmates in each BMI category at admission and at follow-up. On admission to the penitentiary, the combined prevalence of overweight (39.4%) and obesity (26.6%) was 66.0%. During incarceration, the combined prevalence of overweight (38.8%) and obesity (45.4%) increased to 84.2% (a 27.6% increase from admission). The increase in prevalence was mainly due to the 71% increase in inmates who became obese (BMI ≥ 30.0) during incarceration (26.6% obesity on admission v. 45.4% obesity at the time of study). The proportion of inmates with a normal weight (BMI 18.5–24.9) was reduced by about one-half, whereas the proportion of

inmates who were overweight (BMI 25.0–29.9) remained stable.

Table 3 presents data on median weight change, median BMI change, and median annual weight change by sociodemographic factors. The changes are based on the time elapsed between admission and follow-up (mean duration 5.0 ± 8.3 yr). Overall, inmates gained a median of 6.2 kg. The median BMI increase was 2.0. The annual rate of weight gain was 1.5 kg per year. No significant differences were seen between men and women, or between Francophones and Anglophones. Inmates between 45 and 64 years of age gained more weight (median 7.6 kg) than inmates in other age groups. However, younger inmates, between 18 and 24 years of age, gained weight more rapidly (median 3.5 kg/yr). Regional differences were seen; in Atlantic institutions, although inmates had higher mean BMI on admission compared with those from Ontario (28.2 v. 27.3), they gained less weight (median 5.1 v. 7.1 kg) once incarcerated. Aboriginal inmates were more likely to gain weight (median 7.7 kg) than inmates of other ethnicities.

Table 4 presents data on median weight change, median BMI change and median annual weight change by institutional factors, such as feeding system, length of incarceration, security level and total duration of sentence. Inmates in medium security institutions had a significantly higher increase in weight (median 7.0 kg) than those in minimum or maximum (median 5.6 kg for both) security penitentiaries. However, this difference was not related to the feeding system. Inmates incarcerated for shorter periods (< 18 mo) underwent more rapid weight gain (6.4 kg/yr) compared with inmates incarcerated for more than 5 years (0.64 kg/yr). Inmates with longer sentences (> 25 yr) tended to gain more weight (median 7.7 kg) than inmates with shorter sentences.

The combined prevalence for overweight (34.6%) and obesity (26.7%) for the general Canadian population was 61.3% in 2015 (Appendix 1, available at www.cmajopen.ca/content/6/3/E347/suppl/DC1).[6] For inmates, the combined prevalence for overweight (39.4%) and obesity (26.6%) was 66.0% on admission to the penitentiary. This discrepancy is due to the higher rates of overweight in inmates on admission. However, during incarceration, the proportion of inmates with obesity became much higher than that seen in the general population (Appendix 1).

Table 1: Sociodemographic factors for all participants

Factor	No. (%) *n* = 1420
Sex	
Male	1276 (89.9)
Female	144 (10.1)
Age, yr	
18 to ≤ 24	104 (7.3)
≥ 25 to ≤ 34	389 (27.4)
≥ 35 to ≤ 44	315 (22.2)
≥ 45 to ≤ 64	504 (35.5)
≥ 65	108 (7.6)
Region	
Atlantic	520 (36.6)
Ontario	900 (63.4)
First language	
English	1265 (89.1)
French	155 (10.9)
Ethnicity	
White	904 (63.7)
Black	203 (14.3)
Aboriginal	214 (15.1)
Other	99 (7.0)
Feeding system	
Tray (menu)	393 (27.7)
Cafeteria (menu)	522 (36.8)
Kitchenette (no menu)	505 (35.6)
Security level	
Maximum	348 (24.5)
Medium	781 (55.0)
Minimum	291 (20.5)
Length of incarceration at follow-up	
≤ 18 mo	553 (38.9)
> 18 mo to ≤ 5 yr	458 (32.3)
> 5 yr	409 (28.8)
Length of sentence, yr	
2 to ≤ 3	285 (20.1)
> 3 to ≤ 5	286 (20.1)
> 5 to ≤ 25	365 (25.7)
> 25	484 (34.1)

Interpretation

Almost three-quarters (73%) of the 1420 participants in our study gained weight during their incarceration. Median weight gain was 6.2 kg, with a median annual weight gain of 1.5 kg per year. In addition, we saw a 71% increase in the proportion of inmates with obesity during incarceration (from 26.6% at admission to 45.4% at follow-up). This excessive weight gain is concerning and could lead to obesity-related health problems for these individuals.

Penitentiaries in Japan have been shown to be less obesogenic than the general community. Most Japanese inmates lost weight, and BMI scores decreased during incarceration. Unlike Canadian inmates, Japanese inmates follow strict low-calorie diets and are obliged to work and exercise daily.[18,19] However, Japanese inmates were the only outliers in a recent systematic review that examined weight changes during

Table 2: Categories of body mass index for Canadian inmates on admission and at follow-up

Category	BMI range	Admission, no. (%) n = 1420	Follow-up, no. (%) n = 1420	p value
Underweight	< 18.5	17 (1.2)	F	< 0.0001*
Normal	18.5–24.9	466 (32.8)	222 (15.6)	
Overweight	25.0–29.9	559 (39.4)	551 (38.8)	
Obese	≥ 30.0	378 (26.6)	645 (45.4)	
Overweight and obese	≥ 25	937 (66.0)	1196 (84.2)	
Obesity class I	30.0–34.9	236 (16.6)	405 (28.5)	
Obesity class II	35.0–39.9	92 (6.5)	146 (10.3)	
Extreme obesity class III	≥ 40.0	50 (3.5)	94 (6.6)	

Note: BMI = body mass index, F = proportion too low to report and could threaten confidentiality.
*χ^2 test; $p < 0.05$ considered significant.

Table 3: Median change in weight and body mass index, and annual rate of change, between admission and follow-up by sociodemographic characteristic

Characteristic	Median weight change, kg (95% CI)	p value*	Median BMI change (95% CI)	p value*	Median annual rate of change, kg/yr (95% CI)	p value*
Overall	+6.20 (5.55–6.85)		+2.00 (1.79–2.21)		+1.52 (1.24–1.81)	
Sex						
Male	+6.50 (5.82–7.18)	0.3	+2.00 (1.78–2.22)	0.7	+1.46 (1.18–1.75)	0.2
Female	+5.80 (3.60–8.00)		+2.00 (1.19–2.81)		+2.69 (0.99–4.39)	
Age, yr						
18 to ≤ 24	+4.70 (2.99–6.41)	0.05	+1.60 (1.04–2.16)	0.04	+3.51 (2.08–4.93)	< 0.0001
≥ 25 to ≤ 34	+5.70 (4.62–6.78)		+1.80 (1.45–2.15)		+2.30 (1.63–2.98)	
≥ 35 to ≤ 44	+6.30 (4.99–7.70)		+2.00 (1.55–2.45)		+2.13 (1.35–2.92)	
≥ 45 to ≤ 64	+7.60 (6.35–8.85)		+2.50 (2.09–2.91)		+1.03 (0.68–1.39)	
≥ 65	+5.30 (3.87–9.46)		+1.75 (1.28–3.10)		+0.51 (0.16–0.85)	
Region						
Atlantic	+5.05 (4.00–6.10)	0.0004	+1.70 (1.35–2.05)	0.002	+1.42 (0.91–1.92)	0.1
Ontario	+7.10 (6.28–7.92)		+2.30 (2.04–2.56)		+1.57 (1.22–1.92)	
First language						
English	+6.30 (5.61–6.99)	0.3	+2.00 (1.78–2.22)	0.4	+1.50 (1.20–1.80)	0.9
French	+6.00 (4.08–7.92)		+1.90 (1.28–2.52)		+1.75 (0.78–2.72)	
Ethnicity						
White	+6.30 (5.47–7.13)	0.004	+2.00 (1.73–2.27)	0.005	+1.42 (1.07–1.78)	0.06
Black	+7.00 (5.54–8.46)		+2.20 (1.75–2.65)		+2.06 (1.22–2.90)	
Aboriginal	+7.70 (6.92–10.52)		+2.40 (1.83–2.97)		+1.72 (0.89–2.54)	
Other	+3.30 (1.61–4.99)		+1.00 (0.77–1.86)		+1.14 (0.49–1.78)	

Note: BMI = body mass index, CI = confidence interval.
*Wilcoxon test was used in analyses with two categories (sex, region, language), a Kruskal–Wallis test was used in analyses with three or more categories (age and ethnicity); $p < 0.05$ was considered significant.

incarceration.[7] The findings from 16 different studies showed that 50%–80% of inmates gained weight during incarceration in the United States and United Kingdom.[3,7,9,20–23] The amount and pace of weight gained varied by study, and ranged from a modest mean gain of 0.96 kg over 2 years[3] to a substantial 0.5-kg gain per week.[9] The latter study involved female

Table 4: Median change in weight and body mass index, and annual rate of change, between admission and follow-up by institutional characteristic

Characteristic	Median weight change in kg (95% CI)	*p* value*	Median BMI change (95% CI)	*p* value*	Median annual weight change in kg/yr (95% CI)	*p* value*
Overall	+6.20 (5.55–6.85)		+2.00 (1.79–2.21)		+1.52 (1.24–1.81)	
Feeding system						
Tray (menu)	+6.00 (4.83–7.17)	0.97	+1.90 (1.52–2.28)	0.97	+1.48 (0.98–1.97)	0.97
Cafeteria (menu)	+6.85 (5.75–7.95)		+2.20 (1.86–2.54)		+1.63 (1.18–2.08)	
Kitchenette (no menu)	+6.50 (5.41–7.59)		+2.10 (1.74–2.46)		+1.50 (0.93–2.07)	
Security level						
Maximum	+5.55 (4.32–6.78)	0.05	+1.80 (1.42–2.18)	0.04	+1.45 (0.94–1.95)	0.1
Medium	+7.00 (6.10–7.90)		+2.30 (2.01–2.59)		+1.79 (1.39–2.19)	
Minimum	+5.55 (4.07–6.93)		+1.80 (1.34–2.26)		+1.02 (0.24–1.81)	
Length of incarceration at follow-up						
≤ 18 mo	+5.60 (4.70–6.50)	0.001	+1.90 (1.60–2.20)	0.001	+6.40 (5.33–7.47)	< 0.001
> 18 mo to ≤ 5 yr	+5.75 (4.65–6.85)		+1.80 (1.45–2.15)		+2.09 (1.67–2.51)	
> 5 yr	+8.40 (6.92–9.88)		+2.70 (2.23–3.17)		+0.64 (0.54–0.74)	
Length of total sentence, yr						
2 to ≤ 3	+6.00 (4.63–7.37)	0.006	+2.00 (1.55–2.45)	0.007	+6.21 (4.76–7.66)	< 0.001
> 3 to ≤ 5	+6.25 (4.99–7.51)		+2.00 (1.60–2.40)		+3.74 (2.78–4.70)	
> 5 to ≤ 25	+5.50 (4.35–6.65)		+1.70 (1.33–2.07)		+1.95 (1.44–2.46)	
> 25	+7.70 (6.36–9.04)		+2.50 (2.06–2.94)		+0.69 (0.56–0.81)	

Note: BMI = body mass index, CI = confidence interval.
*Kruskal–Wallis test; $p < 0.05$ was considered significant. The mean (± standard deviation) length of time between admission and follow-up was 5.0 (± 8.3) years.

inmates in the US and was based on weight gained during the first 2 weeks of incarceration.[7,9]

Our findings suggest that weight gain was more rapid in the first months of incarceration. A median weight gain of 6.4 kg/yr was noted among inmates incarcerated for less than 18 months, compared with 0.64 kg/yr among inmates incarcerated for more than 5 years at the time of study. Rapid weight gain in the beginning of incarceration could be the result of withdrawal from alcohol, drugs and tobacco.[9] It is well-established that inmates have higher rates of smoking and substance dependence than are seen in the general population.[24,25] In support of this hypothesis, studies performed in penitentiaries where inmates were allowed to smoke tobacco reported modest weight gain.[2,3,23,26] Tobacco withdrawal could explain the variation in gains between studies. In Canada, tobacco became prohibited in federal penitentiaries in 2008.[27] This prohibition may contribute to weight gain for some inmates, because people who smoke tend to have lower BMIs than those who do not,[28] and smoking cessation typically leads to weight gain.[29]

On admission to the penitentiary, inmates had rates of obesity similar to those of the general Canadian adult population (~27% for both groups). However, during incarceration, the prevalence of obesity among inmates increased to 45.4%. The proportion of inmates with weight in the normal range also changed during incarceration. On admission, 32.8% of inmates had a normal BMI; that proportion had decreased to 15.6% at follow-up. On admission, the proportion of inmates with a normal BMI (32.8%) was similar to the proportion seen in the general Canadian adult population (36.1%).[6] Thus, there is little difference in proportions of people in each BMI category between inmates on admission to a penitentiary and the general population. However, during incarceration, the proportion of inmates in the normal and obese ranges changes substantially.

The rate at which Canadian inmates gain weight (median 1.5 kg/yr; mean 4.3 kg/yr) is higher than the rate of weight gain in nonincarcerated Canadian adults (0.37 kg/yr for men, 0.29 kg/yr for women), and our findings suggest that inmates tend to gain more weight during the beginning of their incarceration. Thus, inmates gain excessive weight throughout their incarceration, but the rate at which they gain weight decreases over time. Moreover, only 45% of the Canadian adults gained weight in 2006, compared with 73% of inmates.[30] In the community, men tend to gain weight more rapidly than women.[30] However, the opposite is seen in the correctional setting, where many studies have shown weight gain to be more severe for women than for men.[2,21,31] Because we did not see a significant difference between men and women in terms of weight outcomes in our study, we can conclude that sex did not influence weight gain, suggesting that Canadian correctional institutions are equally obesogenic for men and women.

Some Canadian penitentiaries have a central feeding system that uses a standardized menu,[32] whereas other institutions have a feeding system in which inmates purchase and prepare their own foods.[15] We found no significant difference in weight gain based on these different feeding systems.

Limitations

The observational nature of the data precludes inferences about causality. Residual confounding by unmeasured variables is always possible in observational studies. It was not possible to create a cohort of nonincarcerated adults to match our sample, which would have provided a better comparison group. We used the best data available from Statistics Canada,[6] which allowed us to compare our results with the broader context of obesity in Canada.

Conclusion

Our study provides evidence that correctional institutions in Canada are obesogenic environments. Inmates come into prison with higher BMIs compared with the general adult population, and most inmates gain weight during incarceration. Prison could be an opportunity to address the health needs of inmates, many of whom come from marginalized or vulnerable populations. This opportunity may be missed if the environment is so obesogenic that the most important change to inmates' physical health status is weight gain. Releasing inmates in poorer health than when they were admitted into the penitentiaries is a likely scenario. Further research should identify strategies to make the correctional environment less obesogenic.

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Contributors: Claire Johnson and Lise Dubois directed data planning, data collection and data analysis for the study. Jean-Philippe Chaput provided guidance on which outcomes to examine and which statistical tests to perform. Maikol Diasparra performed all statistical analyses. Claire Johnson drafted the manuscript. Catherine Richard coded the data and prepared it for statistical analysis. All of the authors contributed to the conception and design of the study and the interpretation of the data, critically revised the manuscript for important intellectual content, gave final approval of the version to be published and agreed to be accountable for all aspects of the work.

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6.2 Manuscript 2- How did the tobacco ban increase inmates' bodyweight during incarceration in Canadian federal penitentiaries? A cohort study

This manuscript has been written and formatted based on the submission guidelines for the

journal BMJ-Open, where it was accepted for publication in June 2019.

Abstract

Objectives: This study aimed to determine how inmates' bodyweight changed during incarceration in Canadian federal penitentiaries, based on their history of tobacco use. Since the tobacco ban in 2008, little is known about the unintended health consequences of this ban, especially on inmates' bodyweight.

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 with a history of tobacco use. In 2016-2017, anthropometric data were collected and compared to 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 bodyweight change (kg), body mass index (BMI) change (kg/m^2), annual weight change (kg/year), and BMI and waist circumference (cm) at the time of the interview.

Results: During incarceration, ex-smokers gained twice the amount of weight compared to non-smokers (7.5 kg weight gain for smokers vs. 3.7 kg weight gain for non-smokers). This weight gain was related to the number of cigarettes smoked prior to incarceration (light smokers gained 5.6 kg vs. heavy smokers gained 10.2 kg). These relationships were confirmed in a regression analysis, with adjustment for covariates.

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 programs and regulation.

Key words: inmates, prison, penitentiary, weight, obesity, substance misuse, tobacco ban, smoking cessation

Strengths and limitations of this study:

- A strength of this study is the 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 the data related to tobacco use was self-reported, and therefore subject to recall and social desirability biases.
- The recruitment process was voluntary, 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.

1. Introduction

Smoking, whether permitted or not, is a major part of the prison culture, mainly because so many inmates identify as smokers. In Canada, smoking rates among inmates, prior to incarceration, are estimated to be between 50-93% (24, 59, 61, 62, 78-80). Those rates are four to five times the smoking rate of the general Canadian population (62), estimated to be between 13-17% (81-83). 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 socio-economic backgrounds (84, 85). 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 (86). 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 (87). Canada proactively took the lead and adopted a total tobacco ban for all 41 federal correctional institutions in 2008 (38). That means of the 14 000 inmates incarcerated in federal penitentiaries across Canada, approximately 10 000 were forced to quit smoking upon admission to the penitentiary (or quit smoking when the ban occurred in 2008) (88). Although the tobacco ban is considered a good public health measure in several aspects (improving air quality for example), there is a lack of research on the unintended consequences of tobacco bans in prisons (89-91). 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 (80, 92-94). 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.

Generally, studies on obesity in prison found obesity prevalence in male inmates to be similar or lower than the general population (3, 25, 95). 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 (20). Moreover, there appears to be important variability in weight gain, ranging from a modest 0.96 kg over 2 years (23) to a substantial 0.5 kg gain per week (7). When inmates gained substantial amounts of weight, authors often speculated it is because of withdrawal from tobacco, alcohol or drugs (7, 30). However, they lack data to back up these claims, since there is little data on the factors that contribute to weight gain during incarceration (25). An American study demonstrated that female prisoners who participated in a voluntary smoking cessation program (that included transdermal nicotine replacement) while incarcerated gained more weight at the 6-month post-cessation follow-up compared to inmates who continued to smoke (on average 4.5 kg more than smokers) (96).

The majority of studies on obesity in prison were out of Australia, the United States and the United Kingdom (20). In our recent publication, we reported that Canadian inmates gained a significant amount of weight during incarceration (95). Our findings showed that on admission obesity rates where similar to the general Canadian population (~27%), but after at least six months of incarceration obesity rates increased to 45% for the inmate population (95). We do not know if the observed weight gain is associated with tobacco cessation in Canadian inmates.

To fill this knowledge gap, this study examined, for the first time, how inmates' bodyweight changed in Canadian federal penitentiaries during incarceration based on a history of tobacco use

prior to incarceration. Our aim was to draw a comparison between weight gain (from admission to follow up) in inmates who were in withdrawal from tobacco, or other substances (drugs and/or alcohol), to inmates not battling addictions during incarceration. Because smoking cessation is known to be associated with weight gain (17, 57), we hypothesized 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. Our goal is to provide insight into the factors that contribute to weight gain in Canadian penitentiaries.

2. Materials and Methods

2.1 Participants

This cohort study explored how a history of smoking was associated with weight gain in Canadian penitentiaries. Participants for this study 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 regions. In the Ontario region, we collected data from inmates housed in 5 institutions near Kingston (of the 7 institutions in the Ontario region) (38). These institutions were selected for geographical feasibility reasons. In the Atlantic region, we collected data from inmates housed in all 5 institutions in New Brunswick and Nova Scotia (38). Critically ill inmates admitted to the prison hospital and pregnant inmates were excluded from the study.

2.2 Data collection

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

measured participants' height, weight and waist circumference following a standardized protocol, and 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 standardized protocol was guided by a World Health Organization report (75). 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 was then used to calculate body mass index (BMI) (kg/m^2) (75).

2.3 Outcomes

The main outcome measures for this study were bodyweight 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 World Health Organization (WHO) cut-off points (men >102 cm and women >88 cm) (97). The BMI categories were based on the WHO classification system (2).

2.4 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 5 questions: "Incarceration forces many lifestyle changes, were you a smoker before your incarceration?"

(response options: yes or no); "How many cigarettes did you smoke per day prior to your incarceration?" (response: number of cigarettes per day); "Did you have substance abuse problems before your incarceration?" (response options: yes or no); "Which substance?" (response options: alcohol or drugs or other with specification); and "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.

2.5 Covariates

We adjusted our findings for the covariates: sex, age, ethnicity, region 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.

2.6 Statistical Analysis

We performed chi-square and nonparametric 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 are different for

medium, and high percentiles by modelling the 0.5 (the median), 0.75 and 0.90 quantiles of the BMI change distribution adjusted by sex, ethnicity, region, length of incarceration, substance abuse, physical activity, diet and feeding system. We opted for the conditional quantile regression model (98-100) instead of the multivariate regression analysis on the mean, because the residuals (from the multiple *regression* model) did not meet the model assumptions (i.e., normality, linearity, homoscedasticity). Statistical Analysis Software (SAS) version 9.4 was used. The level of statistical significance was set at $p<0.05$ for all analyses.

2.7 Ethics approval

We obtained ethics approval through the Research Ethics Board at the University of Ottawa and the Research branch at Correctional Service Canada. 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 (76). The verbal consent was obtained by the research assistants, and witnessed by correctional staff. All personal data collected were coded to ensure confidentiality.

2.8 Participant involvement

The research team met with inmate committee members to present the project and to pilot our questionnaire with them. We then got their feedback on how to adapt it to their preferences before starting our data collection. Once that 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 because inmates found it stressful to be called upon (over loudspeaker) without knowing why.

We then reconvened with the inmate committee members to get advice on how to increase participation; they 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 upon. We recruited 754 participants over a 16-month period.

3. Results

The response 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 response 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 at admission and follow-up (mean duration of 5.0 ± 8.3 years). It also shows how those proportions compare to the Canadian adult population (≥ 18 years of age) using data from Statistics Canada (101). The prevalence of obesity for the general Canadian adult population was 26.7% in 2015, similar to our inmate sample at 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 in relation to the general population. Moreover, the observed weight gain is deemed undesirable since it results in an increase in the prevalence of inmates with obesity during incarceration.

Table 2 presents 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 to 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 table).

Table 3 shows 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 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 to 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 to non-smokers over time (7.5 kg vs. 3.7 kg, respectively). Moreover, weight gain was

related to the number of cigarettes smoked daily before incarceration, with heavy smokers gaining the most (light smokers [≤10 cigarettes/day] gained 5.6 kg vs. 10.2 kg for heavy smokers [>25 cigarettes/day]). Approximately 50% of inmates reported a history of substance misuse prior to incarceration. Those inmates gained 64% more weight, with a median weight gain of 7.4 kg, compared to 4.5 kg 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 (8.4 kg vs. 2.6 kg, 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 point of BMI lower than ex-smokers. These findings also show similar findings for alcohol misuse. Moreover, increase in BMI 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 socio-demographic factors (sex, age, region, language and ethnicity) as well as for other factors (length of incarceration, physical activity, feeding system and diet).

4. Discussion

Our findings revealed that inmates in Canadian penitentiaries who quit smoking while incarcerated gained roughly twice the weight that nonsmokers gained (7.5 kg vs. 3.7 kg for ex-smokers and nonsmokers, respectively). Since most inmates are already vulnerable to unhealthy weight gain by

being incarcerated (20), the added stress of involuntary tobacco cessation puts smokers at an even higher risk of becoming obese. This is important because a high proportion of inmates were smokers (67.5% of our sample) before incarceration.

Our findings are consistent with other studies on inmate addiction that found the prevalence for tobacco use and drug misuse to be 3 to 4 times higher in the inmate population (prior to incarceration) than in the general Canadian population (90, 102, 103). 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 (104), 13% used illicit drugs (105), and 17.9% misused alcohol or were considered "heavy drinkers" by WHO standards (i.e., more than 5 drinks on one occasion at least once a month for the past 12 months) (106). Overall, our findings showed that most inmates suffering from addictions (i.e., 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 (i.e. certain types of cancer, CVD, type 2 diabetes, reflux, hypertension, osteoarthritis and sleep apnea).

Our findings showed that obesity rates increased from 24.5% to 42.4% during incarceration, i.e., a 73% increase in the proportion of inmates who became obese behind bars. It has been hypothesized 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 (7, 107). In support of that hypothesis, our findings revealed that a history of tobacco and drug use (prior to incarceration) influenced the amount and speed at which inmates gained weight in prison. As such, inmates with

a history of tobacco use gained more weight, and at a faster rate, than nonsmokers did (1.6 kg/year and 2.4 BMI increase for ex-smokers vs. 0.9 kg/year and 1.2 BMI increase for nonsmokers). Moreover, the higher the number of cigarettes an inmate smoked prior to incarceration the more weight was gained during incarceration, suggesting once again an association between a history of smoking and weight gain. Furthermore, studies from penitentiaries where tobacco is still permitted, reported a modest weight gain (0.7-0.96 kg weight gain over 1-2 years) (3, 20, 23, 108). Contrary to Canadian data on inmate weight gain (95), those studies found that inmates were less likely to be obese than the general population (3, 20, 23, 108), 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 (79, 109). 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 (40, 41). 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 (86, 96, 110, 111). In Canadian federal penitentiaries, those aids are available for inmates to purchase on the canteen list. That 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) (112). This could, in part, explain why inmates gained more weight when in withdrawal from tobacco during incarceration, since they have limited access to tools that may help deal with cravings (89). Furthermore, without those tools, they may turn to food to manage tobacco withdrawal symptoms. This phenomenon 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 ineffective in obtaining long term tobacco cessation (113). 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 (80, 89). Consequently, once released inmates who smoke may end up with two compounding risk factors (tobacco and obesity), which puts them at increased risk for health problems. The tobacco ban policy, intended to improve the prison health environment by improving air quality (114), has been successful at achieving that goal and also at reducing tobacco related diseases (10). The risk of weight gain could be offset by the benefits of long-term smoking cessation (115, 116). However, this may not be the case for Canadians inmates who will likely resume smoking after incarceration, since evidence indicated most inmates resume smoking once released from prison (80). In light of this reality, there are programs aimed at offering support to inmates with continued tobacco abstinence once released from prison. For example, WISE (Working Inside for Smoking Elimination) is a program based

on motivational interviewing and behavioral therapy out of the United States that has been successful at maintaining continued tobacco cessation post-release from institutions where tobacco is forbidden (26, 89). When planning for smoking cessation programs 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 (117). From that perspective, smoking cessation in prison could be viewed as a unique opportunity to help a population typically resistant to mainstream smoking cessation strategies (117). 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 (117). That means, including physical activity in a smoking cessation program in prison could help inmates to quit smoking successfully, and 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.

Lastly, in comparison to inmates who smoked, inmates suffering from drug withdrawal also gained more weight. They gained 8.0 kg compared to inmates without a history of drug use, who gained 4.5 kg, i.e., a difference of 78% between these two groups. The weight gain seen in inmates with a history of tobacco use or drug misuse was similar during incarceration; however, the same increase in weight was not seen in inmates who have a history of alcohol misuse.

4.1 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) was self-reported by participants, and therefore

subject to recall and social desirability biases (118). Third, residual confounding by unmeasured variables is always possible in observational studies. Finally, the generalizability of our findings may be restricted to the prison populations and other long-term care facilities where tobacco is restricted.

5. 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 to 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 program (with post release 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.

6. Contributorship statement

Claire Johnson and Lise Dubois directed data planning, data collection and data analysis for the study. Jean-Philippe Chaput provided guidance on outcomes to examine, statistical tests to perform and revised the manuscript extensively. Maikol Diasparra performed all statistical analyses. Claire

Johnson drafted the manuscript. Catherine Richard coded the data and prepared it for statistical analysis. All of the authors contributed to the conception and design of the study and the interpretation of the data, critically revised the manuscript for important intellectual content, gave final approval of the version to be published and agreed to be accountable for all aspects of the work. Lastly, inmate committee members were instrumental in encouraging participants to volunteer and providing valuable feedback on our questionnaire.

7. Competing interests

Claire Johnson currently works as Coordinator of the Nutrition Management Program for Correctional Service Canada. The data and their interpretation are fully represented in the paper, and no censorship has occurred.

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Table 1. Body mass index (BMI) categories for inmates on admission and follow-up (N=754) in comparison with the Canadian adult population in 2015 (101).

	BMI categories	Inmates at 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 chi-square 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.

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

		All N (%)	Age %					p-value	Region %		p-value	Ethnicity %				p-value
			18≤24 years	≥25≤34 years	≥35≤44 years	≥45≤64 years	≥65 years		Atl.	Ont.		Cau.	Black	Aboriginal	Other	
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	Yes	509 (68)	71	68	66	69	53	0.26	75	63	0.0005*	69	57	77	56	0.0019*
	No	245 (32)	29	32	34	31	47		25	37		31	43	23	44	
Number of cigarettes smoked per day (N= 509)	≤10	105 (21)	18	27	22	14	25	0.0005*	16	25	0.0002*	16	42	19	27	<0.0001*
	>10≤25	303 (59)	67	66	57	56	46		64	56		62	51	54	70	
	>25	101 (20)	16	8	21	30	29		20	19		22	7	27	3	
Illicit drug misuse	Yes	327 (43)	41	48	51	39	20	0.0009*	47	41	0.07	45	28	64	24	<0.0001*
	No	427 (57)	59	52	49	61	80		53	59		55	72	36	76	
Alcohol misuse	Yes	150 (20)	16	15	22	22	29	0.15	26	16	0.0004*	22	6	33	4	<0.0001*
	No	604 (80)	84	85	78	78	71		74	84		78	94	67	96	

A Wilcoxon test was used in analyses with two categories (ex-smoker, substance misuse, illicit drug misuse and alcohol misuse), and a 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), to inmates without a history of substance use prior to incarceration. Atl.: Atlantic; Ont.: Ontario; Cau: Caucasian.

Table 3: Waist circumference and body mass index (BMI) at follow-up by tobacco use and substance misuse (drugs and alcohol).

		All N (%)	**Waist Circumference N (%)**		**p-value**	**Body Mass Index (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. A Wilcoxon test was used in analyses with two categories (ex-smoker, illicit drug misuse and alcohol misuse) in comparison to inmates who reported that they did not use those substances. A 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.

Table 4. Median weight change, body mass index (BMI) change and annual weight change between admission and follow-up by tobacco use and substance misuse

		All N (%)	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, 6.4)		+1.8 (1.5, 2.1)		+1.4 (1.0, 1.8)	
Ex-smoker	Yes	509 (67.5)	+7.5 (4.3, 8.6)	<0.0001*	+2.4 (2.0, 2.8)	<0.0001*	+1.6 (1.1, 2.1)	0.0061*
	No	245 (32.5)	+3.7 (2.5, 4.9)		+1.2 (0.8, 1.6)		+0.9 (0.2, 1.5)	
Number of cigarettes smoked per day	≤ 10	105 (13.9)	+5.6 (3.4, 7.8)	<0.0001*	+1.8 (1.1, 2.5)	<0.0001*	+1.3 (0.3, 2.2)	0.0288*
	>10 ≤25	303 (40.1)	+7.5 (6.1, 8.9)		+2.4 (2.0, 2.8)		+1.6 (0.9, 2.3)	
	>25	101 (13.4)	+10.2 (7.4,13.0)		+3.7 (2.8, 4.6)		+1.4 (0.6, 2.1)	
Substance misuse	Yes	379 (50.2)	+7.4 (6.1, 8.7)	0.0056*	+2.3 (1.9, 2.7)	0.0047*	+1.4 (0.8, 2.8)	0.0885
	No	375 (49.7)	+4.5 (3.4, 5.6)		+1.5 (1.2, 1.8)		+1.3 (0.8, 1.7)	
Substance type (N=379)	Alcohol	52 (13.7)	+2.6 (-1.1, 6.3)	0.0013*	+0.8 (-0.4, 2.8)	0.0013*	+0.3 (-0.6, 1.2)	<0.0001*
	Drugs	229 (60.4)	+8.4 (6.9, 9.9)		+2.6 (2.1, 3.11)		+2.6 (1.6, 3.5)	
	Both	98 (25.9)	+6.8 (4.1, 9.5)		+2.1 (1.2, 3.0)		+0.8 (0.1, 1.5)	
Illicit drug misuse	Yes	327 (43.4)	+8.0 (6.3, 9.7)	0.0004*	+2.4 (2.0, 2.8)	0.0003*	+1.7 (1.0, 2.4)	0.0009*
	No	427 (56.6)	+4.5 (3.4, 5.6)		+1.4 (1.1, 1.7)		+1.1 (0.7, 1.5)	
Alcohol misuse	Yes	150 (19.9)	+5.5 (3.8, 7.2)	0.4147	+1.8 (1.1, 2.5)	0.5435	+1.4 (1.0, 1.8)	0.8075
	No	604 (80.1)	+5.8 (4.3, 7.5)		+1.9 (1.6, 2.2)		+1.3 (0.5, 2.1)	

A Wilcoxon test was used in analyses with two categories (ex-smoker, substance misuse, illicit drug misuse and alcohol misuse), and a 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. CI = confidence interval.

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

Variables		50th percentile (CI 95%)	75th percentile (CI 95%)	90th percentile (CI 95%)
Ex-smoker	Yes	0 (reference)	0 (reference)	0 (reference)
	No	-0.61 (-1.81, 0.20)	-1.64† (-2.72, -0.60)	-2.3† (-4.92, -0.83)
Alcohol misuse	Yes	0 (reference)	0 (reference)	0 (reference)
	No	1.17† (0.24, 1.90)	1.32† (0.42, 2.05)	1.65 (-0.75, 3.07)
Sex	Male	0 (reference)	0 (reference)	0 (reference)
	Female	-0.14 (-0.68, 0.58)	1.44 (-0.80, 3.05)	2.88† (1.29, 7.14)
Age	18≤24 years	-2.39 (-4.16, 0.22)	-2.41† (-5.91, -0.69)	-2.38 (-5.47, 0.97)
	≥25≤34 years	-1.89 (-3.36, 0.40)	-2.2† (-5.06, -0.44)	-2.93† (-5.58, -0.32)
	≥35≤44 years	-1.7 (-3.22, 0.77)	-2.31† (-5.31, -0.40)	-1.6 (-4.49, 0.96)
	≥45≤64 years	-1.04 (-2.50, 1.56)	-0.79 (-3.43, 0.66)	-0.9 (-3.27, 1.40)
	≥65 years	0 (reference)	0 (reference)	0 (reference)
Ethnicity	Caucasian	0 (reference)	0 (reference)	0 (reference)
	Black	0.36 (-0.34, 0.96)	-0.04 (-0.90, 1.26)	-0.15 (-1.78, 2.11)
	Aboriginal	1.21 (-0.50, 2.06)	1.32† (0.57, 2.32)	0.88 (-0.56, 2.54)
	Other	-0.46 (-1.28, 0.43)	-1.07† (-1.54, -0.03)	-1.98 (-3.19, 0.69)
Length of incarceration	≤18 months	0 (reference)	0 (reference)	0 (reference)
	>18 m ≤5 y	-0.34 (-0.92, 0.32)	-0.22 (-0.70, 0.46)	-0.28 (-1.52, 0.55)
	>5 years	0.64 (-0.26, 1.64)	1.57† (0.56, 2.60)	1.93† (0.70, 3.68)

† <0.05 was considered statistically significant.
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 table). BMI, body mass index index; CI, confidence interval.

6.3 Manuscript 3- Influence of physical activity, screen time and sleep on inmates' bodyweight during incarceration in Canadian federal penitentiaries: a retrospective cohort study

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QUANTITATIVE RESEARCH

Influence of physical activity, screen time and sleep on inmates' body weight during incarceration in Canadian federal penitentiaries: a retrospective cohort study

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Abstract

Objective Recent research found that inmates experience undesirable and rapid weight gain during incarceration in Canadian federal penitentiaries. However, little is known about what factors and daily movement behaviours (e.g., physical activity, screen time, and sleep) influence weight gain during incarceration. This study examines how these 24-h movement/non-movement behaviours contribute to weight gain during incarceration.

Methods This retrospective cohort study explored how weight change outcomes during incarceration (weight change, body mass index (BMI) change, and yearly weight gain) were influenced by physical activity, screen time, and sleep in a convenience sample of 754 inmates. The outcome measures were taken twice, once from participants' medical chart at admission and again during a face-to-face follow-up interview (conducted in 2016–2017; mean follow-up time of 5.0 ± 8.3 years). Physical activity, screen time, and sleep were self-reported. The statistical analysis was chi-square testing, non-parametric median comparison testing, and regression analysis to control for confounders.

Results Inmates who engaged in at least 60 min of daily physical activities gained less weight (4.5 kg) compared to inmates who reported not exercising (8.3 kg). Different types of exercise (cardiovascular exercises, weight lifting, and team sports) were helpful at limiting weight gain, but playing sports was the most effective. Screen time and sleep were not associated with weight gain outcomes.

Conclusion Among the behaviours examined, physical inactivity was significantly associated with higher weight gain during incarceration. However, even high levels of physical activity (> 60 min/day) were not sufficient to eliminate weight gain during incarceration in Canada.

Résumé

Objectif Des études récentes démontrent que les détenus gagnent du poids de façon excessive pendant leur incarcération en pénitenciers fédéraux au Canada. Cependant, il y a peu d'information sur les comportements (c'est-à-dire l'activité physique, le temps passé devant un écran, et le sommeil) qui contribuent à ce gain de poids. Cette étude examine comment ces comportements influencent le gain de poids des détenus durant leur incarcération.

Electronic supplementary material The online version of this article (https://doi.org/10.17269/s41997-018-0165-z) contains supplementary material, which is available to authorized users.

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Méthodes Cette étude de cohorte rétrospective examine comment les indicateurs de changement de poids (changement de poids, changement d'indice de masse corporelle (IMC), et gain de poids annuel) ont varié en fonction de l'activité physique, du temps passé devant un écran et du sommeil, dans un échantillon de convenance de 754 détenus. Le poids et la taille ont été mesurés à deux reprises, soit à l'admission (tiré du dossier médical), puis lors de l'entrevue réalisée en 2016–2017 (durée d'incarcération moyenne de 5,0 ± 8,3 ans). Les comportements évalués ont été autodéclarés pendant l'entrevue. Les analyses statistiques réalisées incluent des tests du khi-carré et des analyses de régression.
Résultats Les détenus les plus actifs (>60 min par jour d'activité physique) ont gagné moins de poids (4,5 kg) que les détenus inactifs (8,3 kg). Les exercices cardiovasculaires, la musculation et le sport d'équipe ont réduit le gain de poids, mais les sports d'équipes ont été les plus efficaces. Le temps passé devant un écran et le sommeil n'ont pas influencé le changement de poids.
Conclusion Parmi les facteurs évalués, l'activité physique est le principal facteur qui a limité le gain de poids durant l'incarcération. Toutefois, même à des niveaux d'activité physique élevés (>60 min par jour), les détenus canadiens ont gagné du poids pendant leur incarcération.

Keywords Inmates · Penitentiary · BMI · Obesity · Physical activity · Sedentary behaviours

Mots-clés Détenus · Pénitenciers · IMC · Obésité · Activité physique · Comportements sédentaires

Introduction

Inmates have recently been shown to gain a rapid and undesirable amount of body weight during incarceration in Canadian federal penitentiaries, putting them at increased risk of developing obesity and obesity-related comorbidities (Johnson et al. 2018). However, little is known about what factors contribute to weight gain during incarceration (Choudhry et al. 2018). Movement/non-movement behaviours such as physical activity (Public Health Agency of Canada and Canadian Institute for Health Information 2011), screen time (Shields and Tremblay 2008), and sleep (Chaput et al. 2017a) are known to influence weight. These factors were examined as part of this study because they may contribute to weight gain and they are part of daily life during incarceration.

Inmates have the opportunity to exercise in the gym and in the yard, but their access is often restricted because of security concerns (National Audit Office 2006). Inmates also have many opportunities to engage in screen time since most of them have televisions in their cells, and Canadian studies found a positive association between excessive television watching and weight gain in non-incarcerated adults (Herman and Saunders 2016; Shields and Tremblay 2008). Many inmates also complain about poor sleep and insomnia during incarceration (Elger 2009; Harner and Budescu 2014). Adults with short sleep duration, usually less than 7 h per night, weigh more than those who sleep between 7 and 9 h per night (McNeil et al. 2013; Patel and Hu 2008). Too much sleep (more than 9 h per night) has also been associated with an increased risk for obesity (Chaput et al. 2013).

It is currently unknown whether the significant increase in obesity rates during incarceration in Canadian federal penitentiaries is related to changes in daily movement behaviours (i.e., physical activity, screen time, and sleep). It is particularly relevant to study this question in the prison setting since penitentiaries are controlled by policies and organizational decisions that influence inmates' behaviours and may ultimately influence their weight gain and health. The current evidence suggests that inmates, who are a vulnerable population with multiple negative health determinants (Herbert et al. 2012), leave prison in poorer health than when they were admitted into the penitentiary. This is true, in part, because of excessive weight gain during incarceration (Gebremariam et al. 2017; Johnson et al. 2018). Moreover, inmates' weight gain has potential financial repercussions on provincial healthcare budgets once the inmates are released back into their communities (Johnson et al. 2018).

The objective of this study was to determine, for the first time, how physical activity, screen time, and sleep influenced weight changes in Canadian federal penitentiaries. We hypothesized that physical inactivity, high screen time, and inadequate sleep patterns would be associated with weight gain in inmates.

Methods

Participants

This retrospective cohort study is part of a larger project that aims to examine weight changes and related factors in Canadian federal penitentiaries. The first part of the study found that inmates gained a significant amount of weight during incarceration (Johnson et al. 2018). Here, in the second part of the study, we explore how physical activity, screen time, and sleep are associated with the observed weight gain in Canadian penitentiaries. Participants for this research project were male and female inmates who volunteered to take part in the study. To be included, they had to be incarcerated for at least 6 months in their current federal institution (to ensure the observed weight changes were in relation to the current institutional environment) in the Ontario or Atlantic regions. Critically ill inmates (admitted to the prison hospital) and pregnant inmates were

excluded from the study. In the Ontario region, we collected data from inmates housed in five institutions near Kingston (of the seven institutions in the Ontario region). 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. Overall, 50% of eligible inmates participated in our study. The prison environment is challenging for recruiting inmates to volunteer for a research study, because they are typically not interested in participating in this type of research (Lagarrigue et al. 2017).

Participant recruitment

We used a convenience sample and offered information sessions with the inmate committee in each of the institutions where we were collecting data to encourage inmates to volunteer. Inmates were asked to submit their names to a designated staff member in the penitentiary (Johnson et al. 2018).

In the beginning, we drew a list of random inmates and called them down (over loudspeaker) to our offices to ask if they wanted to participate. We had a very low response rate with this approach because inmates found it stressful to be called down without knowing why. The vast majority refused to participate. However, the volunteer-based recruitment strategy described above was more efficient and easier to manage (Johnson et al. 2018; Sharma 2017).

Data collection

Research assistants gathered data from 754 inmates (from May 2016 to September 2017) who volunteered to participate in a 30-min face-to-face interview. They measured participants' height, weight, and waist circumference following a standardized protocol and subtracted current anthropometric data from the measurements recorded in the participant's medical chart at admission to determine body weight changes during incarceration (i.e., between admission and interview, with a mean follow-up of 5.0 ± 8.3 years). The main outcome measures were weight change (kg), body mass index (BMI) (kg/m^2), BMI change (kg/m^2), annual weight change (kg/year), and waist circumference (cm) at interview only (since waist circumference was not available in the medical chart at admission). The BMI categories were based on the World Health Organization (WHO) classification system (World Health Organization (WHO) 2016). Waist circumference was divided into two categories (high risk and low risk), based on the WHO cut-off points (high-risk: men > 102 cm and women > 88 cm).

During the interview, research assistants also collected self-reported data on physical activity, screen time, and sleep. The questions were based on the Canadian Health Measures Survey (Cycle 3-household questionnaire), with slight modifications to fit the prison setting. See specific questions and full questionnaire in Supplementary material.

Covariates

We adjusted our findings for the following covariates: sex, age, ethnicity, region, and length of incarceration (taken from inmates' chart). We also adjusted for diet by creating an indicator for diet, based on the foods most strongly associated with weight change (vegetables, fruit, and sweetened beverages).

Statistical analysis

We performed chi-square and non-parametric median comparison tests (Wilcoxon and Kruskal–Wallis) to detect statistically significant changes in anthropometric data between admission and interview based on their health behaviour information. These tests were performed because the data did not have a normal distribution (skewed to the right). We performed a multivariate regression analysis for BMI and waist circumference at interview to adjust for covariates (sex, age, ethnicity, sleep, length of incarceration, and diet). The multivariate regression could only be performed on BMI and waist circumference at the time of interview, because the data met the conditions for analysis using the mean. Our data for our weight change outcomes could not use the mean for a regression analysis because it was not normally distributed. Instead, we conducted a quantile regression analysis (that uses the median) to examine the associations at various percentiles (0.50, 0.75, and 0.90 quantiles) on BMI change, since capturing weight change during incarceration was our main objective. The distribution adjusted for sex, ethnicity, region, length of incarceration, and diet. Statistical analyses were performed using the Statistical Analysis Software (SAS) version 9.4. The level of statistical significance was set at $p < 0.05$ for all analyses.

Ethics approval

We obtained ethics approval through the Research Ethics Board at the University of Ottawa and the Research branch at Correctional Service Canada. Inmates volunteered to participate and provided their consent by signing our consent form. Since most inmates hesitated to sign documents or forms, because of low literacy and/or fear of reprisal, participants could provide verbal consent if they preferred (Gostin et al. 2007). The verbal consent was obtained by the research assistants and witnessed by correctional staff. All personal data collected were coded to ensure confidentiality.

Results

Table 1 shows the socio-demographic characteristics (sex, age, region, language, and ethnicity) by movement behaviours (physical activity, screen time, and sleep) for our sample ($N = 754$). As seen, sex and age were associated with all three

Table 1 Socio-demographic characteristics (sex, age, region, and ethnicity) by daily movement behaviours (physical activity, screen time, and sleep)

		All *N* (%)	Sex (%)		*p* value	Age (%)				
			Male	Female		18 ≤ 24 years	≥ 25 ≤ 34 years	≥ 35 ≤ 44 years	≥ 45 ≤ 64 years	≥ 65 years
All *N* (%)		754 (100)	89	11		63 (8)	221 (29)	176 (23)	249 (33)	45 (6)
Physical activity duration per day	0	184 (24)	22	43	< 0.0001*	16	19	25	27	47
	> 0 ≤ 30 min	134 (18)	17	28		11	12	18	23	27
	> 30 ≤ 60 min	196 (26)	27	18		37	26	26	26	11
	> 60 min	240 (32)	34	11		37	43	31	24	16
Physical activity type, *N* = 570	Walk or yoga	228 (40)	38	64	< 0.0001*	21	22	35	64	67
	No walk or yoga	342 (60)	62	36		79	78	65	36	33
	Cardiovascular	218 (38)	37	55	< 0.0001*	42	52	38	25	29
	No cardiovascular	352 (62)	63	45		58	48	62	75	71
	Weights	359 (63)	65	36	< 0.0001*	85	81	63	43	33
	No weights	211 (37)	72	64		15	19	37	57	67
	Sports	108 (19)	20	4	< 0.0001*	25	26	24	9	4
	No sports	462 (81)	80	96		75	74	76	91	96
Screen time during the day	0 min	31 (4)	3	10	< 0.0001*	6	2	6	3	11
	> 0 ≤ 60 min	77 (10)	9	23		0	10	13	15	11
	> 60 ≤ 120 min	102 (14)	13	20		11	15	14	18	16
	> 120 ≤ 300 min	312 (41)	42	33		57	39	36	65	33
	> 300 min	232 (31)	33	15		45	34	31	36	29
Sleep during the night	< 7 h	52	53	44	0.0340*	51	46	56	57	51
	≥ 7 ≤ 9 h	43	43	45		47	47	43	40	49
	> 9 h	5	5	11		21	8	2	4	0
Sleep during the day	0 min	59	57	74	0.0103*	70	53	61	65	44
	> 0 ≤ 120 min	31	32	20		30	33	30	28	51
	> 120 min	10	11	6		19	14	9	7	4

	p value	Region (%)		*p* value	Ethnicity (%)				*p* value
		Atlantic	Ontario		Caucasian	Black	Aboriginal	Other	
All *N* (%)		311 (41)	443 (59)		470 (62)	124 (16)	106 (14)	54 (7)	
Physical activity duration per day	< 0.0001*	27	23	0.25	28	17	19	19	0.89
		17	18		19	16	18	13	
		23	28		24	28	29	28	
		33	31		29	39	34	41	

Table 1 (continued)

Physical activity type, $N = 570$	< 0.0001*	40	40	0.47	48	15	43	32	< 0.0001*
		60	60		52	85	57	68	
	< 0.0001*	33	42	0.07	32	45	44	59	0.0001*
		67	58		68	55	56	41	
	< 0.0001*	63	63	0.47	56	83	62	70	< 0.0001*
		37	37		44	17	38	30	
	< 0.0001*	22	17	0.16	15	30	17	23	0.0009*
		78	83		85	70	83	77	
Screen time during the day	0.0367*	3	5	0.0113*	4	2	7	4	0.10
		13	9		10	6	13	13	
		12	14		15	10	8	19	
		47	38		43	43	13	31	
		25	35		28	39	34	33	
Sleep during the night	< 0.0001*	47	55	0.10	51	53	52	57	0.89
		46	41		43	42	43	41	
		6	5		6	5	5	2	
Sleep during the day	0.0125*	67	53	0.0015*	61	48	62	56	0.08
		25	35		29	43	25	31	
		9	11		10	9	12	13	

A Wilcoxon test was used in analyses with two categories (sex, region), and a Kruskal–Wallis test was used in analyses with three or more categories (age, ethnicity) by daily movement behaviours (physical activity, screen time and sleep)

**p* value < 0.05 was considered statistically significant when comparing daily movement behaviours between sociodemographic factors

movement behaviours, whereas region and language were only associated with sleep duration during the day.

Table 2 presents the relationship between behaviours and BMI and waist circumference at interview. As seen in this table, 57.8% of our sample reported doing at least 30 min of physical activity per day, which corresponds to 210 min/week, therefore meeting the WHO recommendation for weekly physical activity of 150 min/week. It also reveals that the proportion of inmates with high-risk BMI and waist circumference at interview was significantly lower when inmates engaged in physical activity for more than 30 min a day. The type of physical activity was also associated with BMI and waist circumference. We observed that inmates who reported engaging in more intense physical activities (cardiovascular exercises, weight lifting, and team sports) had lower BMI and waist circumference, compared to inmates participating in less intense activities (walking and yoga). Inmates who participated in team sports were about 50% less likely to be obese (23.1%) or have high-risk waist circumference (25.0%) than inmates who did not participate in team sports (43.1% for obesity and 51.7% for waist circumference). Sleep at night and screen time were not significantly associated with BMI or waist circumference at interview. In our study, there was a strong positive correlation ($r = 0.82$) between BMI and waist circumference (data not shown).

Table 2 Body mass index (BMI) and waist circumference at interview by daily movement behaviours (physical activity, screen time, and sleep)

		Number (%)	Body mass index (BMI), *N* (%)			*p* value	Waist circumference, *N* (%)		*p* value
			Normal (18.5–24.9 kg/m^2)	Overweight (25.0–29.9 kg/m^2)	Obese (≥ 30 kg/m^2)		Low risk (men ≤ 102 cm and women ≤ 88 cm)	High risk (men > 102 cm and women > 88 cm)	
All		754 (100)	137 (18.2)	297 (39.4)	320 (42.4)		364 (48.3)	390 (51.7)	
Sex	Male	672 (89.1)	125 (18.6)	275 (40.9)	272 (40.4)	0.0070*	344 (51.2)	328 (48.8)	< 0.0001*
	Female	82 (10.9)	12 (14.6)	22 (26.8)	48 (58.5)		20 (24.4)	62 (75.6)	
Physical activity duration per day	0	184 (24.4)	31 (16.8)	57 (31.0)	96 (52.2)	< 0.0001*	60 (32.6)	124 (67.4)	< 0.0001*
	> 0 ≤ 30 min	134 (17.8)	21 (15.7)	39 (29.1)	74 (55.2)		39 (29.1)	95 (70.9)	
	> 30 ≤ 60 min	196 (26.0)	40 (20.4)	78 (39.8)	78 (39.8)		102 (52.0)	94 (48.0)	
	> 60 min	240 (31.8)	45 (18.8)	123 (51.3)	72 (30.0)		163 (67.9)	77 (32.1)	
Physical activity type	Walking/yoga	228 (30.2)	36 (15.8)	80 (35.1)	112 (49.1)	< 0.0001*	76 (33.3)	152 (66.7)	< 0.0001*
	No walking/yoga	342 (45.4)	70 (20.5)	160 (46.8)	112 (32.7)		228 (66.7)	114 (33.3)	
	Cardio	218 (28.9)	41 (18.8)	107 (49.1)	70 (32.1)	0.0009*	147 (67.4)	71 (32.6)	< 0.0001*
	No cardio	352 (46.7)	65 (18.5)	133 (37.8)	154 (43.8)		157 (44.6)	195 (55.4)	
	Weights	359 (47.6)	72 (20.1)	164 (45.7)	123 (34.3)	0.0005*	233 (64.9)	126 (35.1)	< 0.0001*
	No weights	211 (28.0)	34 (16.1)	76 (36.0)	101 (47.9)		71 (33.6)	140 (66.4)	
	Sports	108 (14.3)	25 (23.1)	58 (53.7)	25 (23.1)	< 0.0001*	81 (75.0)	27 (25.0)	< 0.0001*
	No sports	462 (61.3)	81 (17.5)	182 (39.4)	199 (43.1)		223 (48.3)	239 (51.7)	
Screen time duration per day	0 min	31 (4.1)	6 (19.4)	10 (32.3)	15 (48.4)	0.6195	12 (38.7)	19 (61.3)	0.5192
	> 0 ≤ 60 min	77 (10.2)	11 (14.3)	31 (40.3)	35 (45.5)		32 (41.6)	45 (58.4)	
	> 60 ≤ 120 min	102 (13.5)	24 (23.5)	33 (32.4)	45 (44.1)		48 (47.1)	54 (52.9)	
	> 120 ≤ 300 min	312 (41.4)	51 (16.3)	133 (42.6)	128 (41.0)		156 (50.0)	156 (50.0)	
	> 300 min	232 (30.8)	45 (19.4)	90 (38.8)	97 (41.8)		116 (50.0)	116 (50.0)	
Sleep duration at night	< 7 h	390 (51.7)	77 (19.7)	154 (39.5)	159 (40.8)	0.1278	197 (50.5)	193 (49.5)	0.1320
	≥ 7 ≤ 9 h	324 (43.0)	48 (14.8)	130 (40.1)	146 (45.1)		144 (44.4)	180 (55.6)	
	> 9 h	40 (5.3)	12 (30.0)	13 (32.5)	15 (37.5)		23 (57.5)	17 (42.5)	
Sleep during the day	No	444 (58.9)	76 (17.1)	179 (40.3)	189 (42.6)	0.5789	204 (45.9)	240 (54.1)	0.1255
	Yes	310 (41.1)	61 (19.7)	118 (38.1)	131 (42.3)		160 (51.6)	150 (48.4)	
Sleep duration during the day	0 min	444 (58.9)	76 (17.1)	179 (40.3)	189 (42.3)	0.2649	204 (45.9)	240 (54.1)	0.0988
	> 0 ≤ 120 min	233 (30.9)	47 (20.2)	94 (40.3)	92 (39.5)		126 (54.1)	107 (45.9)	
	> 120 min	77 (10.2)	14 (18.2)	24 (31.2)	39 (50.6)		34 (44.2)	43 (55.8)	

The *p* value is the result of a Wilcoxon test in analyses with two categories (sex, sleep during the day), and a Kruskal–Wallis test was used in analyses with three or more categories (physical activity duration per day, physical activity type, screen time duration during the day, type of screen most often used, sleep duration during the day)

*p value < 0.05 was considered statistically significant when comparing BMI and waist circumference between daily movement behaviour categories

Table 3 presents the weight change outcomes according to the behaviours examined. Physical activity was the behaviour most strongly associated with weight change. There was a significant inverse relationship between time spent in physical activity and weight gain. We observed that inmates who did not engage in physical activity gained 8.3 kg while inmates who did at least 60 min of physical activity daily gained 4.5 kg. In addition to the duration, the type of physical activity was significantly associated with weight gain during incarceration. More vigorous physical activities (cardiovascular exercises, weight lifting, and team sports) were associated with less weight gain. Inmates who played sports gained the least amount of weight (2.3 kg), compared to weight gain (6.0 kg) seen in inmates who engaged in other types of physical activity.

As also seen in Table 3, screen time was not significantly associated with weight change outcomes. However, screen time was very high in this population, since 72% of our sample engaged in more than 2 h of screen time per day. Moreover, 31% reported more than 5 h of screen time per day. Television was the type of screen most used by inmates during incarceration (90.2%).

Finally, roughly half (51.7%) of participants reported not meeting the recommended 7 h of sleep per night. Nightly sleep duration was not significantly associated with weight or BMI change. However, long sleepers (> 9 h/night) gained significantly more weight per year (5.1 kg) compared with average (1.2 kg) and short sleepers (1.3 kg). Inmates who reported sleeping > 120 min during the day also gained more weight (9.6 kg) compared to those who reported not sleeping (5.6 kg) or sleeping ≤ 120 min (5.0 kg).

Table 4 presents the multivariate regression analysis for BMI and waist circumference at the time of interview with adjustment for covariates (sex, age, region, ethnicity, length of incarceration, and diet). Once adjusted for covariates, we found that physical activity and sleep during the day were still associated with BMI and waist circumference at the time of interview. Moreover, our regression model confirmed that screen time and sleep at night were not associated with BMI and waist circumference.

Table 5 presents the results of a quantile regression coefficient analysis that confirms the association between BMI change and physical activity. For inmates from the groups with the highest weight change (50th–75th and 90th percentiles), inmates who were physically inactive had respectively 1.1, 1.85, and 3.04 points of BMI higher than inmates who engaged in more than 60 min physical activity daily. These findings also confirm that screen time and sleep at night were not associated with weight gain during incarceration. Once adjusted for confounders, the association between weight gain and sleep during the day was only significant for inmates who did not sleep during the day (they gained significantly less than inmates who slept more than 2 h daily) for inmates in the 75th percentile. Moreover, BMI gain was significantly higher for inmates over the age of 45 years, for inmates of Aboriginal descent, and for inmates who were incarcerated the longest (length of incarceration > 5 years). These findings were adjusted for socio-demographic factors (sex, age, language, and ethnicity) as well as for other factors (length of incarceration, region, substance use, feeding system, and diet).

Discussion

A key finding of this study was that weight gain was less severe for inmates who engaged in regular physical activity. In other words, inmates who were inactive gained significantly more weight. The inverse dose–response relationship between physical activity and weight gain suggests that the more an inmate was physically active, the less weight he/she gained behind bars. Inactive inmates gained 8.3 kg, whereas inmates who exercised at least 60 min per day gained 4.5 kg. Inmates who reported playing team sports during incarceration gained the least amount of weight (2.3 kg). In contrast, insufficient sleep and high screen time use were not significantly associated with weight gain in inmates.

In many recent studies, the prison environment has been shown to be more obesogenic than the community at large (Gates and Bradford 2015; Baldwin et al. 2016). We already know from the first part of this research project that obesity rates increased from 26.6% at admission to 45.4% during incarceration in Canada (Johnson et al. 2018). With our current findings, we found that 48.8% of male inmates and 75.6% of female inmates had high-risk waist circumference at interview. This finding is higher than in the general Canadian population, where 41% (34% of males and 48% of females) had high-risk waist circumference in 2012–2013 (Statistics Canada 2015a). Moreover, we also found that obesity rates in female inmates were especially high, where 58.5% of females were in the obese range (BMI ≥ 30 kg/m^2) and 75.6% of them had high-risk waist circumference. The clinical relevance of these findings (higher obesity prevalence and higher proportion of inmates with high-risk waist circumference during incarceration) means that the inmate population (a vulnerable population) is at higher risk of developing obesity-related health problems while incarcerated. This is important since they are incarcerated in a controlled (or closed) environment managed by an organization of the federal government.

We found that 58% of inmates in our sample reported doing at least 30 min of physical activity daily and therefore meeting the international guideline of 150 min or more of moderate-to-vigorous physical activity per week. This proportion is higher than the 51.6% of non-incarcerated adult Canadians who meet the physical activity recommendations (Statistics Canada 2015b). Our findings are similar to a systematic review published in the Lancet in 2012, showing

Table 3 Bivariate association of median weight change, body mass index (BMI) change, and annual weight change by lifestyle behaviours between admission and interview

		Number (%)	Median weight change (kg) (CI)	*p* value	Median BMI change (kg/m^2) (CI)	*p* value	Annual weight change (kg/year) (CI)	*p* value
All		754 (100)	+5.6 (4.8–6.4)		+1.8 (1.5–2.1)		+1.4 (1.0–1.8)	
Physical activity duration per day	0	184 (24.4)	+8.3 (6.3–10.3)	0.0215*	+3.0 (2.3–3.7)	0.0077*	+1.8 (0.8–2.8)	0.3044
	> 0 ≤ 30 min	134 (17.8)	+7.1 (4.9–9.2)		+2.2 (1.5–2.9)		+1.3 (0.4–2.1)	
	> 30 ≤ 60 min	196 (26.0)	+5.5 (3.7–7.2)		+1.7 (1.1–2.3)		+1.2 (0.4–1.9)	
	> 60 min	240 (31.8)	+4.5 (3.3–5.7)		+1.5 (1.1–1.8)		+1.2 (0.6–1.8)	
Physical activity type	Walking/yoga	228 (30.2)	+6.2 (4.4–7.9)	0.0127*	+2.1 (1.5–2.7)	0.0034*	+1.3 (0.5–2.0)	0.1598
	No walking/yoga	342 (45.4)	+4.6 (3.6–5.6)		+1.6 (1.2–1.9)		+1.2 (0.7–1.7)	
	Cardio	218 (28.9)	+4.5 (3.3–5.7)	0.0066*	+1.4 (1.0–1.7)	0.0025*	+1.1 (0.5–1.6)	0.0999
	No cardio	352 (46.7)	+6.0 (4.7–7.3)		+2.0 (1.5–2.4)		+1.3 (0.7–1.8)	
	Weights	359 (47.6)	+4.5 (3.6–5.4)	0.0020*	+1.5 (1.2–1.8)	0.0004*	+1.3 (0.8–1.7)	0.1810
	No weights	211 (28.0)	+7.7 (5.7–9.7)		+2.4 (1.7–3.1)		+1.2 (0.3–2.1)	
	Sports	108 (14.3)	+2.3 (0.6–4.0)	0.0007*	+0.8 (0.2–1.3)	0.0002*	+0.9 (0.3–1.5)	0.0501
	No sports	462 (61.3)	+6.0 (4.9–7.0)		+1.9 (1.5–2.2)		+1.4 (0.9–1.8)	
Screen time duration per day	0 min	31 (4.1)	+1.7 (−3.0–6.4)	0.1583	+0.6 (−1.0–2.2)	0.1664	+0.9 (−3.0–4.7)	0.3195
	> 0 ≤ 60 min	77 (10.2)	+5.5 (2.7–8.3)		+1.6 (0.7–2.5)		+0.9 (−0.3–2.1)	
	> 60 ≤ 120 min	102 (13.5)	+4.5 (2.2–6.8)		+1.5 (0.6–2.3)		+1.0 (0.1–1.8)	
	> 120 ≤ 300 min	312 (41.4)	+6.1 (4.8–7.3)		+2.0 (1.5–2.4)		+1.5 (0.8–2.2)	
	> 300 min	232 (30.8)	+6.0 (4.5–7.5)		+2.0 (1.5–2.5)		+1.5 (0.9–2.0)	
Type of screen most often used	Not applicable	31 (4.1)	+1.7 (−3.0–6.4)	0.9094	+0.6 (−1.0–2.2)	0.3899	+0.9 (−3.0–4.7)	0.6475
	Television	680 (90.2)	+5.5 (4.6–6.4)		+1.8 (1.5–2.1)		+1.4 (1.0–1.8)	
	Computer	29 (3.8)	+9.8 (6.6–13.0)		+2.8 (1.7–3.9)		+1.8 (0.5–2.2)	
	Videogames	14 (1.9)	+6.9 (0.2–13.6)		+2.3 (0.0–4.5)		+1.2 (0.1–2.3)	
Sleep duration at night	< 7 h	390 (51.7)	+5.9 (4.6–7.1)	0.1107	+1.8 (1.4–2.2)	0.0840	+1.3 (0.8–1.7)	0.0051*
	≥ 7 ≤ 9 h	324 (43.0)	+5.5 (4.2–6.8)		+1.8 (1.4–2.2)		+1.2 (0.6–1.8)	
	> 9 h	40 (5.3)	+10.7 (7.5–13.9)		+3.6 (2.4–4.7)		+5.1 (1.3–8.9)	
Sleep interruption	No	230 (30.5)	+5.6 (4.2–6.9)	0.8781	+1.9 (1.5–2.3)	0.9938	+1.7 (1.0–2.4)	0.2520
	Yes	524 (69.5)	+5.7 (4.6–6.8)		+1.8 (1.5–2.1)		+1.3 (0.8–1.7)	
Reason for sleep interruption	Not applicable	230 (30.5)	+6.0 (4.2–6.8)	0.8980	+1.9 (1.5–2.3)	0.8714	+1.7 (1.0–2.4)	0.6495
	Environment	164 (21.8)	+5.5 (4.2–6.9)		+1.8 (0.8–2.8)		+1.1 (−0.5–2.8)	
	Personal	360 (47.7)	+6.0 (3.1–8.9)		+1.9 (1.4–2.3)		+1.3 (0.7–1.8)	
Sleep during the day	No	444 (58.9)	+5.6 (4.5–6.6)	0.5299	+1.8 (1.4–2.2)	0.5335	+1.4 (0.9–1.9)	0.9301
	Yes	310 (41.1)	+5.7 (4.3–7.0)		+1.9 (1.4–2.3)		+1.4 (0.8–2.0)	
Sleep duration during the day	0 min	444 (58.9)	+5.6 (4.5–6.6)	0.0291*	+1.8 (1.4–2.2)	0.0274*	+1.4 (0.9–1.9)	0.2124
	> 0 ≤ 120 min	233 (30.9)	+5.0 (3.6–6.4)		+1.7 (1.3–2.1)		+1.1 (0.5–1.7)	
	> 120 min	77 (10.2)	+9.6 (6.5–12.7)		+3.3 (2.3–4.3)		+1.8 (0.4–3.2)	

A Wilcoxon test was used in analyses with two categories (sleep interruption, sleep during the day), and a Kruskal–Wallis test was used in analyses with three or more categories (physical activity duration per day, physical activity type, screen time duration during the day, type of screen most often used, sleep duration during the day), in comparison with weight change outcomes to determine the *p* value

CI confidence interval (95%)

*p value < 0.05 was considered statistically significant when comparing weight change outcomes by daily movement behaviours. The average length between admission and interview was 5.0 ± 8.3 years

that more inmates were meeting international physical activity guidelines in comparison to non-incarcerated citizens (Herbert et al. 2012). The studies were mostly from the United States, Australia, and the United Kingdom. Although inmates behind bars appeared to be more likely to meet the physical activity guidelines, this level of activity did not seem sufficient to stop weight gain during incarceration in Canada, since even the most active inmates still gained weight.

The type of physical activity was associated with the amount of weight gained in our sample. Walking and yoga were the least intense types of physical activity reported and were associated with more weight gain than other more intense activities such as cardiovascular exercises, weight lifting, or team sports. Among all types of physical activities, team sports were associated with the least amount of weight gain during incarceration (2.3 kg). There are many proponents for

Table 4 Multivariate regression analysis for mean body mass index (BMI) and waist circumference at interview, including physical activity, screen time and sleep duration, adjusted for each other and for sex, ethnicity, and region ($N = 754$)

		Variation from reference for BMI at interview (CI)	Probt	Variation from reference for waist circumference at interview (CI)	Probt
Physical activity duration per day	0	+ 0.05 (0.02, 0.09)	0.0048*	+ 0.07 (0.04, 0.10)	< 0.0001*
	> 0 ≤ 30 min	+ 0.06 (0.02, 0.10)	0.0049*	+ 0.06 (0.03, 0.10)	< 0.0001*
	> 30 ≤ 60 min	+ 0.56 (−0.02, 0.04)	0.5573	+ 0.02 (− 0.01, 0.04)	0.1646
	> 60 min	0 reference	0 reference	0 reference	0 reference
Screen time duration per day	0 min	0 reference	0 reference	0 reference	0 reference
	> 0 ≤ 60 min	− 0.01 (− 0.09, 0.08)	0.8802	− 0.01 (− 0.08, 0.06)	0.7141
	> 60 ≤ 120 min	− 0.01 (− 0.09, 0.07)	0.9121	− 0.01 (− 0.08, 0.05)	0.7096
	> 120 ≤ 300 min	+ 0.00 (− 0.07, 0.07)	0.9990	− 0.01 (− 0.07, 0.05)	0.7290
	> 300 min	+ 0.01 (− 0.07, 0.08)	0.8811	+ 0.01 (− 0.06, 0.07)	0.8609
Sleep duration at night	< 7 h	+ 0.03 (− 0.02, 0.09)	0.2477	+ 0.03 (− 0.02, 0.07)	0.2689
	≥ 7 ≤ 9 h	+ 0.05 (− 0.01, 0.11)	0.1049	+ 0.04 (− 0.00, 0.09)	0.0708
	> 9 h	0 reference	0 reference	0 reference	0 reference
Sleep duration during the day	0 min	− 0.03 (− 0.07, 0.01)	0.1220	− 0.02 (− 0.06, 0.01)	0.2239
	> 0 ≤ 120 min	− 0.04 (− 0.08, 0.00)	0.0522	− 0.04 (− 0.07, − 0.00)	0.0470*
	> 120 min	0 reference	0 reference	0 reference	0 reference
Sex	Male	0 reference	0 reference	0 reference	0 reference
	Female	+ 0.55 (0.003, 0.11)	0.0399*	− 0.04 (− 0.09, − 0.00)	0.0487*
Ethnicity	Caucasian	+ 0.05 (− 0.00, 0.10)	0.0699	+ 0.06 (0.01, 0.10)	0.0124*
	Black	+ 0.02 (− 0.04, 0.07)	0.5740	− 0.00 (− 0.05, 0.05)	0.9820
	Aboriginal	+ 0.09 (0.02, 0.15)	0.0039*	0.10 (0.05, 0.15)	< 0.0001*
	Other	0 reference	0 reference	0 reference	0 reference
Region	Atlantic	+ 0.03 (0.00, 0.06)	0.0376*	− 0.08 (− 0.03, 0.01)	0.4676
	Ontario	0 reference	0 reference	0 reference	0 reference

Probt is the result of a regression analysis. Results were also adjusted for age, language, length of incarceration, and diet

CI confidence interval (95%)

*p value < 0.05 was considered statistically significant. The average length between admission and interview (follow-up) was 5.0 ± 8.3 years

team sports in prison. In addition to being an effective tool against weight gain, team sports can also reduce re-offense rates, by offering an alternative means of excitement and risk taking (Meek 2014). Team sports can also provide an alternative social network and more positive role models for inmates during incarceration (Meek 2014). Furthermore, a study showed that inmates required less healthcare services when following an exercise program in prison, thus making these exercise programs financially beneficial given the reduction in required care (Cashin et al. 2008). Organizing team sport activities in prison could be helpful at managing body weight, reducing healthcare costs, and providing other benefits to inmates who participate.

The proportion of inmates (52%) in our sample who reported sleeping less than the recommended 7–9 h per night was higher than the proportion of non-incarcerated Canadian adults (30%) who reported not sleeping enough hours per night (Chaput et al. 2017b). A study from Switzerland found that insomnia was the most frequent health complaint in prison, and most inmates with insomnia blamed the prison officers (or "guards") for making noise and disrupting sleep during "rounds" (security checks) at night (Elger 2009). Contrary to that, our findings found that although 70% of inmates from our sample reported interrupted sleep during the night, only 22% reported the environment as the culprit (data shown in Table 3). This suggests that the policy on guards waking inmates was not the main cause for sleep disruption in Canadian penitentiaries. Our findings also found that inmates who reported sleeping more than 9 h (5.3% of our sample) at night had higher annual weight gain (5.1 kg/year) compared to short (< 7 h/night) and average (≥ 7 ≤ 9 h/night) sleepers who gained 1.3 kg/year and 1.2 kg/year, respectively. There is some evidence that excessive sleep may be associated with weight gain (Chaput et al. 2008). Sometimes excessive sleep (defined as sleep > 9 h per night) can be an indicator for poor sleep quality and associated with health problems (Ohayon et al. 2013). It is also possible that inmates who reported sleeping more than 9 h per night were suffering from health problems associated with excessive sleep,

Table 5 Quantile regression coefficients (median) testing for estimated BMI change based on physical activity, screen time, sleep duration, socio-demographic factors, and length of incarceration ($N = 754$)

Variables		50th percentile (CI 95%)	75th percentile (CI 95%)	90th percentile (CI 95%)
Physical activity	0 min	+ 1.1* (0.23, 2.31)	+ 1.85* (0.99, 2.85)	+ 3.04* (2.0, 4.50)
	≤ 30 min	+ 0.8 (− 0.30, 1.50)	+ 1.25* (0.14, 2.17)	+ 2.05* (0.44, 4.03)
	> 30 ≤ 60 min	+ 0.1 (− 0.83, 0.81)	+ 0.95* (0.19, 1.54)	+ 1.95 (− 0.06, 2.72)
	≥ 60 min	0 (reference)	0 (reference)	0 (reference)
Screen time	0 min	0 (reference)	0 (reference)	0 (reference)
	> 0 ≤ 60 min	+ 1.1 (− 1.12, 3.58)	+ 0.1 (− 4.50, 2.05)	− 2.74 (− 7.69, 2.91)
	> 60 ≤ 120 min	+ 0.6 (− 1.91, 2.60)	+ 0.3 (− 4.79, 2.18)	− 2.59 (− 7.91, 2.76)
	> 120 ≤ 300 min	+ 1.3 (− 1.04, 3.28)	+ 0.55 (− 3.78, 2.19)	− 2.75 (− 7.28, 2.53)
	> 300 min	+ 1.3 (− 0.85, 3.61)	+ 0.05 (− 4.39, 1.82)	− 3.1 (− 8.08, 2.65)
Sleep during the day	0 min	− 1.6 (− 2.80, 0.10)	− 0.85* (− 2.04, −0.05)	− 1.04 (− 3.0, 0.62)
	> 0 ≤ 120 min	− 1.6 (− 2.75, 0.12)	− 0.7 (− 2.06, 0.04)	− 1.56 (− 3.5, 0.70)
	> 120 min	0 (reference)	0 (reference)	0 (reference)
Sex	Male	0 (reference)	0 (reference)	0 (reference)
	Female	− 0.14 (− 0.68, 0.58)	1.44 (− 0.80, 3.05)	2.88* (1.29, 7.14)
Age	18 ≤ 24 years	− 2.39 (− 4.16, 0.22)	− 2.41* (− 5.91, − 0.69)	− 2.38 (− 5.47, 0.97)
	≥ 25 ≤ 34 years	− 1.89 (− 3.36, 0.40)	− 2.2* (− 5.06, − 0.44)	− 2.93* (− 5.58, − 0.32)
	≥ 35 ≤ 44 years	− 1.7 (− 3.22, 0.77)	− 2.31* (− 5.31, − 0.40)	− 1.6 (− 4.49, 0.96)
	≥ 45 ≤ 64 years	− 1.04 (− 2.50, 1.56)	− 0.79 (− 3.43, 0.66)	− 0.9 (− 3.27, 1.40)
	≥ 65 years	0 (reference)	0 (reference)	0 (reference)
Ethnicity	Caucasian	0 (reference)	0 (reference)	0 (reference)
	Black	0.36 (− 0.34, 0.96)	− 0.04 (− 0.90, 1.26)	− 0.15 (− 1.78, 2.11)
	Aboriginal	1.21 (− 0.50, 2.06)	1.32* (0.57, 2.32)	0.88 (− 0.56, 2.54)
	Other	− 0.46 (− 1.28, 0.43)	− 1.07* (− 1.54, − 0.03)	− 1.98 (− 3.19, 0.69)
Length of incarceration	≤ 18 months	0 (reference)	0 (reference)	0 (reference)
	> 18 m ≤ 5 y	− 0.34 (− 0.92, 0.32)	− 0.22 (− 0.70, 0.46)	− 0.28 (− 1.52, 0.55)
	> 5 years	0.64 (− 0.26, 1.64)	1.57* (0.56, 2.60)	1.93* (0.70, 3.68)

The results presented were adjusted for each other and also adjusted for language, region, feeding system type, sleep at night, and diet

such as chronic pain, depression, bipolar disorder, and/or mood disorders (Ohayon et al. 2013). It is well established that those health problems are frequent in the prison population (Herbert et al. 2012; Wolff et al. 2012; Stewart et al. 2015; Correctional Service Canada 2004). In support of those observations, inmates who reported sleeping more than 2 h during the day (10.2% of our sample) were also shown to gain almost twice the weight (9.6 kg) than those who slept less than 2 h (5.0 kg) or those who did not sleep during the day (5.2 kg). However, once we controlled for confounders, this association disappeared for most inmates. This may be because we adjusted for diet, and it is generally accepted that the sleep and weight relationship is heavily dependent on diet and food intake.

Last, although screen time was not significantly associated with weight outcomes, it was very high in Canadian penitentiaries. Our findings revealed that 72% of inmates reported more than 2 h of screen time per day, compared to 31% of non-incarcerated Canadian adults who reported watching the same amount (Herman and Saunders 2016). In the general population, Canadians who reported watching 2 h or more of television per day had higher BMI than adults who watched less than 1 h of television per day (Herman and Saunders 2016). In Canadian penitentiaries, we did not find similar results with regard to weight gain, possibly because regardless of television watching habits, inmates' access to food and exercise time remained controlled by other factors.

Limitations of the study

This study should be interpreted with the following limitations in mind. First, the observational nature of the study precludes inferences about causality to be made. Second, our self-reported data were taken from a convenience sample and therefore are subject to recall and selection biases. In addition, movement behaviours were only collected once during the interview since this information was not taken on admission. That means, we only had one time-point in the behaviours of interest. Last, we were unable to reproduce a similar non-

incarcerated control group, which would have provided a better comparison group than the Canadian general adult population.

Conclusion

In conclusion, the observed weight gain was higher for inmates who abstained from physical activity. This was especially true for inmates who engaged in team sports. As such, future research should measure the effectiveness of organized team sport leagues in prison as a means to manage inmate weight gain during incarceration. However, regardless of the protective effect of exercise on weight gain and the fact that more inmates exercise regularly while incarcerated (compared to non-incarcerated Canadians), inmates were still gaining weight and were still at higher risk of becoming obese during incarceration. There is a need for future research to continue exploring other factors that influence weight gain during incarceration. The significance of these findings will guide decision-makers on which factors to address when attempting to manage weight gain of inmates in Canadian penitentiaries.

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Compliance with ethical standards

We obtained ethics approval through the Research Ethics Board at the University of Ottawa and the Research branch at Correctional Service Canada. Inmates volunteered to participate and provided their consent by signing our consent form. Since most inmates hesitated to sign documents or forms, because of low literacy and/or fear of reprisal, participants could provide verbal consent if they preferred (Gostin et al. 2007). The verbal consent was obtained by the research assistants and witnessed by correctional staff. All personal data collected were coded to ensure confidentiality.

Competing interests Claire Johnson currently works as Coordinator of the Nutrition Management Program for Correctional Service Canada. The data and their interpretation are fully represented in the paper, and no censorship has occurred.

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RESEARCH ARTICLE

An exploration of reported food intake among inmates who gained body weight during incarceration in Canadian federal penitentiaries

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Data Availability Statement: Our database contains personal and medical information on the inmates who participated in our study. As per our ethical agreement, we are not to share the data we collected other than to share our research findings. Furthermore, the Privacy Act prohibits us to share the data we collected other than for the purpose of sharing our research findings. For data requests, please contact: 1) For the University of Ottawa: Melanie Rioux, Ethics Coordinator, Office of Research Ethics and Integrity, University of Ottawa,

Abstract

Background

Canadian penitentiaries have recently been shown to be obesogenic. However, little is known about the eating habits of inmates who gained weight while living in the prison environment.

Methods

This retrospective cohort study examined the reported food intake of inmates during incarceration in federal penitentiaries. During a face to face interview, anthropometric measures (2016–2017) were taken and compared to anthropometric data at the beginning of incarceration (mean follow-up of 5.0 ± 8.3 years). Self-reported data on food intake were collected via a food frequency questionnaire.

Results

Inmates who gained the most weight (15.7 kg) during incarceration reported not eating vegetables. They were followed by inmates who gained 14.3 kg and reported not eating fruit. Other inmates who gained a significant amount of weight reported not eating cereal, dairy or legumes. Moreover, inmates' weight gain was also assessed by special diets: inmates following a religious diet (4.5 kg) or a diet of conscience (-0.3 kg) gained less weight than inmates not following a diet (5.8 kg). In comparison to other types of diets, inmates on a medical diet gained the most weight (7.5 kg). Furthermore, inmates who gained significant weight (8.0 kg) also reported not purchasing healthy foods from the commissary store (or "canteen"), whereas inmates who gained less weight (4.8 kg) reported purchasing healthy foods from the commissary store (or "canteen"). The observed weight gain was positively

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associated with food purchased from the commissary store (or "canteen"), but was not associated with the feeding system of the penitentiary (tray, cafeteria or meal plan).

Discussion

Food intake during incarceration is a modifiable risk factor that could be the target of weight management interventions with inmates. Our findings suggest that inmates who gained the most weight also reported having low intake of foods deemed healthy (vegetables, fruit, cereal, dairy and legumes) from food services and from the commissary store (or "canteen") purchases.

Introduction

Correctional Service Canada is responsible for feeding all men and women incarcerated in federal penitentiaries in Canada. As such, inmates forfeit much of their control when being fed. This makes food a daily preoccupation for prisoners. In support of that statement, correctional staff, who hear the chatter in prison halls confirm that inmates are often discussing their previous meal or anticipating their next one [1]. As author Rosie Meek wrote, many experts from the correctional service world agree: "There are three things you need to get right in prison: the food, the visits and the gym"[2].

To feed the prison population, Correctional Service Canada has a four week non selective cycle menu that is based on Canada's Food Guide and provides ~2600 calories per day for male inmates and ~2000 calories per day for female inmates [3]. The budget to purchase food for this standardized menu is ~$5 daily per inmate [3]. In Canada, federal penitentiaries use the menu for two of the three different feeding systems. The menu is used in the central food production system with tray delivery, or with cafeteria delivery. The third system is called small group meal plan program, and inmates on this plan do not follow the standardized menu. In this setting, inmates are responsible for the purchase and preparation of their food. With the latter system, inmates are given a food budget of ~$35 per week and they choose their food items to purchase from the prison "grocery store". Depending on the food system, inmates may eat alone in their cell (central production and tray delivery), or they may eat with their fellow inmates in a dining hall (central production and cafeteria delivery), or they may prepare and eat their meals in kitchenettes with a few housemates (decentralized production in small group meal plan).

In all penitentiaries, regardless of the feeding system, inmates have access to the commissary store (or "canteen") where they can purchase foods of their choice with their own funds [4]. The foods available for purchase are chosen by the inmate committee of the penitentiary and approved by management. The list of foods can vary between penitentiaries since it is not standardized by Correctional Service Canada. In addition to the menu, accommodation diets are available to inmates for religious reasons (e.g., kosher diets, halal diets), as part of their medical treatment (e.g., diabetic diets, anti-reflux diet) or for reasons related to conscience (e.g., vegetarian diets). These diets typically resemble the meals provided to the rest of the population but are modified to accommodate the inmates' dietary restrictions and beliefs. Typically, inmates' diet prescriptions remain the same throughout incarceration. They usually request a religious diet or a diet of conscience at the beginning of their incarceration. The only exception is the medical diet since it is commonly prescribed during incarceration, because an inmate may get diagnosed with a new medical condition.

Our recent study found that 73% of inmates in Canada gained weight behind bars, putting them at increased risk of becoming obese [5]. We observed that obesity rates increased from 26% to 46% during incarceration [5]. Our findings also revealed that inmates behind bars gained more weight, at a faster rate, than adults in the general population in Canada. Given these findings, weight gain in prison is generally deemed as undesirable since most inmates go into prison with normal or overweight bodyweights, and become overweight or obese during incarceration [5]. It is generally known that food intake [6] and the food environment influence weight status [7]. However, we do not know how the observed weight gain in the inmate population was related to their reported food intake, and/or if the inmates who gained more weight were following the standardized menu, a special diet or their own meal plan (based on the feeding system of their institution).

A few studies, mostly out of the United States, have assessed inmates' diets and food intake and have shown high variations in food provision between penitentiaries [8]. In most cases, menus served to inmates have been shown to be higher in sodium and sugar; and lower in fiber, magnesium, potassium, vitamin D and vitamin E than the daily recommended intake [8–10]. To our knowledge, there are no published studies on inmates' food intake in Canada. To fill this knowledge gap, this study examined for the first time reported eating habits and diet prescriptions of inmates based on their body weight changes during incarceration in Canadian federal penitentiaries. In other words, the objective of this study was to examine the eating habits of inmates who gained the most weight in prison. Firstly, we hypothesized that inmates who gained the most weight would report having poorer diets (e.g. high in soda drinks, junk food, and pastries, and low in fruits and vegetables) compared with those who gained less weight. We also hypothesized that weight gain would be associated with frequent consumption of foods deemed unhealthy from the commissary store (or 'canteen'). Lastly, we hypothesized that inmates who gained more weight would be following the standardized menu or their own meal plan (in small group meal plan), instead of an accommodation diet (medical, religious or diet of conscience).

Materials and methods

This retrospective cohort study explored how weight gain in the inmate population was related to their reported food intake, and/or their meal plan (e.g., the standardized menu, their own meal plan or a special diet) in Canadian penitentiaries [11]. 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 regions. Critically ill inmates admitted to the prison hospital and pregnant inmates were excluded from the study. In the Ontario region, we collected data from inmates housed in 5 institutions near Kingston (of the 7 institutions in the Ontario region) [12]. These institutions were selected for geographical feasibility reasons. In the Atlantic region, we collected data from inmates housed in all 5 institutions in New Brunswick and Nova Scotia [12]. We used a convenience sample, and advertised the study by offering information sessions with the inmate committee in each of the institutions where we were collecting data to encourage inmates to volunteer. In addition, there were advertisements about the study posted on the prison telecommunication service. Inmates were asked to submit their names to a designated staff member in the penitentiary.

Recruitment strategy

In the beginning, we drew a list of random inmates, and called them down (over loud speaker) to our offices to ask if they wanted to participate. We had a very low response rate with this

approach since inmates found it stressful to be called down without knowing why. With this approach, the vast majority of inmates refused to participate. However, the recruitment strategy described above where we asked for volunteers was more successful since the inmates were empowered to volunteer if they wanted to. Getting them to submit their names to a staff member also increased their confidence in the study. We did not keep track of who volunteered and who did not. For ethical reasons (i.e., confidentiality), we could not gather data on inmates who did not volunteer to participate since we did not have their consent to access their administrative files. At the time of data collection, there were approximately 3000 inmates living in the penitentiaries who participated in the study. From that population, approximately 1600 were eligible to participate. Overall, roughly 50% of eligible inmates volunteered to participate in our study. The prison setting is known to be challenging for recruiting participants because inmates are not typically interested in participating in this type of research study. Our challenge was getting inmates to volunteer and to wait while we coordinated with security to organize the interview. From our literature review, we found that the participation rates are generally quite low for studies on prisoners' weight and weight change, where inmates are asked to participate in an interview and to have anthropometric measurements taken. For example, a French study only managed to recruit 18 male participants because of lack of interest in the study [13]. In addition, an American study had a sample of 103 participants [14], because recruiting inmates to participate in body weight related research is challenging. Typically, studies on weight during incarceration with large sample sizes were using secondary data.

Data collection

Research assistants (who were trained registered dietitians) gathered data from 754 inmates who volunteered for a 30-minute face-to-face interview from May 2016 until September 2017. They also objectively measured participants' height and weight following a standardized protocol, and subtracted current anthropometric data from those measured at the admission and recorded in the medical charts of participants to determine anthropometric changes during incarceration. The main outcome measures for this study were body weight change (kg), body mass index (BMI) change (kg/m^2) and annual weight change (kg/year).

During the interview, we gathered self-reported data on food intake with a food frequency questionnaire. The questions were based on the Canadian Health Measures Survey (Cycle 3-household questionnaire: Statistics Canada-Cycle 3), with slight modifications to fit the prison setting and to make the questions easier for inmates to answer (based on feedback from inmates while piloting the questionnaire). The full food frequency questionnaire is presented in S1 Table in the supplementary material section of this article. We asked the following specific questions regarding food consumed from the canteen: "What type of food do you typically consume from canteen?" (response options: nothing, junk food (e.g., chocolate bars, chips, cakes etc.), healthy foods (e.g. yogurt, dried fruit, nuts, tuna, oats), beverages (specify type), supplements (specify type), or other (specify). Lastly, we gathered data on diets (medical, religious and diets of conscience) from their digital medical charts.

Covariates

We adjusted our models using the following covariates: sex, age, ethnicity, region, 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 adjusted for reported vegetables (indicator for healthy eating), and for sugar-sweetened beverages (indicator for unhealthy eating) consumed daily.

Statistical analysis

We performed chi-square and nonparametric median comparison tests (Wilcoxon and Kruskal-Wallis) to detect statistically significant changes in anthropometric measurements (weight change, BMI change, yearly weight change). We then assessed the weight outcomes with reported diet factors (special diet, canteen food and supplementation) and reported food intake (from food frequency questionnaire), to determine how the diet related factors differed depending on the amount of weight inmates gained. These tests were performed on the median because the data did not have a normal distribution (it was skewed to the right). In addition, we performed quantile regression analysis to examine whether associations were different for medium, and high percentiles by modelling the 0.5 (the median), 0.75 and 0.90 quantiles of the BMI change distribution adjusted by sex, ethnicity, region, length of incarceration, substance abuse, physical activity, diet and feeding system. We opted for the conditional quantile regression model [15–17] instead of the multivariate regression analysis on the mean, because the residuals (from the multiple regression model) did not meet the model assumptions (i.e., normality, linearity, homoscedasticity). Statistical analyses were performed using the Statistical Analysis Software (SAS) version 9.4. The level of statistical significance was set at $p<0.05$ for all analyses.

Ethics approval

We obtained ethics approval through the Research Ethics Board at the University of Ottawa and the Research branch at Correctional Service Canada. Inmates volunteered to participate and provided their consent by signing our consent from. Since many inmates hesitate to sign documents or forms, because of low literacy and/or fear of reprisal, participants could provide verbal consent if they preferred [18]. All personal data collected were coded to ensure confidentiality.

Results

Table 1 presents sociodemographic information by diet-related factors, such as feeding system, diet and purchases from the commissary store (or "canteen"). The vast majority of inmates (95%) reported purchasing food from the commissary store (or "canteen"). Age was associated with diet-related factors; younger inmates typically reported making healthier food choices from the commissary store (or "canteen") than older inmates. We also observed ethnic variations, with Caucasian (40%) and Aboriginal (47%) inmates more likely to report not purchasing healthy foods from canteen compared to black (22%) and other ethnic minorities (25%). We observed regional variations in diet prescriptions. A higher proportion of inmates were on a special diet in the Ontario region (27%) compared to the Atlantic region (19%). Variation based on sex, language groups (Anglophone vs Francophone), and ethnic variations were associated with other diet-related factors (see Table 1).

Table 2 presents sociodemographic information by food intake (as estimated with the food frequency questionnaire). Overall food frequency intake was similar regardless of sociodemographic factors, but some variations were seen by sex, region, language and ethnicity. For example, women reported drinking more fruit drinks; whereas men reported drinking more diet soft drinks. Younger inmates ($\leq$ 64 years) drank regular soft drink more frequently; whereas older inmates ($\geq$65 years) drank diet soft drinks more frequently. In addition, we observed regional and ethnic variations with regards to soft drink consumption and vegetable intake.

Table 3 shows data on weight change during incarceration in relation to food systems, type of diet, quality of food and intake of supplements. In comparison to inmates without a special

Table 1. Sociodemographic information by diet-related factors (N = 754).

		All N (%)	Sex		p-value	Age %					p-value	Region %		p-value	Language		p-value	Ethnicity %				p-value
			Male	Fem		18≤24 years	≥25≤ 34 years	≥35≤44 years	≥45≤64 years	≥65 years		Atl.	Ont.		Anglo	Franco		Cau.	Black	Abori	Other	
All N (%)		**754 (100)**	**672 (89)**	**82 (11)**		**63 (8)**	**221 (29)**	**176 (23)**	**249 (33)**	**45 (6)**		**311 (41)**	**443 (59)**		**645 (86)**	**109 (14)**		**470 (62)**	**124 (16)**	**106 (14)**	**54 (7)**	
Feeding system	Tray	195 (26)	28	13	<0.0001*	41	35	26	16	11	<0.0001*	15	33	<0.0001*	27	19	0.0020*	19	34	39	44	<0.0001*
	Cafeteria	225 (30)	33	0		33	32	28	30	20		35	26		27	44		31	31	24	24	
	Meal plan	334 (44)	39	87		25	33	46	53	69		49	41		46	37		50	35	38	31	
Special diet	Yes	180 (24)	24	21	0.4797	33	33	21	16	24	<0.0001*	19	27	0.0134*	24	22	0.6234	14	57	17	46	<0.0001*
	No	574 (76)	76	79		67	67	79	85	76		81	73		76	78		86	43	83	54	
Diet type	Medical	55 (31)	28	59	0.0165*	14	18	35	54	55	<0.0001*	40	26	0.0066*	27	54	0.0677	56	6	56	16	<0.0001*
	Religious	75 (42)	45	6		62	51	43	16	18		43	41		44	25		20	62	28	52	
	Diet of conscience	50 (28)	27	35		24	31	22	30	27		17	33		29	21		24	32	17	32	
Canteen purchase	Yes	718 (95)	95	96	0.7879	98	97	92	95	98	0.1194	96	95	0.5212	95	94	0.6991	96	97	92	94	0.4547
	No	36 (5)	5	4		2	3	8	5	2		4	5		5	6		4	3	8	6	
Canteen healthy food (N = 718)	Yes	452 (63)	65	49	0.0254*	74	70	64	56	50	0.0019*	58	66	0.0589	62	67	0.6112	60	78	53	75	0.0005*
	No	266 (37)	35	51		26	30	36	44	50		42	34		38	33		40	22	47	25	
Canteen junk food (N = 718)	Yes	528 (74)	72	86	0.0236*	81	72	73	74	68	0.2791	77	71	0.2555	73	77	0.6828	75	72	77	63	0.3627
	No	190 (26)	28	14		19	28	27	26	32		23	29		27	23		25	28	23	37	

A Wilcoxon test was used in analyses with two categories (special diet, canteen purchase, canteen-healthy food, canteen-junk food), and a Kruskal-Wallis test was used in analyses with three or more categories (feeding system and diet type). A p-value <0.05 was considered statistically significant. Fem: Female; Atl.: Atlantic; Ont.: Ontario; Anglo: Anglophone; Franc: Francophone; Cau: Caucasian; Abori: Aboriginal.

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Table 2. Sociodemographic information by food frequency intake (N = 742).

	Daily intake	All (%)	Sex %		p-value	Age %					p-value	Region %			Language %		p-value	Ethnicity %				p-value
			Male	Fem		18≤24 years	≥25≤34 years	≥35≤44 years	≥45≤64 years	≥65 years		Atl.	Ont.		Anglo	Franc		Cau.	Black	Aboriginal	Other	
All N (%)		**742 (100)**	**660 (89)**	**82 (11)**		**63 (8)**	**216 (29)**	**174 (23)**	**247 (33)**	**42 (6)**		**311 (42)**	**431 (58)**		**634 (85)**	**108 (15)**		**466 (63)**	**124 (17)**	**99 (13)**	**53 (7)**	
Vegetables per day	0	24 (3)	3	2	0.0541	0	2	3	6	0	0.0544	2	6	<0.0001*	3	4	0.8175	3	3	6	4	0.0715
	<1	199 (27)	27	22		25	29	24	25	40		27	26		26	31		24	39	23	28	
	≥1<2	229 (31)	32	26		33	29	34	31	24		37	26		31	31		32	23	34	36	
	≥2<3	194 (26)	26	27		35	29	24	23	29		27	25		26	25		29	25	20	19	
	>3	96 (13)	12	23		6	11	15	16	7		6	18		13	10		13	10	16	13	
Fruits per day	0	32 (4)	4	4	0.0528	3	1	5	6	7	0.0688	3	5	0.1027	4	8	0.0076*	4	4	7	0	0.1346
	<1	159 (21)	22	21		17	21	21	21	31		20	23		20	31		20	31	17	21	
	≥1<2	223 (30)	30	34		33	28	32	32	17		35	27		31	24		31	24	29	36	
	≥2<3	161 (22)	21	30		27	23	25	18	17		20	23		23	15		22	17	23	28	
	>3	167 (23)	24	11		19	27	17	23	29		23	23		23	22		23	23	23	15	
Fruit drinks per day	0	558 (75)	78	51	<0.0001*	75	78	76	74	62	0.2504	77	74	0.3674	74	81	0.0134*	74	73	82	75	0.2094
	<1	104 (14)	12	33		17	14	14	13	17		12	16		14	17		14	19	8	19	
	≥1	80 (11)	10	16		8	8	10	13	21		11	11		12	3		12	9	10	6	
Regular soft drinks per day	0	314 (42)	43	38	0.6343	29	39	40	47	62	0.0046*	37	46	0.0008*	43	41	0.8800	45	30	48	38	0.0130*
	<1	327 (44)	43	49		52	51	45	38	26		52	38		44	46		42	52	37	57	
	≥1	101 (14)	14	13		19	10	14	15	12		11	16		14	13		13	19	14	6	
Diet soft drinks per day	0	649 (87)	86	98	0.0129*	98	90	90	83	76	0.0015*	89	86	0.5277	88	85	0.1810	86	90	89	89	0.4604
	<1	72 (10)	11	2		2	9	7	13	12		8	11		10	9		11	7	8	11	
	≥1	21 (3)	3	0		0	1	3	4	12		3	3		2	6		3	2	3	0	

A Kruskal-Wallis test was used in all analyses. A p-value <0.05 was considered statistically significant. Fem: Female; Atl.: Atlantic; Ont.: Ontario; Anglo: Anglophone; Franc: Francophone; Cau: Caucasian.

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Table 3. Change in median weight, body mass index (BMI) and annual weight between admission and study follow-up in relation to feeding systems, type of diet, quality of food and intake supplements.

		All N (%)	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 (4.8–6.4)		+1.8 (1.5–2.1)		+1.4 (1.0–1.8)	
Feeding system	Tray	195 (26)	+ 5.1 (3.5–6.6)	0.5515	+ 1.6 (1.2–2.1)	0.4641	+ 1.5 (0.9–2.1)	0.5602
	Cafeteria	225 (30)	+ 5.0 (3.4–6.6)		+ 1.7 (1.2–2.2)		+ 1.3 (0.7–1.9)	
	Meal plan	334 (44)	+ 6.9 (5.6–8.2)		+ 2.2 (1.8–2.2)		+1.3 (0.6–2.1)	
Type of diet at interview	No diet	586 (78)	+ 5.8 (4.8–6.8)	0.0002*	+ 1.9 (1.6–2.2)	0.0060*	+ 1.5 (1.0–2.0)	0.0210*
	Medical	98 (13)	+ 7.5 (4.6–10.4)		+ 2.4 (1.4–3.4)		+ 1.3 (0.2–2.4)	
	Religious	41 (5)	+ 4.5 (1.4–7.6)		+ 1.5 (0.5–2.5)		+ 1.1 (0.2–2.0)	
	Diet of conscience	29 (4)	-0.3 (-3.8–3.2)		-0.1 (-1.2–1.0)		-0.1 (-0.8–0.6)	
Canteen purchase	Yes	718 (95)	+5.5 (4.6–6.3)	0.2932	+ 1.8 (1.5–2.1)	0.2912	+ 1.4 (1.0–1.8)	0.7874
	No	36 (5)	+7.0 (3.3–10.7)		+ 2.3 (1.1–3.4)		+ 1.1 (-1.0–3.2)	
Healthy food from canteen (N = 718)	Yes	452 (63)	+ 4.8 (3.7–5.7)	0.0055*	+ 1.6 (1.5–2.3)	0.0036*	+ 1.2 (0.8–1.6)	0.0363*
	No	266 (37)	+ 8.0 (6.4–9.6)		+ 2.5 (2.4–3.4)		+ 1.8 (0.9–2.7)	
Junk food from canteen (N = 718)	Yes	528 (74)	+ 5.6 (4.5–6.6)	0.3651	+ 1.9 (1.5–2.2)	0.3245	+ 1.6 (1.1–2.0)	0.3433
	No	190 (26)	+ 5.1 (3.4–6.7)		+ 1.6 (1.1–2.1)		+ 1.0 (0.3–1.8)	
Protein supplement from canteen (N = 718)	Yes	99 (14)	+ 3.6 (1.7–5.5)	0.0160*	+ 1.2 (0.6–1.8)	0.0098*	+ 0.9 (-0.3–2.1)	0.1704
	No	619 (86)	+6.0 (4.8–7.2)		+ 1.9 (1.6–2.2)		+ 1.5 (1.1–1.9)	
Vitamin supplement from canteen (N = 718)	Yes	63 (9)	+ 4.4 (1.2–7.6)	0.3470	+ 1.5 (0.3–2.7)	0.4334	+ 0.5 (-0.5–1.5)	0.1264
	No	655 (91)	+ 5.6 (4.7–6.5)		+1.8 (1.5–2.1)		+1.5 (1.1–1.9)	

A Wilcoxon test was used in analyses with two categories (Canteen purchase, Healthy food, Junk food, Protein supplement, Vitamin supplement), and a Kruskal-Wallis test was used in analyses with three or more categories (Feeding system and Type of diet).

*p-value <0.05 was considered statistically significant.

The average length between admission and follow-up was 5.0 ± 8.3 years. CI = confidence interval.

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diet (who gained 5.8 kg), inmates on a medical diet gained more weight (7.5 kg). Whereas, inmates on a religious accommodation diet gained less weight (4.5 kg) and inmates on a diet of conscience lost weight (-0.3 kg). The same patterns were seen in BMI and annual weight change outcomes. Furthermore, inmates who gained significantly less weight also reported eating healthy foods and protein supplements from the commissary store (or "canteen"). The same patterns were observed with BMI change.

Table 4 and Table 5 present data on changes in median weight, median BMI and median annual weight for inmates in relation to the frequency of different food group consumption. Inmates who gained the most weight (15.7 kg) reported not eating vegetables, whereas inmates who gained less weight (4.8 kg) reported consuming vegetables more than 3 times per day. Similar patterns were observed in inmates who reported eating healthy food regularly, such as fruit, cereal, dairy and legumes. Moreover, inmates who gained more weight also reported eating high calorie non-nutritious foods regularly (i.e. pastries and regular soft drinks). Similar patterns of associations were observed for BMI and annual weight change. Data on other foods (bread, rice, poultry, fish, red meat, eggs, peanut butter, nuts, chocolate, ice cream and water) where not found to be significantly different for inmates based on their weight gain during incarceration.

Table 6 presents the results of a quantile regression coefficients analysis that confirms the association between BMI change and diet. For inmates from the groups with the highest weight change (50^{th}, 75^{th} and 90^{th} percentiles), inmates who reported eating no vegetables had respectively 2.3, 3.4 and 0.9 point of BMI higher than inmates who reported eating vegetables daily. Moreover, BMI gain was significantly higher for inmates above the age of 65, for inmates of Aboriginal decent and inmates who were incarcerated the longest (length of incarceration >5 years). These findings were adjusted for socio-demographic factors (sex, age, region, language and ethnicity) as well as for other factors (length of incarceration, physical activity, substance abuse and feeding system).

Discussion

Our findings show that the inmates who gained the most weight during incarceration reported infrequent intake of healthy foods (i.e. vegetables, fruit, cereal, dairy and legumes) and more frequent intake of unhealthy foods (i.e. pastries and regular soft drinks). For example, inmates with the highest weight increase (15.7 kg) reported never eating vegetables while inmates who gained less weight (4.8 kg) reported eating vegetables at least 3 times daily. Inversely, the weight gain was lower for inmates who limited their intake of non-nutritious high calorie foods. This was true for the food coming from food services through institutional meals, and for the food purchased from the commissary store (or "canteen"). These observations are well supported in nutrition research, where low calorie, high fiber foods (such as fruits and vegetables) are associated with lower body weight and lower BMI [6, 19, 20], whereas non-nutritious energy dense foods are associated with obesity and higher BMI [6, 21].

We observed that inmates who gained the least during incarceration also reported consuming healthy foods from the commissary store (or "canteen"). As such, we observed a median weight gain of 0.48 kg in inmates who reported purchasing healthy foods from the commissary store (or "canteen") (e.g. legumes, tuna fish, oatmeal and nuts). Whereas, inmates who gained a median of 8 kg, reported not consuming these healthy foods. In addition, inmates who only gained a median 3.6 kg reported consuming protein supplements, compared to a median 6 kg weight gain for inmates who reported not taking protein supplements. Moreover, the consumption of commissary (or "canteen") foods appears to influence inmates' weight gain more than the food service system of the institution, since the data on commissary store (or "canteen") use was associated with weight gain, whereas the food system of the penitentiary was not. This could in part explain why penitentiaries were deemed to be obesogenic since there are commissary stores (or "canteens") in all institutions (regardless of the feeding system used in the penitentiary).

The food purchased at the commissary stores (or "canteen") appeared to influence weight change outcomes more than the feeding system of the penitentiaries. That means targeting

Table 4. Change in median weight, body mass index (BMI) and annual weight between admission and study follow-up in relation to food group intake (food frequency questionnaire).

	Daily intake	All N (%)	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		742 (100)	+ 5.6 (4.8–6.4)		+ 1.8 (1.5–2.1)		+1.4 (1.0–1.8)	
Vegetables per day	0	24 (3)	+15.7 (8.8–22.5)	0.0043*	+ 4.9 (2.7–7.1)	0.0037*	+ 4.6 (1.9–7.2)	0.0453*
	<1	199 (27)	+ 6.0 (4.3–7.7)		+ 2.0 (1.5–2.5)		+ 1.5 (0.7–2.3)	
	≥1<2	223 (30)	+ 4.8 (3.3–6.3)		+ 1.7 (1.2–2.2)		+ 1.5 (0.7–2.2)	
	≥2<3	194 (26)	+ 6.1 (4.3–7.9)		+ 1.9 (1.3–2.4)		+ 1.2 (0.5–1.9)	
	>3	96 (13)	+ 4.8 (3.3–6.3)		+ 1.6 (0.9–2.2)		+ 1.0 (0.3–1.8)	
Fruits per day	0	32 (4)	+ 14.3 (10–18.5)	0.0030*	+ 4.7 (3.1–6.3)	0.0010*	+ 3.0 (0.3–5.7)	0.0186*
	<1	159 (21)	+ 7.5 (5.6–9.4)		+ 2.4 (1.8–3.0)		+ 1.9 (0.8–3.0)	
	≥1<2	223 (30)	+ 5.2 (3.6–6.8)		+ 1.8 (1.3–2.3)		+ 1.3 (0.5–2.0)	
	≥2<3	161 (22)	+ 5.0 (3.3–6.7)		+ 1.6 (1.1–2.1)		+ 1.4 (0.6–2.2)	
	>3	167 (23)	+ 4.0 (2.2–5.8)		+ 1.3 (0.8–1.8)		+ 0.9 (0.4–1.5)	
Bread per day	0	88 (12)	+ 7.5 (5.3–9.7)	0.1127	+ 2.5 (1.7–3.2)	0.1383	+ 1.8 (0.4–3.3)	0.4474
	<1	203 (27)	+ 4.5 (3.0–6.0)		+ 1.4 (0.9–1.9)		+ 1.4 (0.6–2.1)	
	≥1	451 (61)	+6.0 (4.9–7.1)		+ 2.0 (1.6–2.4)		+ 1.4 (0.9–1.9)	
Cereal per day	0	202 (27)	+ 7.6 (5.9–9.3)	0.0264*	+ 2.5 (1.9–3.0)	0.0246*	+ 2.2 (1.4–3.0)	0.1880
	<1	272 (37)	+ 5.0 (3.5–6.5)		+ 1.7 (1.2–2.2)		+ 1.1 (0.5–1.8)	
	≥1	268 (36)	+ 4.9 (3.6–6.2)		+ 1.6 (1.2–2.0)		+ 1.3 (0.8–1.8)	
Rice and pasta per day	0	51 (7)	+ 7.5 (4.3–10.7)	0.5374	+ 2.4 (1.2–3.6)	0.4627	+ 2.3 (0.0–4.6)	0.2449
	<1	554 (75)	+ 5.4 (4.3–6.4)		+ 1.8 (1.4–2.1)		+ 1.2 (0.8–1.7)	
	≥1	137 (18)	+ 5.5 (3.8–7.2)		+ 1.8 (1.3–2.3)		+ 1.8 (0.8–2.8)	
Dairy per day	0	316 (43)	+7.5 (6.2–8.7)	0.0141*	+ 2.3 (1.9–2.7)	0.0186*	+ 1.7 (1.2–2.3)	0.1879
	<1	119 (16)	+6.0 (3.6–8.4)		+ 2.0 (1.2–2.8)		+ 1.1 (-0.2–2.5)	
	≥1<2	129 (17)	+3.2 (1.1–5.3)		+ 0.9 (0.3–1.5)		+ 0.9 (0.1–1.7)	
	≥2	178 (24)	+5.1 (3.3–6.8)		+ 1.6 (1.0–2.2)		+ 1.4 (0.7–2.1)	

(*Continued*)

Table 4. (Continued)

Poultry per day	0	92 (12)	+ 4.5 (1.5–7.5)	0.3078	+ 1.6 (0.6–2.5)	0.2552	+ 1.0 (-0.1–2.1)	0.5046
	<0.5	327 (44)	+ 7.1 (5.8–8.4)		+ 2.4 (2.0–2.8)		+ 1.4 (0.9–2.1)	
	≥0.5	323 (44)	+ 4.8 (3.6–6.0)		+ 1.6 (1.2–2.0)		+ 1.4 (1.0–2.0)	
Fish per day	0	178 (24)	+7.1 (5.0–9.1)	0.4966	+ 2.3 (1.6–2.9)	0.4575	+ 1.7 (0.9–2.5)	0.8412
	<0.5	488 (66)	+ 5.2 (4.1–6.2)		+ 1.7 (1.4–2.0)		+ 1.4 (0.9–1.8)	
	≥0.5	76 (10)	+ 5.2 (3.1–7.2)		+ 1.8 (1.1–2.4)		+ 1.6 (0.4–2.8)	
Red meat per day	0	89 (12)	+ 4.5 (1.9–7.1)	0.3538	+ 1.6 (0.7–2.5)	0.4220	+ 1.3 (0.2–2.3)	0.6425
	<0.5	417 (56)	+ 6.5 (5.4–7.6)		+ 2.1 (1.7–2.5)		+ 1.5 (1.0–2.1)	
	≥0.5	236 (32)	+ 4.9 (3.4–6.4)		+ 1.6 (1.1–2.1)		+ 1.1 (0.5–1.7)	
Eggs per day	0	104 (14)	+6.7 (4.4–9.0)	0.5201	+ 2.2 (1.4–2.9)	0.4856	+ 1.5 (0.0–3.0)	0.4576
	<0.5	331 (45)	+ 5.5 (4.2–6.8)		+ 1.8 (1.4–2.2)		+ 1.3 (0.8–1.8)	
	≥0.5	307 (41)	+ 5.5 (4.1–6.9)		+ 1.7 (1.3–2.1)		+ 1.5 (1.0–2.1)	
Peanut butter	0	135 (18)	+ 7.5 (5.7–9.3)	0.5116	+ 2.4 (1.8–3.0)	0.4779	+1.8 (0.7–2.9)	0.2909
	<0.5	242 (33)	+ 5.7 (4.2–7.2)		+1.9 (1.4–2.4)		+ 1.4 (0.7–2.1)	
	≥0.5	365 (49)	+ 5.0 (3.7–6.3)		+ 1.6 (1.2–2.0)		+ 1.3 (0.8–1.8)	

A Kruskal-Wallis test was used in all analyse.

*p-value <0.05 was considered statistically significant.

The average length between admission and follow-up was 5.0 ± 8.3 years. CI = confidence interval.

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canteens and their food availability will likely be an effective tool when planning weight management interventions in prison. This is interesting since food available for purchase at canteens may vary between institutions, whereas the food provided by food service is controlled (by the standardized menu and related policies). As previously mentioned, food offerings for central feeding systems (with tray delivery and cafeteria) follow the same standardized menu across Canada. In other words, for both regions where data was collected the food available was the same (the menu or the grocery list for small group meal plan). This is interesting since weight gain during incarceration did not significantly differ based on the food system. That means, it did not appear to make a difference whether inmates were being fed in the highly structured food environment such as the central production and tray delivery system in comparison to the unstructured nature of the small group meal plan. With the tray delivery system, inmates get very little say in what and when they eat. The food is controlled by Correctional Service Canada and follows the standardized meal plan (based on Canada's Food Guide and provides ~2600 kcal daily for male inmates, and ~2000 kcal for female inmates), and delivered to them directly in their cells. In this setting, inmates eat alone and have little opportunity to trade food with others. In the second food system (cafeteria), the food production is also

Table 5. Change in median weight, body mass index (BMI) and annual weight between admission and study follow-up in relation to food group intake (food frequency questionnaire).

	Daily intake	All N (%)	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
Nuts and seeds per day	0	455 (61)	+ 6.0 (4.9–7.1)	0.1550	+ 1.9 (1.5–2.3)	0.4027	+ 1.6 (1.0–2.2)	0.0599
	<0.5	179 (24)	+ 5.6 (3.9–7.3)		+ 2.0 (1.4–2.6)		+ 1.5 (0.9–2.0)	
	≥0.5	108 (15)	+ 4.3 (2.2–6.3)		+ 1.6 (0.9–2.2)		+ 0.7 (-0.1–1.5)	
Legumes per day	0	235 (32)	+ 6.5 (4.8–8.2)	0.0110*	+ 2.2 (1.6–2.8)	0.0096*	+ 1.5 (0.6–2.5)	0.0552
	<0.5	417 (56)	+ 6.0 (4.9–7.1)		+ 1.9 (1.5–2.2)		+ 1.5 (1.0–1.9)	
	≥0.5	90 (12)	+ 4.0 (2.1–5.9)		+ 1.3 (0.7–1.9)		+ 0.8 (0.0–1.7)	
Pastries (cakes and cookies) per day	0	140 (19)	+ 5.5 (3.6–7.4)	0.0246*	+ 1.7 (1.1–2.3)	0.0137*	+ 1.3 (0.6–2.0)	0.0091*
	<0.29	294 (40)	+ 5.1 (3.8–6.3)		+ 1.7 (1.2–2.1)		+ 1.6 (1.0–2.2)	
	≥0.29<0.5	136 (18)	+ 4.3 (2.4–6.2)		+ 1.4 (0.8–2.0)		+ 0.8 (0.1–1.4)	
	≥0.5	172 (23)	+ 8.3 (6.4–10.2)		+ 2.8 (2.2–3.4)		+ 1.8 (0.5–3.2)	
Chocolate per day	0	417 (56)	+ 5.9 (4.8–7.0)	0.5722	+ 1.9 (1.5–2.3)	0.6211	+ 1.4 (1.0–1.9)	0.9569
	<0.29	219 (30)	+ 5.0 (3.4–6.6)		+ 1.7 (1.2–2.2)		+ 1.3 (0.4–2.1)	
	≥0.29<0.5	58 (8)	+ 6.1 (2.9–9.3)		+ 2.1 (1.0–3.2)		+ 1.8 (0.1–3.5)	
	≥0.5	48 (6)	+ 5.8 (2.8–8.7)		+ 1.8 (0.9–2.7)		+ 1.2 (0.4–2.1)	
Ice cream per day	0	371 (50)	+ 5.5 (4.3–6.7)	0.7982	+ 1.8 (1.4–2.2)	0.8413	+ 1.4 (0.8–2.0)	0.8547
	<0.29	238 (32)	+ 5.9 (4.3–7.5)		+ 1.8 (1.3–2.3)		+ 1.3 (0.6–2.0)	
	≥0.29<0.5	62 (8)	+ 7.5 (4.6–10.4)		+ 2.4 (1.6–3.2)		+ 1.5 (0.3–2.6)	
	≥0.5	71 (10)	+ 5.0 (2.6–7.4)		+ 1.7 (0.9–2.5)		+ 1.6 (0.1–3.0)	
Regular soft drinks per day	0	314 (42)	+5.3 (4.0–6.5)	0.0065*	+ 1.7 (1.3–2.1)	0.0071*	+ 1.3 (0.7–2.0)	0.0076*
	<1	327 (44)	+4.8 (3.5–6.1)		+ 1.7 (1.3–2.1)		+ 1.2 (0.6–1.7)	
	≥1	101 (14)	+10 (7.7–12.3)		+ 3.2 (2.4–4.0)		+ 3.3 (2.2–4.3)	
Diet soft drinks per day	0	649 (87)	+ 5.5 (4.6–6.4)	0.3489	+ 1.8 (1.5–2.1)	0.3111	+1.5 (1.1–1.9)	0.5529
	<1	72 (10)	+7.3 (3.7–10.8)		+ 2.2 (1.1–3.3)		+ 0.9 (-0.7–2.5)	
	≥1	21 (3)	+ 12 (1.9–22.1)		+ 4.1 (1.0–7.2)		+ 1.0 (-0.5–2.4)	

(*Continued*)

Table 5. (Continued)

	Daily intake	All N (%)	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
Fruit drinks per day	0	558 (75)	+ 5.3 (4.3–6.2)	0.5682	+ 1.8 (1.5–2.1)	0.4747	+ 1.4 (1.0–1.8)	0.3306
	<1	104 (14)	+ 7.0 (4.5–9.4)		+ 2.3 (1.5–3.1)		+ 1.4 (0.0–2.9)	
	≥1	80 (11)	+ 8.5 (5.6–11.4)		+ 3.0 (2.0–3.9)		+ 1.3 (-0.6–3.3)	
Water per day	0	26 (4)	+10.1 (5.9–14.1)	0.0916	+ 3.4 (2.1–4.7)	0.0741	+ 1.8 (-0.7–4.3)	0.1391
	<3	92 (12)	+7.2 (4.7–9.6)		+ 2.5 (1.6–3.2)		+ 2.9 (1.4–4.4)	
	≥3<7	205 (28)	+5.0 (3.4–6.6)		+ 1.6 (1.1–2.1)		+ 1.4 (0.6–2.2)	
	≥7<10	156 (21)	+4.9 (3.2–6.5)		+ 1.6 (1.0–2.1)		+ 1.0 (0.5–1.6)	
	≥10	263 (35)	+6.1 (4.6–7.6)		+ 1.9 (add)		+ 1.4 (0.8–2.1)	

A Kruskal-Wallis test was used in all analyse.

*p-value <0.05 was considered statistically significant.

The average length between admission and follow-up was 5.0 ± 8.3 years. CI = confidence interval.

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centralized and follows the same standardized menu, but there is more trading between inmates since they all eat together in the dining area. Lastly, in the small group meal plan program there is a large potential for variability in meal plans since it is left to the discretion of each inmate to decide what food to purchase within their allotted food budget of ~$35 per week. With this feeding system, inmates get to choose what food to purchase from a standardized list that is the same across Canada. Our findings suggest that the feeding system did not significantly influence weight gain during incarceration.

Although weight gain was not associated with the feeding system, our findings suggest that the menu served to inmates was influential to weight gain since inmates on special diets had different weight gain patterns. Inmates with a median weight gain of 5.8 kg were on the regular meal plan (or not following a special diet). Whereas, inmates with less weight gain (4.5 kg) were following a religious diet; and some inmates who lost weight (-0.3 kg) were following a diet of conscience (usually a vegetarian meal plan). This suggests that the meal plans for religious accommodations and diets of conscience may provide different nutritional content. However, it is not known at this time how these modified diets compare to the standardized regular menu in terms of calories and other nutrients. The finding that inmates who gained the most (7.5 kg) were on medical diets was unexpected and concerning. It is possible that the reduced calories from the medical diets could cause inmates to seek extra calories elsewhere (from the commissary store or "canteen") and consequently lead to weight gain. It is also possible that inmates who gain more weight during incarceration were then subsequently placed on a medical diet. In the second scenario, the medical diets were not necessarily contributing to weight gain, but were used as a tool to manage existing weight gain. Lastly, it is possible that the weight gain observed in inmates on a medical diet was related to medication use, since it is well established that some medications may lead to weight changes [22, 23]. At this point, we do not know why inmates on a medical diet gain more weight than other inmates, but it would be worth exploring in future research projects.

Table 6. Quantile regression coefficients analysis for estimated BMI change based on the daily frequency of vegetable intake and sociodemographic factors and length of incarceration.

Variables		50th percentile (CI 95%)	75th percentile (CI 95%)	90th percentile (CI 95%)
Diet- vegetable intake per day	0	+2.3 (-1.19, 4.83)	+3.4† (2.04, 4.25)	+0.9† (0.15, infinity)
	<1	+0.01 (-0.64, 0.84)	+0.46 (-0.72, 1.39)	-0.3 (-2.01, 1.61)
	≥1<2	-0.14 (-0.96, 0.61)	-0.09 (-1.13, 0.59)	-0.88 (-2.59, 0.70)
	≥2<3	0 (reference)	0 (reference)	0 (reference)
	≥3	-0. 83 (-1.51, 0.35)	-0.71 (-1.74, 0.19)	-2.55 (-4.28, 0.53)
Sex	Male	0 (reference)	0 (reference)	0 (reference)
	Female	-0.14 (-0.68, 0.58)	+1.44 (-0.80, 3.05)	+2.88† (1.29, 7.14)
Age	18≤24 years	-2.39 (-4.16, 0.22)	-2.41† (-5.91, -0.69)	-2.38 (-5.47, 0.97)
	≥25≤34 years	-1.89 (-3.36, 0.40)	-2.2† (-5.06, -0.44)	-2.93† (-5.58, -0.32)
	≥35≤44 years	-1.7 (-3.22, 0.77)	-2.31† (-5.31, -0.40)	-1.6 (-4.49, 0.96)
	≥45≤64 years	-1.04 (-2.50, 1.56)	-0.79 (-3.43, 0.66)	-0.9 (-3.27, 1.40)
	≥65 years	0 (reference)	0 (reference)	0 (reference)
Ethnicity	Caucasian	0 (reference)	0 (reference)	0 (reference)
	Black	+0.36 (-0.34, 0.96)	-0.04 (-0.90, 1.26)	-0.15 (-1.78, 2.11)
	Aboriginal	+1.21 (-0.50, 2.06)	+1.32† (0.57, 2.32)	+0.88 (-0.56, 2.54)
	Other	-0.46 (-1.28, 0.43)	-1.07† (-1.54, -0.03)	-1.98 (-3.19, 0.69)
Length of incarceration	≤18 months	0 (reference)	0 (reference)	0 (reference)
	>18 m ≤5 y	-0.34 (-0.92, 0.32)	-0.22 (-0.70, 0.46)	-0.28 (-1.52, 0.55)
	>5 years	+0.64 (-0.26, 1.64)	+1.57† (0.56, 2.60)	+1.93† (0.70, 3.68)

† <0.05 was considered statistically significant.

The results presented were adjusted for the factors seen in the table and other factors (language, feeding system, physical activity and substance abuse) (data not shown in table). BMI, body mass index; CI, confidence interval. The vegetable daily intake represents the reported frequency of vegetable consumption (0 means the inmate reported never eating vegetables, <1 means the inmate reported eating vegetables less than once daily, ≥1<2 means the inmate reported eating vegetables once or twice per day etc.)

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There are reports of inmates using junk food (chips, soft drinks and chocolate bars) from the commissary store (or "canteen") as currency since the tobacco ban in 2008 [24]. Before the ban, tobacco and cigarettes were the main source of currency, but now inmates use junk food to exchange services and to gamble [24, 25]. This new phenomenon, where junk food is being used as a currency, may explain the obesogenic effect of the commissary store (or "canteen"). Junk food has now become omnipresent, and possibly consumed more frequently by all inmates and staff. There is data to support this peculiarity, but it is well documented that food is a big part of the prison micro-economy and the black market [1]. A more in-depth examination of food as currency would be worth exploring in future research.

Lately, the food environment has been identified as a key determinant for healthy eating and priority area for research. Many governments are developing public policies in an attempt to improve the food environment and improve population health [26]. Across Canada, we have seen multiple examples of successful initiatives, such as guideline for healthy food environments in British Columbia schools [27], the Ontario government offered workshops to transform the food environment by focusing on capacity building [28] and measuring the food environment by Health Canada [26]. These innovative approaches coincide well with this

research project since the food environment in penitentiaries are "closed environments" that are heavily controlled by public policy and regulations. Therefore, allowing an examination of how prison regulation contributes to food choices and subsequent weight changes. Thus far, there is little evidence that prison authorities are using a population based approach for improving the food environment in Canadian penitentiaries; since there are no publications on initiatives aimed at improving the food environment in the prison setting.

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 food intake were self-reported by participants, and therefore subject to recall bias [29]. Furthermore, the data related to food was only collected once, which means we only have one time-point of the behavior of interest. Also, only the food frequency was reported and no information was available on the amount consumed (kcal), so it was not possible to estimate energy and nutrient intake. Finally, residual confounding by unmeasured variables is always a possibility in observational studies.

Conclusion

In conclusion, inmates are vulnerable to weight gain while incarcerated in Canadian penitentiaries probably in part because of the food they eat (or do not eat). Inmates who gained the most weight reported lower healthy food consumption (vegetables, fruit, legumes, cereal, dairy and legumes). Inversely, inmates who gained less weight reported eating those healthy foods daily. Given food intake is a modifiable risk factor for weight gain during incarceration, the findings from our study could help decision makers when choosing how to feed inmates, and which foods to have available to them. The commissary store (or "canteen") appears to be more influential on weight gain than the food provided by food services (run by Correctional Service Canada). Making the commissary (or "canteen") an efficient target for weight loss interventions or a means to improve the food environment in prison. Further research could examine the effectiveness of interventions aimed at increasing healthy food consumption through the commissary store (or "canteen"). An analysis of existing interventions in the community could be helpful to see what could be adapted to the prison environment. Furthermore, an in-depth analysis of the modified diets provided to inmates with special dietary needs and beliefs could also provide more insight into weight gain during incarceration.

Supporting information

S1 Table. Food frequency questionnaire: How often do you eat these foods?
(DOCX)

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6.5 Mental health and weight gain

6.5.1 Introduction

This study explored the relationship between mental health and inmate weight gain during incarceration in Canadian federal penitentiaries. This is important since it is well known that the inmate population suffers from mental illness in disproportionately higher numbers compared to the general population (6). Studies estimate that roughly 30-50% of inmates in Canada suffer from some form of mental illness (119, 120). Moreover, mental illness and psychotropic medication use are known contributors to weight gain and obesity because they both affect metabolism and food intake (63, 121).

Given the observed weight gain in our study, where 73% of inmates in our sample gained weight and obesity rates increased significantly during incarceration (going from 27% to 46%) (95), we suspected that weight gain could be associated with mental health and psychotropic medication use. Specifically, we hypothesized that weight gain would be more severe for inmates with a mental illness and who were taking psychotropic medication.

6.5.2 Results for mental health and weight gain

Table 3 presents sociodemographic information based on inmates' mental health status and psychotropic medication use. For each mental illness, the prevalence in our sample (N=1420) is presented. In addition, the disease evolution is also shown, if the inmate had the disease prior to incarceration it is indicated as "history", if the disease was diagnosed during incarceration it is indicated as "acquired in prison". Our findings revealed that most often inmates already had a mental health diagnosis prior to incarceration. This was the case for 90% of our sample with mental

illness and who were diagnosed prior to incarceration. The only exception was with insomnia, where 40% of cases were first diagnosed during incarceration.

Variations between sexes for more "mild" mental health diagnosis (depression and anxiety) were observed, where female inmates had almost twice the prevalence (16% for male inmates vs 28-29% for female inmates). Caucasian and Aboriginal inmates had a higher prevalence of depression and anxiety (~20%) compared to other ethnic groups who had lower prevalence (10%). Moreover, Caucasian and Aboriginal inmates were more likely to have a diagnosis prior to incarceration, whereas the visible minority groups were more likely to be diagnosed during incarceration. Age was associated with mental health for "other mental illness" (schizophrenia, psychosis, bipolar disorder, etc), where prevalence was higher in younger inmates (18% in inmates ages 18-24 years, 17% in inmates 25-34 years; whereas the prevalence was only 10% in inmates 35 years and older). The Atlantic region had a higher prevalence of mental illness (depression, anxiety and other mental illness), compared to the prevalence in the Ontario region. Another notable regional difference was the proportion of inmates diagnosed with insomnia in Ontario penitentiaries compared to the inmates in the Atlantic region (56% of insomnia cases were diagnosed in Ontario penitentiaries vs 15% in penitentiaries in the Atlantic region). The total prevalence was however similar in both regions.

Table 3 Sociodemographic information by mental health diagnosis (N=1420).

		All (%)	Sex N (%)		p-value	Age N (%)					p-value	Region N (%)		p-value	Language N (%)		p-value	Ethnicity N (%)				p-value
			Male	Fem		18≤24 years	≥25≤34 years	≥35≤44 years	≥45≤64 years	≥65 years		Atl.	Ont.		Anglo	Franc		Cau.	Black	Abori	Other	
All N (%)		1420 (100)	1276 (90)	144 (10)		104 (7)	389 (27)	315 (22)	504 (36)	108 (8)		520 (37)	900 (63)		1265 (89)	155 (11)		904 (64)	203 (14)	214 (15)	99 (7)	
Depression	Yes	241 (17)	200 (16)	41 (28)	0.0001*	16 (15)	69 (18)	57 (18)	77 (15)	22 (20)	0.6372	128 (25)	113 (13)	<0.0001*	217 (17)	24 (15)	0.6011	180 (20)	20 (10)	32 (15)	9 (9)	0.0005*
	No	1179 (83)	1076 (84)	103 (72)		88 (85)	320 (82)	258 (82)	427 (85)	86 (80)		392 (75)	787 (87)		1048 (83)	131 (85)		724 (80)	183 (90)	182 (85)	90 (90)	
Depression progression (N=241)	History	218 (90)	184 (92)	34 (83)	<0.0001*	15 (94)	64 (93)	54 (95)	68 (88)	17 (77)	0.2553	116 (91)	102 (90)	<0.0001*	200 (92)	18 (75)	0.0291*	166 (92)	17 (85)	27 (84)	8 (89)	0.0010*
	Acquired in prison	23 (10)	16 (8)	7 (17)		1 (6)	5 (7)	3 (5)	9 (12)	5 (23)		12 (9)	11 (10)		17 (8)	6 (25)		14 (8)	3 (15)	5 (16)	1 (11)	
Anxiety	Yes	249 (18)	207 (16)	42 (29)	0.0001*	17 (16)	76 (20)	58 (18)	82 (16)	16 (15)	0.6521	133 (26)	116 (13)	<0.0001*	225 (18)	24 (15)	0.6011	179 (20)	17 (8)	40 (19)	13 (13)	0.0009*
	No	1171 (82)	1069 (84)	102 (71)		87 (84)	313 (80)	257 (82)	422 (84)	92 (85)		387 (74)	784 (87)		1040 (82)	131 (85)		725 (80)	186 (92)	174 (81)	86 (87)	
Anxiety progression (N=249)	History	234 (94)	197 (95)	37 (88)	<0.0001*	16 (94)	74 (97)	52 (90)	77 (94)	15 (94)	0.6248	126 (95)	108 (93)	<0.0001*	211 (94)	23 (96)	0.7221	168 (94)	14 (82)	39 (98)	13 (100)	0.0008*
	Acquired in prison	15 (6)	10 (5)	5 (12)		1 (6)	2 (3)	6 (10)	5 (6)	1 (6)		7 (5)	8 (7)		14 (6)	1 (4)		11 (6)	3 (18)	1 (2)	0 (0)	
Insomnia	Yes	95 (7)	90 (7)	5 (3)	0.1030	9 (9)	23 (6)	25 (8)	30 (6)	8 (7)	0.6750	40 (8)	55 (6)	0.2506	82 (6)	13 (8)	0.3703	70 (8)	9 (4)	10 (5)	6 (6)	0.1935
	No	1325 (93)	1186 (93)	139 (97)		95 (91)	366 (94)	290 (92)	474 (94)	100 (93)		480 (92)	845 (94)		1183 (94)	142 (92)		834 (92)	194 (96)	204 (95)	93 (94)	
Insomnia progression (N=95)	History	57 (60)	52 (58)	5 (100)	0.1021	6 (67)	14 (61)	16 (64)	16 (53)	5 (63)	0.8667	33 (83)	24 (44)	0.0002*	47 (57)	10 (77)	0.2247	43 (61)	6 (7)	6 (60)	2 (3)	0.3685
	Acquired in prison	38 (40)	38 (42)	0 (0)		3 (33)	9 (39)	9 (36)	14 (47)	3 (38)		7 (18)	31 (56)		35 (43)	3 (23)		27 (39)	3 (3)	4 (40)	4 (7)	
Other mental illness	Yes	175 (12)	151 (12)	24 (17)	0.0944	19 (18)	65 (17)	33 (10)	46 (9)	12 (11)	0.0027*	112 (22)	63 (7)	<0.0001*	156 (12)	19 (12)	0.9789	122 (13)	21 (10)	22 (10)	10 (10)	0.3670
	No	1245 (88)	1125 (88)	120 (83)		85 (82)	324 (83)	282 (90)	458 (91)	96 (89)		408 (78)	837 (93)		1109 (88)	136 (88)		782 (87)	182 (90)	192 (90)	89 (90)	
Other mental illness progression (N=175)	History	168 (96)	146 (97)	22 (92)	0.1021	19 (100)	64 (98)	31 (94)	42 (91)	12 (100)	0.0033*	109 (97)	59 (94)	<0.0001*	152 (97)	16 (84)	0.0215*	117 (96)	19 (90)	22 (100)	10 (100)	0.5297
	Acquired in prison	7 (4)	5 (3)	2 (8)		0 (0)	1 (2)	2 (6)	4 (9)	0 (0)		3 (3)	4 (6)		4 (3)	3 (16)		5 (4)	2 (10)	0 (0)	0 (0)	

A Wilcoxon test was used in all analyses in table above. A p-value <0.05 was considered statistically significant. Fem= Female; Atl.: Atlantic; Ont.: Ontario; Anglo: Anglophone; Franc: Francophone; Cau: Caucasian, Abori: Aboriginal.

Table 4 presents sociodemographic information for psychotropic medication use. As expected based on findings from Table 3, female inmates took psychotropic medications more frequently compared to their male counterparts. Moreover, a higher proportion of female inmates took multiple types of psychotropic medication (24% of female inmates took more than 3 psychotropic medications vs 11% of male inmates who took the same number of medication). We also observed psychotropic medication use was proportionately higher in the Atlantic region (compared to Ontario) and also proportionately higher in Caucasian and Aboriginal groups (compared to other ethnic groups).

Table 4 Sociodemographic information by psychotropic medication use (N=1420).

	Daily intake	All (%)	Sex N (%)		p-value	Age N (%)					p-value	Region N (%)			Language N (%)		p-value	Ethnicity N (%)				p-value
			Male	Female		18≤24 years	≥25≤34 years	≥35≤ 44 years	≥45≤ 64 years	≥65 years		Atl.	Ont.		Anglo	Franc		Cau.	Black	Aborigi nal	Other	
All N (%)		1420 (100)	1276 (90)	144 (10)		104 (7)	389 (27)	315 (22)	504 (36)	108 (8)		520 (37)	900 (63)		1265 (89)	155 (11)		904 (64)	203 (14)	214 (15)	99 (7)	
Psychotropic medication use	Yes	691 (49)	593 (46)	98 (68)	<0.0001*	49 (47)	192 (49)	153 (49)	241 (48)	56 (52)	0.9438	286 (55)	405 (45)	0.0003*	612 (48)	79 (51)	0.5429	470 (52)	68 (33)	117 (55)	36 (36)	<0.0001*
	No	729 (51)	683 (54)	46 (32)		55 (53)	197 (51)	162 (51)	263 (52)	52 (48)		234 (45)	495 (55)		653 (52)	76 (49)		434 (48)	135 (67)	97 (45)	63 (64)	
Number of psychotropic medication	0	729 (51)	683 (54)	46 (32)	<0.0001*	55 (53)	197 (51)	162 (51)	263 (52)	52 (48)	0.9863	234 (45)	495 (55)	0.0002*	653 (52)	76 (49)	0.3882	434 (48)	135 (67)	97 (45)	63 (64)	<0.0001*
	1	328 (23)	288 (23)	40 (28)		24 (23)	95 (24)	68 (22)	113 (22)	28 (26)		120 (23)	208 (23)		296 (23)	32 (21)		217 (24)	35 (17)	58 (27)	18 (18)	
	2	191 (13)	168 (13)	23 (16)		12 (12)	56 (14)	42 (13)	65 (13)	16 (15)		85 (16)	106 (12)		169 (13)	22 (14)		126 (14)	19 (9)	37 (17)	9 (9)	
	>3	172 (12)	137 (11)	35 (24)		13 (13)	41 (11)	43 (14)	63 (13)	12 (11)		81 (16)	91 (10)		147 (12)	25 (16)		127 (14)	14 (7)	22 (10)	9 (9)	

A Wilcoxon test was used in the analysis on psychotropic medication use (yes or no). A Kruskal-Wallis test was used in analysis for the number of psychotropic medication. A p-value <0.05 was considered statistically significant when comparing data between sexes, age groups, regions, language and ethnicity groups.
Fem= Female; Atl.: Atlantic; Ont.: Ontario; Anglo: Anglophone; Franc: Francophone; Cau: Caucasian, Abori= Aboriginal.

Table 5 presents findings on BMI categories, mental health diagnosis and psychotropic medication use. We observed that inmates who took psychotropic medications also had higher obesity prevalence (50% of inmates on psychotropic medications were obese vs 41% of inmates not taking psychotropic medications). Moreover, the proportion of obese inmates increased proportionately with the number of psychotropic medications taken.

The proportion of overweight inmates was higher for inmates with "other" mental illness (45% of inmates with a diagnosis vs 38% of inmates without one). The obesity prevalence was similar in both groups of inmates.

Table 5 Body mass index (BMI) and waist circumference at interview by mental health diagnosis and psychotropic medication use.

		N (%)	Body Mass Index (BMI) N (%)			p-value
			Normal (18.5-24.9 kg/m^2)	Overweight (25.0-29.9 kg/m^2)	Obese (≥30 kg/m^2)	
All		1420 (100)	224 (16)	551 (39)	645 (45)	
Depression	Yes	241 (17)	35 (14)	88 (37)	118 (49)	0.4769
	No	1179 (83)	189 (16)	463 (39)	527 (45)	
Depression progression	History	218 (90)	33 (15)	76 (35)	109 (50)	0.3827
	Acquired in prison	23 (10)	2 (9)	12 (52)	9 (39)	
Anxiety	Yes	249 (18)	39 (16)	99 (40)	111 (45)	0.9413
	No	1171 (82)	185 (16)	452 (39)	534 (46)	
Anxiety progression	History	234 (94)	37 (16)	88 (38)	109 (47)	0.0831
	Acquired in prison	15 (6)	2 (13)	11 (73)	2 (13)	
Insomnia	Yes	95 (7)	11 (12)	36 (38)	48 (51)	0.4186
	No	1325 (93)	213 (16)	515 (39)	597 (45)	
Insomnia progression	History	57 (60)	8 (14)	19 (33)	30 (53)	0.5266
	Acquired in prison	38 (40)	3 (8)	17 (45)	18 (47)	
Other mental illness	Yes	175 (12)	16 (9)	78 (45)	81 (46)	0.0259*
	No	1245 (88)	208 (17)	473 (38)	564 (45)	
Other mental illness progression	History	168 (96)	16 (10)	75 (45)	77 (46)	0.0814
	Acquired in prison	7 (4)	0 (0)	3 (43)	4 (57)	
Psychotropic medication use	Yes	691 (49)	96 (14)	252 (36)	343 (50)	0.0062*
	No	729 (51)	128 (18)	299 (41)	302 (41)	
Number of psychotropic medication	0	729 (51)	128 (18)	299 (41)	302 (41)	0.0027*
	1	328 (23)	54 (16)	130 (40)	144 (44)	
	2	191 (13)	19 (10)	68 (36)	104 (54)	
	>3	172 (12)	23 (13)	54 (31)	95 (55)	

A Wilcoxon test was used in analyses with two categories (presence of disease yes or no and disease progression), and a Kruskal-Wallis test was used in analyses with three or more categories (number of psychotropic medication). *p-value <0.05 was considered statistically significant. The average length between admission and follow-up was 5.0 ± 8.3 years. CSC: Correctional Service Canada; CI = confidence interval.

Table 6 presents findings on weight change outcomes based on mental health diagnosis and psychotropic medication use. No association was observed between weight change outcomes and mental health status or psychotropic medication use. On the contrary, inmates with anxiety diagnosed in prison gained less weight (1 kg) compared to those who were diagnosed with anxiety prior to incarceration (5.4 kg). This means that the discrepancies in obesity prevalence observed in table 6 were present at the time of admission to the penitentiary, since the weight gain patterns were not significantly different during incarceration.

Additional analysis: in addition to the above-mentioned results, regression analysis testing was conducted to control for BMI changes associated with psychotropic medication use. Once adjusted for psychotropic medication use, the influential determinants (tobacco use and physical activity) were still significantly associated with BMI change. These analyses confirm that the factors identified as having a significant influence on BMI change were still influential after thorough controls (data not shown).

Table 6. Change in median weight, body mass index (BMI) and annual weight between admission and study follow-up in relation to mental health diagnosis and psychotropic medication use.

		All N (%)	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		1420 (100)	+5.6 (4.8-6.4)		+1.8 (1.5-2.1)		+1.4 (1.0-1.8)	
Depression	Yes	241 (17)	+ 6.5 (4.9-8.1)	0.8107	+ 2.0 (1.4-2.6)	0.6687	+ 1.7 (0.9-2.5)	0.7715
	No	1179 (83)	+ 6.2 (5.5-6.9)		+ 2.0 (1.8-2.2)		+ 1.5 (1.2-1.8)	
Depression progression	History	218 (90)	+ 6.8 (5.0-8.6)	0.4011	+ 2.2 (1.5-2.8)	0.3439	+ 1.7 (0.7-2.7)	0.2367
	Acquired in prison	23 (10)	+ 4.8 (-2.6-12.2)		+ 1.7 (-0.7-4.1)		+ 1.0 (-0.5-2.6)	
Anxiety	Yes	249 (18)	+ 5.0 (3.4-6.6)	0.0442*	+ 1.6 (1.1-2.1)	0.0602	+ 1.4 (0.6-2.2)	0.6329
	No	1171 (82)	+ 6.6 (5.9-7.3)		+ 2.1 (1.9-2.3)		+ 1.5 (1.2-1.8)	
Anxiety progression	History	234 (94)	+ 5.4 (3.7-7.0)	0.0400*	+ 1.8 (1.3-2.3)	0.0484*	+ 1.6 (0.6-2.6)	0.0913
	Acquired in prison	15 (6)	+ 1.0 (-7.0-9.0)		+ 0.4 (-2.0-2.8)		+ 0.02 (-2.4-2.4)	
Insomnia	Yes	95 (7)	+ 7.5 (4.8-10.2)	0.1043	+ 2.4 (1.5-3.3)	0.0858	+ 2.0 (0.8-3.2)	0.1859
	No	1325 (93)	+ 6.1 (5.4-6.8)		+ 2.0 (1.8-2.2)		+ 1.5 (1.2-1.8)	
Insomnia progression	History	57 (60)	+ 6.0 (3.0-9.0)	0.1292	+ 2.1 (1.2-3.0)	0.1235	+ 2.5 (0.8-4.2)	0.3768
	Acquired in prison	38 (40)	+ 12.5 (8.0-17.0)		+ 4.0 (2.6-5.4)		+ 1.9 (0.4-3.5)	
Other mental illness	Yes	175 (12)	+ 6.1 (4.4-7.8)	0.2121	+ 2.0 (1.5-2.5)	0.2601	+ 1.7 (0.9-2.4)	0.6864
	No	1245 (88)	+ 6.3 (5.6-7.0)		+ 2.0 (1.8-2.2)		+ 1.5 (1.2-1.8)	
Other mental illness progression	History	168 (96)	+ 6.1 (4.4-7.7)	0.4400	+ 2.0 (1.4-2.5)	0.5256	+ 1.7 (0.9-2.4)	0.3082
	Acquired in prison	7 (4)	+ 10.0 (-8.1-28.1)		+ 3.7 (-2.2-9.6)		+ 0.6 (-1.4-2.7)	
Psychotropic medication use	Yes	691 (49)	+ 6.5 (5.5-7.5)	0.8707	+ 2.1 (1.8-2.4)	0.6473	+ 1.8 (1.3-2.2)	0.1845
	No	729 (51)	+ 6.0 (5.1-6.9)		+ 2.0 (1.7-2.3)		+ 1.3 (0.9-1.6)	
Number of psychotropic medication	0	729 (51)	+ 6.0 (5.1-6.9)	0.7807	+ 2.0 (1.7-2.3)	0.6958	+ 1.3 (0.9-1.6)	0.3810
	1	328 (23)	+ 7.0 (5.6-8.4)		+ 2.2 (1.7-2.7)		+ 1.7 (0.9-2.4)	
	2	191 (13)	+ 5.9 (4.0-7.8)		+ 2.0 (1.4-2.6)		+ 1.8 (1.1-2.5)	
	≥3	172 (12)	+ 6.8 (4.8-8.7)		+ 2.3 (1.7-2.9)		+ 1.8 (0.7-2.9)	

A Wilcoxon test was used in analyses with two categories (presence of disease yes or no and disease progression), and a Kruskal-Wallis test was used in analyses with three or more categories (number of psychotropic medication). *p-value <0.05 was considered statistically significant. The average length between admission and follow-up was 5.0 ± 8.3 years. CSC: Correctional Service Canada; CI = confidence interval.

6.5.3 Discussion for mental health and weight gain

We found that the prevalence of anxiety and depression in inmates (35%) was higher than in the general population (12.4%) (122). This discrepancy in prevalence is well documented with multiple studies that found mental illness to be higher in the inmate population worldwide (6, 123-125). Also, in accordance with research on the topic, we found that female inmates were more likely to be diagnosed with depression and anxiety compared to male inmates (58% in female inmates vs 32% prevalence in male inmates). This finding coincided with many studies that found incarcerated women to have a high prevalence of "mild" mental illness (depression and anxiety) in prison (6, 123). These findings also match the tendencies in the non-incarcerated population where women are more likely to suffer from depression and anxiety than men (12.6% of Canadian women vs 7.5% of Canadian men) (122, 126, 127). The prevalence of mental illness was higher in inmates of Caucasian and Aboriginal ethnic backgrounds.

As expected, the same tendency was observed in our results on psychotropic medication use (higher psychotropic medication use in female inmates, Caucasians and Aboriginals). This was expected since psychotropic medication is the most common treatment for mental disorders (128). Our findings indicated that 68% of female inmates and 46% of male inmates took at least one psychotropic medication. This was much higher than findings from study out of Quebec on the subject that found ~40% of female inmates and ~20% of male inmates took at least one psychotropic medication (119). Regardless of discrepancies between studies, more inmates took psychotropic medications compared to the general population. In Canada, ~10% of non-incarcerated women and 5% of non-incarcerated men took at least one psychotropic medication in 2011 (119). We also found that a larger proportion of female inmates took a higher number of

psychotropic medications than males: 24% of female inmates took 3 or more medications, whereas 11% of male inmates took the same amount. Similar tendencies were observed in the general population with variations between sexes with regards to diagnosis of mental illness (129).

Contrary to our expectations, most of the variables related to mental health were not significantly associated with weight outcomes, with the exception of psychotropic medication use. We found that inmates taking psychotropic medications were more likely to be obese at the time of data collection. This relationship between weight gain and psychotropic medication is well supported in studies on the topic (121). Psychotropic medications are known to contribute to weight gain because of increased appetite and reduced metabolism (63). Half (50%) of inmates taking at least one psychotropic medication were obese; in comparison, 41% of inmates not taking psychotropic medication were obese. The proportion of obese inmates increased with the number of psychotropic medications taken. As such, 55% of inmates who took 3 or more medications were in the obese range.

However, none of the weight change outcomes were associated with mental health status, or psychotropic medication use. That means that the observed weight gain in the inmate population documented earlier in this study (95) was not associated with mental health or psychotropic medication use. This makes sense, given that most inmates were diagnosed with mental illness prior to their incarceration. That means they were probably already taking psychotropic medications when they were incarcerated, and already more obese than inmates not taking psychotropic medication. Consequently, they did not gain significantly more weight during incarceration. That indicates that the obesogenic effect of the prison environment and inmate

weight gain found in this study does not appear to be in relation to psychotropic medication use or mental illness. Our findings are similar to a study out of the United-States conducted on over 4 000 inmates in state prisons, found that although roughly 60% of inmates (male and female) gained weight during incarceration, mental health was not a significant factor associated with the weight gain (130). Similar to our findings, both groups of inmates (with or without a mental health diagnosis) had the same likelihood to gain weight during incarceration (130). Therefore suggesting, as our results did as well, that the weight gain is unrelated to mental health status or use of psychotropic medication.

6.5.4 Conclusion

In conclusion, inmates from our sample with mental illness and/or taking psychotropic medication had a higher proportion of obesity. However, they did not gain significantly more weight during incarceration than inmates without mental illness. This means that the observed weight gain in inmates during incarceration did not appear to be related to the higher prevalence of mental illness or use of psychotropic medication.

6.6 Weight gain and inmate health

6.6.1 Introduction

This section is not part of an article yet, but the data will be used for one in the future. The results for this section are different than the rest of the data analysed for this thesis. Up until now, we assessed factors related to inmate weight gain, whereas here we are assessing the health status of inmates who gained significant weight during incarceration. In this section, we assessed health

status (obesity related comorbidities) as an outcome (or consequence) of the weight gain. Our goal here was to explore if the inmates who gained weight during incarceration were more likely to suffer from obesity related illness or to have acquired those diseases in prison.

It is well established that weight gain increases the risk of obesity related illnesses (17, 18). Given that most inmates (73%) gain weight during incarceration (95), and that obesity prevalence significantly increased during incarceration (from 27% to 46%) (95), it is possible that the observed weight gain could influence inmates' health by increasing the risk of obesity related comorbidities (3). We hypothesized that obese inmates (BMI $\geq$30 kg/m^2) more frequently suffered from obesity related chronic diseases. We also hypothesized that inmates who gained a significant amount of weight also more frequently acquired obesity related diseases during incarceration.

The data presented in this section were taken from participants medical charts. The same methodology and statistical analysis was used as for the first manuscript presented in section 6.1 of this thesis (95).

6.6.2 Results for weight gain and inmate health

Table 7 presents sociodemographic information based on inmates' chronic diseases. For each disease, the prevalence for our sample (N=1420) is presented. In addition, the disease evolution is also shown, meaning that if the inmate had the disease prior to incarceration it is indicated as "history", and if the disease was diagnosed during incarceration it is indicated as "acquired in prison".

As expected, all chronic diseases tended to increase with inmates' age. For example, CVD and type 2 diabetes were associated with higher age and sex (male). As such, we observed higher prevalence (51% for CVD and 43% for type 2 diabetes) in inmates 65 years and older, compared to younger inmates who had lower prevalence of those diseases. In Ontario, CVD and type 2 diabetes were more frequently acquired in prison; whereas in the Atlantic region, inmates were more frequently already diagnosed prior to incarceration.

The majority of digestive ailments (80% of reflux cases) were acquired in prison. Reflux was more frequent in male inmates (22%) than female inmates (11%). Black inmates had lower reflux prevalence (18%) compared to other ethnic groups (35%).

The prevalence of hypertension was 40% in our sample. We observed an increase with age and with certain ethnic groups (Caucasian and Aboriginal). Moreover, 80% of cases were acquired during incarceration. In Ontario, hypertension was more often acquired in prison; whereas in Atlantic inmates were diagnosed prior to incarceration. Most cases of dyslipidemia were also acquired in prison (78%), and it was more frequent in male inmates (19%) compared to female inmates (7%).

Table 7. Sociodemographic information by chronic disease diagnosis and progression (N=1420).

		All (%)	Sex N (%)		p-value	Age N (%)					p-value	Region N (%)		p-value	Language N (%)		p-value	Ethnicity N (%)				p-value
			Male	Fem		18≤24 years	≥25≤34 years	≥35≤44 years	≥45≤64 years	≥65 years		Atl.	Ont.		Anglo	Franc		Cau.	Black	Abori	Other	
All N (%)		1420 (100)	1276 (90)	144 (10)		104 (7)	389 (27)	315 (22)	504 (36)	108 (8)		520 (37)	900 (63)		1265 (89)	155 (11)		904 (64)	203 (14)	214 (15)	99 (7)	
Cancer	Yes	19 (1)	14 (1)	5 (3)	0.0360*	2 (2)	2 (1)	6 (2)	5 (1)	4 (4)	0.0690	9 (2)	10 (1)	0.3275	19 (2)	0 (0)	0.2542	15 (2)	2 (1)	2 (1)	0 (0)	0.7124
	No	1401 (99)	1262 (99)	139 (97)		102 (98)	387 (99)	309 (98)	499 (99)	104 (96)		511 (98)	890 (99)		1246 (98)	155 (100)		889 (98)	201 (99)	212 (99)	99 (100)	
Cancer progression (N=19)	History	8 (42)	4 (29)	4 (80)	0.0092*	2 (100)	1 (50)	4 (67)	0 (0)	1 (25)	0.0109*	5 (56)	3 (30)	0.2684	8 (42)	0 (0)	0.6971	7 (47)	0 (0)	1 (50)	0 (0)	0.9304
	Acquired in prison	11 (58)	10 (71)	1 (20)		0 (0)	1 (50)	2 (33)	5 (100)	3 (75)		4 (44)	7 (70)		11 (58)	0 (0)		8 (53)	2 (100)	1 (50)	0 (0)	
Cardio Vascular Disease (CVD)	Yes	172 (12)	163 (13)	9 (6)	0.0229*	1 (1)	5 (1)	16 (5)	95 (19)	55 (51)	<0.0001*	66 (13)	106 (12)	0.6109	154 (12)	18 (12)	0.8399	133 (15)	12 (6)	21 (10)	6 (6)	0.0005*
	No	1248 (88)	1113 (87)	135 (94)		103 (99)	384 (99)	299 (95)	409 (81)	53 (49)		454 (87)	794 (88)		1111 (88)	137 (88)		771 (85)	191 (94)	193 (90)	93 (94)	
CVD progression (N=172)	History	74 (43)	69 (42)	5 (56)	0.0638	1 (100)	3 (60)	13 (81)	32 (34)	25 (45)	<0.0001*	45 (68)	29 (27)	<0.0001*	63 (41)	11 (61)	0.2690	59 (44)	6 (50)	8 (38)	1 (17)	0.0045*
	Acquired in prison	98 (57)	94 (58)	4 (44)		0 (0)	2 (40)	3 (19)	63 (66)	30 (55)		21 (32)	77 (73)		91 (59)	7 (39)		74 (56)	6 (50)	13 (62)	5 (83)	
Type 2 Diabetes	Yes	197 (14)	185 (14)	12 (8)	0.0944	1 (1)	11 (3)	19 (6)	120 (24)	46 (43)	<0.0001*	51 (10)	146 (16)	0.0008*	171 (14)	26 (17)	0.2683	132 (15)	20 (10)	29 (14)	16 (16)	0.3079
	No	1223 (86)	1091 (86)	132 (92)		103 (99)	378 (97)	296 (94)	384 (76)	62 (57)		469 (90)	754 (84)		1094 (86)	129 (83)		772 (85)	183 (90)	185 (86)	83 (84)	
Type 2 Diabetes progression (N=197)	History	67 (34)	65 (35)	2 (17)	0.0746	0 (0)	4 (36)	8 (42)	41 (34)	14 (30)	<0.0001*	33 (65)	34 (23)	<0.0001*	49 (29)	18 (69)	<0.0001*	44 (33)	5 (25)	10 (34)	8 (50)	0.3937
	Acquired in prison	130 (66)	120 (65)	10 (83)		1 (100)	7 (64)	11 (58)	79 (66)	32 (70)		18 (35)	112 (77)		122 (71)	8 (31)		88 (67)	15 (75)	19 (66)	8 (50)	
Reflux	Yes	472 (33)	415 (33)	57 (40)	0.0882	21 (20)	106 (27)	103 (33)	194 (38)	48 (44)	<0.0001*	196 (38)	276 (31)	0.0068*	414 (33)	58 (37)	0.2418	327 (36)	36 (18)	75 (35)	34 (34)	<0.0001*
	No	948 (67)	861 (67)	87 (60)		83 (80)	283 (73)	212 (67)	310 (62)	60 (56)		324 (62)	624 (69)		851 (67)	97 (63)		577 (64)	167 (82)	139 (65)	65 (66)	
Reflux progression (N=472)	History	96 (20)	90 (22)	6 (11)	0.0248*	6 (29)	20 (19)	22 (21)	36 (19)	12 (25)	0.0004*	52 (27)	44 (16)	0.0004*	84 (20)	12 (21)	0.5027	66 (20)	9 (25)	16 (21)	5 (15)	0.0002*
	Acquired in prison	376 (80)	325 (78)	51 (89)		15 (71)	86 (81)	81 (79)	158 (81)	36 (75)		144 (73)	232 (84)		330 (80)	46 (79)		261 (80)	27 (75)	59 (79)	29 (85)	

A Wilcoxon test was used in all analyses in table above. A p-value <0.05 was considered statistically significant. Fem= Female; Atl.: Atlantic; Ont.: Ontario; Anglo: Anglophone; Franc: Francophone; Cau: Caucasian, Abori= Aboriginal.

Table 7 (continued). Sociodemographic information by chronic disease diagnosis and progression (N=1420).

		All (%)	Sex N (%)		p-value	Age N (%)					p-value	Region N (%)		p-value	Language N (%)		p-value	Ethnicity N (%)				p-value
			Male	Fem		18≤24 years	≥25≤34 years	≥35≤44 years	≥45≤64 years	≥65 years		Atl.	Ont.		Anglo	Franc		Cau.	Black	Abori	Other	
All N (%)		1420 (100)	1276 (90)	144 (10)		104 (7)	389 (27)	315 (22)	504 (36)	108 (8)		520 (37)	900 (63)		1265 (89)	155 (11)		904 (64)	203 (14)	214 (15)	99 (7)	
Hypertension	Yes	569 (40)	523 (41)	46 (32)	0.1030	20 (19)	87 (22)	104 (33)	266 (53)	92 (85)	<0.0001*	221 (43)	348 (39)	0.1556	515 (41)	54 (35)	0.1591	386 (43)	59 (29)	96 (45)	28 (28)	0.0001*
	No	851 (60)	753 (59)	98 (68)		84 (81)	302 (78)	211 (67)	238 (47)	16 (15)		299 (58)	552 (61)		750 (59)	101 (65)		518 (57)	144 (71)	118 (55)	71 (72)	
Hypertension progression (N=569)	History	115 (20)	108 (21)	7 (15)	0.0806	2 (10)	14 (16)	17 (16)	58 (22)	24 (26)	<0.0001*	55 (25)	60 (17)	0.0297*	96 (19)	19 (35)	0.0095*	78 (20)	14 (24)	14 (15)	9 (32)	0.0004*
	Acquired in prison	454 (80)	415 (79)	39 (85)		18 (90)	73 (84)	87 (84)	208 (78)	68 (74)		166 (75)	288 (83)		419 (81)	35 (65)		308 (80)	45 (76)	82 (85)	19 (68)	
Dyslipidemia	Yes	258 (18)	248 (19)	10 (7)	0.0002*	8 (8)	29 (7)	29 (9)	139 (28)	53 (49)	<0.0001*	81 (16)	177 (20)	0.0542	221 (17)	37 (24)	0.0511	186 (21)	22 (11)	34 (16)	16 (16)	0.0078*
	No	1162 (82)	1028 (81)	134 (93)		96 (92)	360 (93)	286 (91)	365 (72)	55 (51)		439 (84)	723 (80)		1044 (83)	118 (76)		718 (79)	181 (89)	180 (84)	83 (84)	
Dyslipidemia progression (N=258)	History	56 (22)	53 (21)	3 (30)	0.0010*	2 (25)	6 (21)	4 (14)	30 (22)	14 (26)	<0.0001*	24 (30)	32 (18)	0.0207*	44 (20)	12 (32)	0.0235*	43 (23)	3 (14)	5 (15)	5 (31)	0.0270*
	Acquired in prison	202 (78)	195 (79)	7 (70)		6 (75)	23 (79)	25 (86)	109 (78)	39 (74)		57 (70)	145 (82)		177 (80)	25 (68)		143 (77)	19 (86)	29 (85)	11 (69)	

A Wilcoxon test was used in all analyses in table above. A p-value <0.05* was considered statistically significant. Fem= Female; Atl.: Atlantic; Ont.: Ontario; Anglo: Anglophone; Franc: Francophone; Cau: Caucasian, Abori:Aboriginal

Table 8 presents a comparison of BMI categories between inmates with and without a given obesity-related chronic medical condition. We observed a significant difference in obesity (BMI ≥30 kg/m^2) prevalence in inmates with many chronic conditions, such as CVD, type 2 diabetes, reflux, hypertension, osteoarthritis and sleep apnea. In all these cases, the proportion of obese inmates was significantly higher for each group of inmates who were diagnosed with a comorbidity. However, there was no significant difference observed between the proportion of obese inmates for those who had cancer, gout and non-alcoholic liver stenosis.

Table 8 Body mass index (BMI) at interview by chronic disease (N=1420).

		N (%)	Body Mass Index (BMI) N (%)			p-value
			Underweight and Normal (18.5-24.9 kg/m²)	Overweight (25.0-29.9 kg/m²)	Obese (≥30 kg/m²)	
All		1420 (100)	224 (16)	551 (39)	645 (45)	
Cancer	Yes	19 (1)	1 (5)	8 (42)	10 (53)	0.4441
	No	1401 (99)	223 (16)	543 (39)	635 (45)	
Cardio Vascular Disease	Yes	172 (12)	18 (10)	51 (30)	103 (60)	0.0002*
	No	1248 (88)	206 (17)	500 (40)	542 (43)	
Type 2 Diabetes	Yes	197 (14)	14 (7)	43 (22)	140 (71)	<0.0001*
	No	1223 (86)	210 (17)	508 (42)	505 (41)	
Reflux	Yes	472 (33)	54 (11)	167 (35)	251 (53)	<0.0001*
	No	948 (67)	170 (18)	384 (41)	394 (42)	
Gout	Yes	28 (2)	5 (18)	11 (39)	12 (43)	0.9410
	No	1392 (98)	219 (16)	540 (39)	633 (45)	
Non-Alcoholic Fatty Liver	Yes	17 (1)	2 (12)	6 (35)	9 (53)	0.8009
	No	1403 (99)	222 (16)	545 (39)	636 (45)	
Hypertension	Yes	569 (40)	43 (8)	176 (31)	350 (62)	<0.0001*
	No	851 (60)	181 (21)	375 (44)	295 (35)	
Dyslipidemia	Yes	258 (18)	31 (12)	79 (31)	148 (57)	0.0001*
	No	1162 (82)	193 (17)	472 (41)	497 (43)	
Osteoarthritis	Yes	71 (5)	11 (15)	16 (23)	44 (62)	0.0082*
	No	1349 (95)	213 (16)	535 (40)	601 (45)	
Sleep apnea	Yes	67 (5)	7 (10)	16 (24)	44 (66)	0.0030*
	No	1353 (95)	217 (16)	535 (40)	601 (44)	

The p-value is the result of a Wilcoxon test. A p-value <0.05* was considered statistically significant when comparing BMI categories between inmates with and without the chronic disease in question, and comparing BMI categories when the condition was present on admission compared to inmates who acquired the condition during incarceration.

Table 9 presents findings on median weight gain, increase in BMI and annual weight gain by diagnosis and progression of chronic medical conditions during incarceration. We observed an association between weight gain and disease progression for many types of chronic diseases. This was the case for cancer, where inmates who acquired cancer in prison also gained significantly more weight (16.5 kg) compared to inmates who were diagnosed with the disease prior to incarceration (3.1 kg). We observed similar relationships in inmates who developed type 2 diabetes, hypertension, dyslipidemia and sleep apnea. We also observed a significant difference in weight gain between inmates with and without certain chronic medical conditions (regardless of diagnosis prior or during incarceration). As such, we observed that inmates with hypertension gained significantly more weight (8.0 kg) compared to inmates who did not suffer from hypertension who gained less weight (5.5 kg) during incarceration. Similar relationships were observed in inmates with CVD and dyslipidemia.

Table 9 Change in median weight, body mass index (BMI) and annual weight between admission and study follow-up by chronic disease diagnosis and progression (N=1420).

		All N (%)	Median weight change kg (95% CI)	p-value	Median BMI change kg/m^2 (95% CI)	p-value
All		1420 (100)	+5.6 (4.8-6.4)		+1.8 (1.5-2.1)	
Cancer	Yes	19 (1)	+12.5 (8.3-16.7)	0.1079	+3.5 (2-5.0)	0.1276
	No	1401 (99)	+6.2 (5.5-6.9)		+2 (1.8-2.2)	
Cancer progression	History	8 (42)	+3.1 (-7.8-14)	0.0133*	+1 (-2.6-4.6)	0.0131*
	Acquired	11 (58)	+16.5 (11.1-21.9)		+ 5.7 (4.1-7.3)	
Cardio vascular disease	Yes	172 (12)	+8.1 (5.8-10.3)	0.0334*	+2.6 (1.9-3.3)	0.0265*
	No	1248 (88)	+6 (5.3-6.7)		+2 (1.8-2.2)	
Cardio vascular progression	History	74 (43)	+6.5 (3.3-9.7)	0.0560	+2 (0.9-3.1)	0.0450*
	Acquired	98 (57)	+9.4 (6.2-12.6)		+3.2 (2.3-4.1)	
Type 2 Diabetes	Yes	197 (14)	+7.9 (5.8-10.1)	0.0564	+2.5 (1.8-3.2)	0.0513
	No	1223 (86)	+6 (5.3-6.7)		+2 (1.8-2.2)	
Type 2 Diabetes progression	History	67 (34)	+5.1 (2.4-7.8)	0.0035*	+1.7 (0.8-2.6)	0.0033*
	Acquired	130 (66)	+9.3 (6.1-12.4)		+3.2 (2.2-4.2)	
Reflux	Yes	472 (33)	+ 7 (5.8-8.2)	0.2879	+2.2 (1.8-2.6)	0.2263
	No	948 (67)	+ 6 (5.2-6.8)		+2 (1.8-2.2)	
Reflux progression	History	96 (20)	+ 6.8 (4.3-9.2)	0.4681	+2.2 (1.4-3.0)	0.4041
	Acquired	376 (80)	+ 7 (5.5-8.5)		+2.4 (1.9-2.8)	
Gout	Yes	28 (2)	+ 4.6 (1.3-7.8)	0.1268	+1.5 (0.5-2.4)	0.1829
	No	1392 (98)	+ 6.3 (5.6-7)		+2 (1.8-2.2)	

Table 9 (continued). Change in median weight, body mass index (BMI) and annual weight between admission and study follow-up by chronic disease diagnosis and progression

		All N (%)	Median weight change kg (95% CI)	p-value	Median BMI change kg/m^2 (95% CI)	p-value
All		1420 (100)	+5.6 (4.8-6.4)		+1.8 (1.5-2.1)	
Gout progression	History	11 (39)	+ 0.4 (-6.1-6.7)	0.2869	+0.2 (-2.1-2.5)	0.3716
	Acquired	17 (61)	5.1 (1.3-8.9)		+1.7 (0.6-2.8)	
Non-alcoholic fatty liver	Yes	17 (1)	+ 4 (-3.4-11.4)	0.3697	+1.3 (-1.1-3.7)	0.3513
	No	1403 (99)	+ 6.4 (5.8-7.0)		+2 (1.8-2.2)	
Non-alcoholic fatty liver progression	History	3 (18)	+3.8 (-2.1-9.7)	0.5427	+1.1 (-1.1-3.3)	0.5409
	Acquired	14 (82)	+4.2 (-4.9-13.2)		+1.4 (-1.5-4.2)	
Hypertension	Yes	569 (40)	+ 8 (6.8-9.2)	0.0078*	+2.5 (2.1-2.9)	0.0061*
	No	851 (60)	+ 5.5 (4.7-6.3)		+1.8 (1.6-2.0)	
Hypertension progression	History	115 (20)	+ 6.3 (4.2-8.4)	0.0026*	+2 (1.4-2.6)	0.0015*
	Acquired	454 (80)	+8.4 (6.9-9.8)		+2.8 (2.3-3.2)	
Dyslipidemia	Yes	258 (18)	+7.5 (5.6-9.4)	0.0309*	+2.6 (1.9-3.2)	0.0229*
	No	1162 (82)	+ 6 (5.3-6.7)		+2 (1.8-2.2)	
Dyslipidemia progression	History	56 (22)	+4.5 (0.9-8)	0.0030*	+1.4 (0.2-2.6)	0.0020*
	Acquired	202 (78)	+8.8 (6.6-10.9)		+3 (2.3-3.6)	
Osteoarthritis	Yes	71 (5)	+8.4 (4.7-12.1)	0.1878	+2.7 (1.5-3.9)	0.1703
	No	1349 (95)	+ 6.1 (5.4-6.8)		+2 (1.8-2.2)	
Osteoarthritis progression	History	29 (41)	+9.1 (2.8-15.4)	0.3813	+2.8 (0.8-4.8)	0.3329
	Acquired	42 (59)	+7 (1.6-12.4)		+2.3 (0.6-4.0)	
Sleep apnea	Yes	67 (5)	+11.2 (7.4-15)	0.0560	+3.6 (2.4-4.8)	0.0573
	No	1353 (95)	+6 (5.3-6.7)		+2 (1.8-2.2)	
Sleep apnea progression	History	18 (27)	+1.1 (-6.1-8.3)	0.0093*	+0.3 (-1.8-2.4)	0.0070*
	Acquired	49 (73)	+13.5 (9.4-17.6)		+4.2 (3-5.4)	

A Wilcoxon test was used in all analyses. *p-value <0.05 was considered statistically significant. The average length between admission and follow-up was 5.0 ± 8.3 years. SC: Correctional Service Canada; CI = confidence interval.

6.6.3 Discussion for weight gain and inmate health

These findings on comorbidities were assessed differently from the rest of our findings. Up until now, we were assessing the factors that could be contributors to weight gain. However, with comorbidities, we are analyzing the influence of weight gain during incarceration on an increase in obesity related ailments. In the literature, it is well established that overweight and obesity increase the risk of developing these chronic diseases. For example, obesity increases the risk for certain types of cancer [esophageal, gastric, colon, rectum, liver, gallbladder, pancreas, postmenopausal breast, ovary, kidney, meningioma, thyroid and multiple myeloma (131)], CVD, cancer, type 2 diabetes, reflux, hypertension, dyslipidemia, osteoarthritis and sleep apnea (2, 18). For every disease listed above, the proportion of obese inmates from our sample was significantly higher for inmates who were diagnosed with those conditions compared to inmates who were not. This clearly illustrated the relationship between higher BMI and presence of the obesity related chronic illness.

Our findings on obesity comorbidities coincided with obesity research that found these conditions were related to weight gain (17). Generally speaking, our results indicated that inmates who gained significant weight would then subsequently acquire these obesity related diseases during incarceration. For example, inmates who got cancer during incarceration gained 16.5 kg between admission and follow up, compared to 6.2 kg for inmates who did not have cancer or 3.1 kg for inmates who were diagnosed with cancer prior to incarceration. It is well established that certain types of cancer are associated with obesity and weight gain (2, 18, 132). In addition to cancer, the most striking examples from our study were CVD, type 2 diabetes, hypertension and dyslipidemia. In each case, inmates who acquired these diseases during incarceration had also gained a

significant amount of weight (and/or had a significant increase in BMI) during their incarceration. These findings suggest that since the prison environment was contributing to weight gain, it could have also been contributing to making inmates ill.

Also, the prevalence of many of these diseases were higher in our sample than in the general Canadian population (122). For example, the prevalence for hypertension in non-incarcerated Canadian adults was 20-25% in 2015 (133), but it was 40% in our sample (with 80% of those cases acquired during incarceration). Furthermore, those inmates who were diagnosed with hypertension during incarceration, had also gained 8.4 kg and 2.8 BMI points. That weight gain was significantly higher for those inmates, compared to inmates without hypertension who gained 5.5 kg and 1.8 BMI points.

A Canadian study found diabetes prevalence to be 4.2% on admission to Canadian penitentiaries (4). This is consistent with our findings that revealed that 4.7% of inmates from our sample had diabetes on admission. However, at the time of the interview the prevalence of diabetes increased to 14%. This represents a 94% increase in prevalence during incarceration. Moreover, the observed weight gain was significantly higher for inmates who acquired diabetes during incarceration (9.4 kg), compared to weight gain in inmates who do not have diabetes (6 kg), or who had diabetes prior to incarceration (5.1 kg). This suggest that weight gain during incarceration could indeed contribute to higher diabetes rates during incarceration. In support of that statement, the obesity rate for inmates with diabetes was significantly higher than for inmates without the disease (71% of diabetic inmates were obese vs 41% of non-diabetics). Similar relationships were observed for

inmates who acquired CVD, dyslipidemia and sleep apnea during incarceration in Canadian federal penitentiaries.

Our findings revealed that inmates' health deteriorated during incarceration (and this may be due in part because of weight gain). This finding is consistent with the research on inmate health out of the United States, the United Kingdom and Australia (3), where inmates were typically more sick behind bars than their counterparts in the community. This is however not always the case, since in Japan inmates actually lose weight and their metabolic health generally improves during incarceration (134, 135). As discussed in manuscript 1 (section 6.1 of this thesis), Japanese inmates are placed on strict low-calorie diets and obligated to exercise during incarceration. A WHO paper found that inmates reported incarceration as a possible opportunity to improve their health (6, 117); however, based on our findings, it does not seem to be the case in Canadian prison.

6.6.4 Conclusion

In conclusion, disease acquisition of obesity-related illness appeared to be related to inmates' weight gain during incarceration. Since inmates who acquired these diseases (cancer, type 2 diabetes, hypertension, dyslipidemia and sleep apnea), also gained significantly more weight than inmates who did not have the disease or who had the disease prior to incarceration. Which means when inmates gained weight during incarceration, they were more likely to subsequently suffer from obesity related ailments. Our findings indicate that many inmates were getting ill during incarceration, and this may be in part because of the weight they gained. This means inmates were frequently being released from prison heavier and sicker than when they were first incarcerated in Canadian federal penitentiaries.

7. Discussion

This discussion section is an overview of this project as a whole by first examining our main findings in relation to our model found in Figure 2 of this thesis. This is followed by a discussion on our purpose, goals and hypotheses (section 7.2), and by a brief discussion on the suitability of this study as a thesis in Population Health (section 7.3). Then it is followed by a brief discussion on health inequities in prison (section 7.4). We also offer a summary of our recommendations (section 7.5) and describe the strengths and limitations of this study (section 7.6). Lastly, we present a summary of suggestions for future research (section 7.7).

7.1 Penitentiaries as obesogenic environments: findings in relation to our analytical model

To address the complex issue of Canadian penitentiaries as obesogenic environments, the first goal of this study was to examine the prison setting to determine if inmates gained weight in this environment. To reach this goal, we assessed weight outcomes in the inmate population of the Ontario and Atlantic federal correctional institutions. We found that almost three quarters of inmates (73%) did indeed gain weight during incarceration. This finding was similar to other research done on inmate weight gain, where most inmates (43-73%) gained weight during incarceration (20). Most of the previous research done on inmate weight gain was based on self-reported weight changes (3, 20, 25). We used measured weights (measured weight on admission in comparison to measured weight at the time of interview); this may explain in part why we found higher weight gain than in previous studies. As reported in a previous study, the discrepancy between self-reported weight and measured weight is around 10% (17).

In the penitentiary setting, we often hear that the observed weight gain is thought to be beneficial to inmate health. Many people from the field believe that inmates enter the penitentiary underweight and malnourished, and that our job is to "overfeed" them back to health. However, our findings did not support this opinion, since we found that obesity rates increased by 71%, going from 27% to 46% (95). That means the observed weight gain was deemed unhealthy, since a significant proportion of inmates were entering the penitentiary at a healthy weight or overweight, and becoming obese during incarceration. This indicated to us that the situation warranted further investigation. Therefore, we situated this examination within a broader context of socio-demographic, behavioral, institutional and policy determinants, using our model in Figure 2 presented in section 3.2 of this thesis. The goal was to identify which factors were influential to inmate weight gain during incarceration in Canadian penitentiaries.

7.1.1 The macrosystem level

As shown in our results section, many of the factors from our model influenced inmates' weight outcomes. First at the macrosystem level, we examined how the national policies influenced the prison environment. For example, the national policy to ban tobacco and to force smoking abstinence during incarceration had an important impact on inmates' weight gain. Inmates who were forced to quit smoking during incarceration gained significantly more weight than non-smokers. See details in manuscript 2, in section 6.2 of this thesis. However, we did not find the national menu (another factor at the macrosystem level) to be influential to inmate weight gain since we found the food service feeding system was not significantly associated with weight gain during incarceration. The national menu and the feeding system go together since two systems

(central tray and cafeteria service) served the national menu, whereas the third system (small group meal plan) did not use the national menu. Since we did not find a significant association between feeding systems, that meant there was not a significant difference in weight gain between inmates being fed by the national menu and those who were not. Thus suggesting, all three food service feeding systems are equally contributing to weight gain This finding was presented in manuscript 1, in section 6.1 of this thesis; and this finding was also explained in more detail in manuscript 4, in section 6.4 of this thesis. Throughout this study, regional differences were observed in many areas (i.e. diet prescriptions, food intake, increase in BMI, feeding system, social network, marital status, chronic disease progression, mental illness, education levels, etc). This suggests there were variations in how each region implemented national policies; however, we are unable to confirm or explain further how those differences occurred with this current study. Further examination of how policy is implemented at the regional level could provide insight into these observed discrepancies.

7.1.2 The microsystem level

At the microsystem level, we explored how the feeding systems and other related factors were associated with weight gain. However, as mentioned in the previous paragraph, the feeding system, and therefore, the dinning practices, the food environment and institutional meals did not appear to have a significant influence on our weight outcomes. This was not expected, since in the beginning, we suspected inmates who fed themselves as part of the small group meal plan would gain more weight since they were not following a standardized menu. This was however not the case.

7.1.3 The individual level

At the individual level, our findings revealed many factors were associated with weight outcomes. For starters, many socio-demographic determinants were associated with weight gain. Age was strongly associated with weight; this was expected since age and weight gain were strongly correlated in the community (19). Sex was also associated with our weight outcomes. However, contrary to community findings where women were less likely to be obese (101), we found that female inmates gained more weight and were more likely to be obese than male inmates. This finding was similar to the research on inmate weight gain that commonly found female inmates gained more weight than male inmates during incarceration (3, 7, 30). In those studies, female inmates had higher weights and BMIs than their non-incarcerated counterparts, which was similar to our findings. Whereas, those studies typically found male inmates were less likely to be overweight or obese than their non-incarcerated counterparts (3, 25). Our findings were different since we found male inmates already had higher overweight and obesity rates (66%) than the general population (61.3%) on admission, then they gained a significant amount of weight during incarceration. Our findings were similar to other data on inmates' weight on admission to Canadian penitentiaries (4). That study found that overweight and obesity rates were 64.5% on admission (4), and we found that overweight and obesity rates were 66% on admission. Comparing inmates to the general population was debated on multiple occasions during this study. Some reviewers commented on our comparison with the obesity rates to the general population, stating the inmate population was too different from the general population. Ideally, we would have done a control group in the general population; but that was unrealistic for this study because we wanted to assess change in weight outcomes over time in the penitentiary setting. It was impossible for us to

reproduce this in the community setting. We still used data from the community as comparison to provide context to our findings. This was deemed acceptable by reviewers.

We also found ethnicity to be associated with weight outcomes. We observed many differences based on the ethnic background of inmates. Overall, Aboriginal inmates gained the most weight of all the ethnic groups studied. We found that obesity rates (BMI ≥30 kg/m^2) were 29% at admission in the Aboriginal inmates from our sample, then rose to 50% at interview. This was higher in comparison to non-Aboriginal inmates who had 26% obesity rates at admission and 45% obesity rates at follow-up. These findings were consistent with research on Aboriginal obesity at the community level, that found obesity rates to be higher among Aboriginal populations (17). However, Aboriginal obesity rates were lower outside the prison (26%) (136) compared to the rates seen in prison (29% on admission and 50% at the time of interview). Examining variations with Aboriginal inmates was important, since a high proportion of Aboriginals are incarcerated in Canadian penitentiaries. Although Aboriginals only represent approximately 4% of the Canadian population, they represent 23-27% of the inmates population in Canadian penitentiaries (12, 137). Aboriginal inmates only represented 15% of our sample, which is still an overrepresentation compared to the 4% proportion found in the community. A possible explanation for our sample to have a lower proportion of Aboriginals was because we did not recruit participants in the regions where the proportion of Aboriginal inmates are the highest: Manitoba (74% of the inmate population were Aboriginals) and Saskatchewan (76% of the inmate population were Aboriginals) (137). The overrepresentation of incarcerated Aboriginals is an important source of inequity in Canada, suggesting that there are more vulnerable population subgroups within the already

vulnerable prison population. We will discuss this point further in section 7.4 on health inequities in the prison population.

In addition, we found obesity rates in visible minority inmate groups were similar to data on obesity in immigrant populations in Canada (17). The research on the topic typically found that immigrants were less likely to gain weight when they were surrounded by ethnic social networks or neighborhoods (33). Whereas, their obesity rates match Canadians when they are in similar environments (neighborhoods and social networks) as Canadians (33). Our findings revealed black inmates and other visible minority groups consistently gained less weight than Caucasian and Aboriginal inmates. This suggests that even in a controlled environment such as a penitentiary, it appears ethnic sub environments may be present. Since they were all in the same environment, we would expect the weight gain to be similar for all ethnicities, yet it was not. We found some explanations for the discrepancies, for example black inmates and inmates from other visible minority groups reported doing more weight lifting exercises and playing sports which were both associated with less weight gain. See manuscript 3, in section 6.3 of this thesis for more details. In addition, these inmates reported more frequently purchasing healthy food from canteen and were more frequently on special diets (mostly religious diets and diets of conscience). We found that both those diets were associated with less weight gain in our study. Whereas, surprisingly, inmates who were on medical diets gained significantly more weight (7.5 kg), than inmates who were on the regular meal plan (5.8 kg). Our study does not provide evidence on why this phenomenon occurred, we can speculate that the weight gain occurred prior to being placed on a medical diet; or possibly that restricting calories, fat and sodium on the medical diets provoked excessive caloric intake between meals (See manuscript 4, in section 6.4 of this thesis for more details. Lastly, these

inmates (black and other visible minority groups) were less likely to be ex-smokers or to have a history of drug of substance misuse. These factors were all associated with weight gain in Canadian penitentiaries. See manuscript 2, in section 6.2 of this thesis for more details.

Length of incarceration was also associated with weight change outcomes; the longer inmates were incarcerated the more weight they gained. We found that inmates gained weight more quickly in the first 18 month of incarceration (6.4 kg/year), after that they continued to gain weight but at a slower pace. Even inmates incarcerated more than five years gained weight at a pace of 0.64 kg/year. This is important since inmates continued to gain weight, even once they had probably adapted to the environment. This is not a typical finding, in research on other obesogenic environments, such as university campuses, where students gained weight (at a fast pace) in the first month but their weight typically stabilized after that (138). Even after five years in prison, inmates continued to gain weight at a faster pace than non-incarcerated Canadians, who gained at an average pace of ~0.46 kg/year (19). Moreover, only roughly half of Canadians gained weight (at the pace of ~0.46 kg/year), the other half of non-incarcerated adults did not gain weight at all (19). In addition to gaining weight at faster pace, we found that a higher proportion of inmates gained weight (73% of inmates gained weight during incarceration, compared to roughly 50% of adults in the general population who gained weight) (19). See manuscript 1, in section 6.1 of this thesis for more details.

Based on our findings, other factors, such as education, former profession and spoken language were not associated with weight gain in Canadian penitentiaries. We expected these factors to contribute to weight change, since they typically do at the community level (17, 32, 37, 139).

However, in the closed/controlled environment of the penitentiaries, these factors (considered indirectly influential) did not influence weight outcomes in inmates. A possible explanation is the male dominance of the prison population (89% of our sample was male), as the relationship between education, revenue and weight is not as clear in non-incarcerated men (17). In women the trend is clear, more education and more revenue means less obesity (17). Another possible explanation is that direct causes of obesity (food and exercise) were heavily controlled in the prison environment, therefore education and employment (generally recognized as indirect causes of obesity) were not impactful. In other words, a controlled environment is more influential to weight gain than indirect socioeconomic and demographic factors (education, employment and spoken language).

At the individual level, we also assessed behavioral determinants (physical activity, screen time, sleep and eating habits). Physical inactivity was strongly associated with weight gain in our findings. Inmates who did not engage in physical activity gained more weight than inmates who exercised regularly. These findings are well supported in research in the general population (17). We did not expect that even very active inmates (> 60 minutes of daily exercise) would still gain weight; they simply gained less weight than inactive inmates. This suggests that, even very active inmates either overate (140), or were very sedentary the rest of the day. Both scenarios are possible in the penitentiary setting, but we cannot determine which is the case in the context of this study.

Inmates' diet was also associated with weight gain in Canadian penitentiaries. Food consumed from the commissary store (or "canteen") was associated with weight gain, but the menu and the food system were not. This suggested the obesogenic nature of the environment may be more

within inmates' control than we initially thought. Food services and the menu were under the management and control of Correctional Service Canada (68); whereas the commissary store (or "canteen") was managed by the inmates themselves (with oversight from Correctional Service Canada staff). The inmate committee of each institution chose what items were to be on the commissary store (or "canteen") list, and then each inmate used their own funds to choose and order what food they wanted to purchase. The decision to allow inmates to run the commissary store (or "canteen") was intended to build responsibility and empowerment to inmates in an effort to prepare them for their eventual release (68). However, with our findings suggesting the commissary store (or "canteen") was contributing to weight gain may lead to a change in its organization. Given our findings, correctional services may choose to take a more active role in controlling what items are available on the commissary store (or "canteen") list or limit the amount of junk food allowed for purchase.

Furthermore, we found that inmates who did not eat vegetables and fruits gained much more weight than inmates who ate those foods regularly. See manuscript 4, in section 6.4 of this thesis for more details. This finding was not surprising since fruits and vegetables are known to be associated with lower weight (17). It would be helpful to investigate determinants for vegetables and fruit intake, in an effort to encourage consumption during incarceration. With the non-selective menu, there is no choice given to inmates on which food to eat. It is possible that with a selective menu or a self-serve model, where inmates have some choice provided on the foods they can eat, they would eat more fruits and vegetables. However, this is not known with the current data we have on inmate food intake in Canada.

Although screen time and sleep were not found to be associated with weight gain, we found inmates frequently reported high screen time usage and short sleep duration. This may have an impact on other aspects of their health, but it was not assessed as part of this study.

Finally, the last part of the individual level was health status. For this part, we assessed certain health indicators (psychotropic medication use and mental health) to investigate how they were related to weight outcomes. For mental health, we found that inmates taking psychotropic medications had higher obesity rates; but the observed weight gain was not significantly more for inmates taking psychotropic medications or who suffered from a mental illness compared to those who did not. See section 6.5 of this thesis for more details.

Lastly, we assessed comorbidities as an outcome (or consequence) of the weight gain. We found inmates suffering from obesity related chronic diseases were more obese than the inmates who did not suffer from these ailments. Furthermore, inmates who acquired these diseases during incarceration also gained significantly more weight than inmates who did not get sick. This suggests that weight gain during incarceration may indeed lead to a disproportionate increase in obesity related diseases during incarceration. See section 6.6 of this thesis for more details.

7.2 Penitentiaries as obesogenic environments: our purpose, goals and hypotheses

From the literature, the current evidence on obesogenic environments is still inconsistent (141). It is very difficult to produce robust data while assessing environments as obesogenic because of the heterogeneity of variables in any given environment (141). In the prison environment, these variables are much more homogeneous than at the community level. Since so many environmental

variables are controlled by rules, regulation and policy, it lends itself well to obesogenic research. The overarching purpose of this thesis project was to investigate inmates' weight change to assess if penitentiaries in Canada are obesogenic.

The results comprised in this thesis indicate that Canadian penitentiaries possibly obesogenic since most inmates gained undesirable weight during incarceration (manuscript 1, in section 6.1). Moreover, we documented the main modifiable factors that were related to the observed weight gain in the inmate population (smoking cessation, physical inactivity, low intake of healthy foods from the commissary store (or "canteen") and low intake of vegetables and fruits). See manuscripts in section 6.2, 6.3 and 6.4 of this thesis for more details.

7.3 Suitability for a Population Health thesis

The information from this study is valuable from a population health perspective because inmates are a vulnerable and hard to reach population (3, 142). Prior to this study, there was no data regarding inmates' weight gain during incarceration in Canadian penitentiaries. That meant for a whole segment of our population, we had no idea what was happening with their weight while under the care (and responsibility) of the federal government. This lack of information meant we had no idea how the decisions, rules, regulations and policy affected inmates' weight status and consequently their health. Now, we know the majority (73%) of inmates' weight increased, and their health may actually deteriorate during incarceration, in part because of weight gain. That means inmates' health may be worse because of incarceration, thus making the health inequity gap even larger between inmates and the rest of the Canadian population. With our findings, we also have a better sense of which factors contribute the most to the observed weight gain. This gives

decision makers a starting point for possible interventions to manage inmates' weight during incarceration. Furthermore, even within the prison population some inequities were observed throughout this study. For example, Aboriginal inmates gained more weight than other ethnicities and French speaking inmates were less likely to be employed in the penitentiary. This suggests that even in a controlled environment some health inequities may still be present. This is worth exploring in future research since prison offers a unique opportunity to examine the potential contributors of health inequities in a controlled setting where many determinants are homogenous.

7.4 Health inequities in prison

It is well established that health inequities are persisting in Canada, and elsewhere around the world (143). As such, it is widely recognized that some populations are more vulnerable to poor health; these population subgroups typically have lower socioeconomic status, lower education, and lower social capital; thus lowering their life expectancy (129, 144). Inmates are seen as a vulnerable population with poor health outcomes and are typically a hard to reach population (94, 142). Incarceration could be an opportunity to intervene and to improve inmates' health, since inmates are all in one place and under constant supervision (94). If organized differently, penitentiaries in Canada could be a place to reduce health inequities, and a unique opportunity to provide care and help rehabilitate in a healthy environment. However, based on the findings of this study, incarceration is not used as an opportunity to improve inmates' health and reduce health inequities of this vulnerable population. To improve this situation, this study provided valuable insight into the factors that contribute to inmate weight gain during incarceration. In the right context, these factors can be used to improve inmates' health. For example, physical inactivity, lack of support during forced tobacco cessation and poor diet were significantly associated with

our weight change outcomes. They could all be the target of effective weight management interventions in Canadian penitentiaries.

7.5 Summary of recommendations

First, we recommend continued (and possibly increased) monitoring of inmates' weight during incarceration; it is crucial to have a measured weight on admission (this was missing in many charts), then have weigh-ins at regular intervals. This would allow health care professionals and inmates themselves to be aware of changes in weight status. These weights must be well documented, to allow for proper follow up and trend analysis.

We also recommend studying why inmates who are on a medical diet gain more weight than inmates on the regular meal plan. It would be worth looking into the phenomenon to gain insight into the possible explanations in an effort to manage this weight gain, since the goal of medical diets is often to promote weight loss.

Based on our findings, we also recommend more support for inmates who are withdrawing from tobacco during incarceration. This support may come as nicotine replacement therapy or exercise programs or conducting research on how inmates want to get support in this area.

We also recommend to encourage physical activity for all incarcerated inmates by ensuring the gym and other exercise areas are safe and inclusive. It may be beneficial to explore barriers to physical activity with inmates who are inactive. We recommend offering various types of exercise

opportunity (not just the gym). This could be organized exercise in the yard, or on the penitentiary units. We recommend having targeted exercise programs for vulnerable groups (Aboriginals and older inmates for example). Organizing team sports in the prison would also be an effective way to manage weight, but again special attention needs to be brought to vulnerable groups to get maximum reach.

Lastly, we also recommend studying the healthy food availability at the commissary store (or "canteen") to attempt to increase intake, a possible solution could be to include a larger variety of affordable healthy foods. In addition, we think it would be wise to set limits on the junk food by regulating purchases allowed per week. To reach this goal, a collaborative approach with the inmates themselves to find out how they would like to improve the food availability at the commissary store (or "canteen") will hopefully continue to make them feel empowered.

7.6 Strengths and limitations of the study

A strength of this study is the large sample size. We interviewed 754 inmates from 10 penitentiaries in two geographical regions. We also had access to administrative data for these inmates, and we were able to double our sample with these data (n=1420). This allowed us to work with a larger sample size and provided more power to our analysis. This is remarkable since the prison population is typically a difficult environment to study. Along the same lines, we were able to assess objectively-measured weight outcomes from admission to follow-up in a closed controlled environment (a "total institution") (145). This is a unique strength of this study and of the prison environment, since all inmates entered this homogenous environment at specific measurable points in time. This does not normally occur at the community level, and it gave us a unique opportunity

to study this environment as potentially obesogenic. However, the study herein is not without limitations. The behavioural data was mostly self-reported, and therefore subject to recall and social desirability biases. In addition, the recruitment process was voluntary, therefore there is a risk for selection bias. And, given the observational nature of the data, it makes inferences about causality difficult. In addition, the residual confounding by unmeasured variables is always possible in observational studies. Moreover, the anthropometric data taken on admission was not taken as part of this study. That means different staff members from the health care team at Correctional Service Canada measured inmates' weight at admission to the penitentiary, and the same equipment was not always used. Finally, we only recruited participants from two geographical regions, which limits our ability to generalize our findings across Canada.

7.7 Summary of suggestions for future studies

Throughout this thesis, we presented areas for future research. In particular, we identified 4 specific areas for future research we deemed as important:

1- As a next step, we plan to run focus groups and present our findings to different levels of correctional staff (at the institutional level, regional management and upper management) to get their perspective on our findings in this study. We will include the inmates themselves to also get their perspective. The goal would be to raise awareness of the issue and to possible gain insight into possible solutions that would be acceptable in the field. We will be gathering qualitative data during these focus groups to produce more articles regarding obesity in the prison setting.

2- This was an explorative study, and we found some factors that influenced weight gain in the prison setting (tobacco cessation, physical inactivity, low vegetable and fruit intake, high sweetened beverage intake and low intake of healthy food from the commissary store or "canteen"). It would be worth doing a more in-depth study to examine more closely each factor to determine what influences them in the prison setting and to find out more about how to manage them.

3- To determine if tobacco bans can explain the variations in weight gain observed in penitentiaries around the world, we plan to do an analysis of studies on weight gain by tobacco control policy. There are already two systematic reviews on the subject, so we could easily contact the researchers or the correctional facility to find out if tobacco was banned or not. Then analyze weight gain based on tobacco control. We suspect that in many cases tobacco use was an influential determinant that could explain why so many studies found male inmates' weight to be lower than the general population. We also think it explains the huge discrepancies in observed weight gain between different correctional institutions around the world. This is relevant now because many penitentiaries are contemplating tobacco control policies. These findings would illustrate a need for providing support to inmates withdrawing from tobacco in institutions were tobacco is banned to avoid (or at least limit) weight gain.

4- We found evidence throughout this study that policies were implemented differently in the two regions we studied. We suggest exploring how national policies are implemented at

the regional level and institutional level to help explain why regional variations were observed.

8. Conclusion

Based on our findings, most inmates (73%) from our study gained undesirable weight (6.2 kg) during their incarceration. The weight gain was found to be associated with certain modifiable factors mostly at the individual level: tobacco cessation, physical inactivity, low fruit and vegetable intake and low healthy food intake. We also found a relationship between weight gain and obesity related illnesses in the inmate population during incarceration. These findings are important because weight gain during incarceration may be detrimental to inmates' metabolic health, which may likely widen the health inequity gap between incarcerated and non-incarcerated Canadians.

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10. Appendices

Appendix A: Conceptual Frameworks

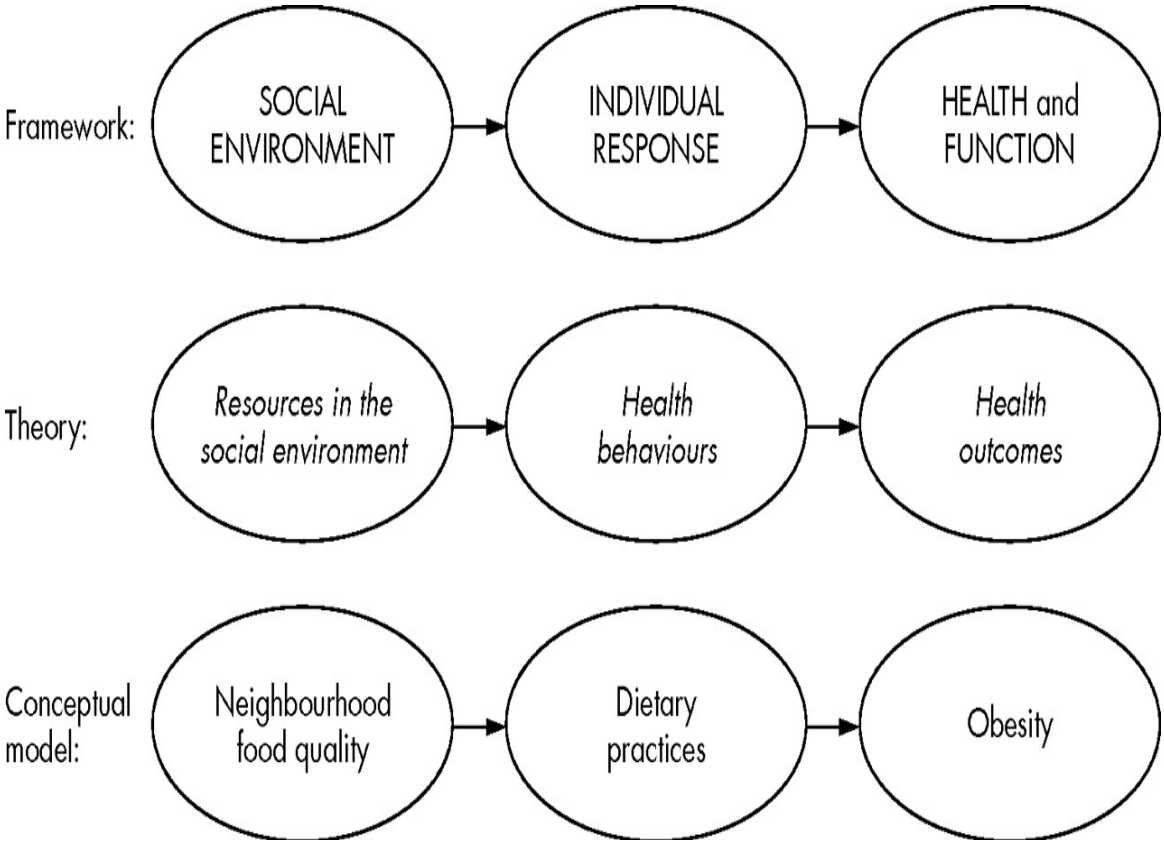

Figure A1. Carpiano and Daily's conceptual model (69).

Table 1. An Ecological Perspective: Levels of Influence

Concept	*Definition*
Intrapersonal Level	Individual characteristics that influence behavior, such as knowledge, attitudes, beliefs, and personality traits
Interpersonal Level	Interpersonal processes and primary groups, including family, friends, and peers that provide social identity, support, and role definition
Community Level	
Institutional Factors	Rules, regulations, policies, and informal structures, which may constrain or promote recommended behaviors
Community Factors	Social networks and norms, or standards, which exist as formal or informal among individuals, groups, and organizations
Public Policy	Local, state, and federal policies and laws that regulate or support healthy actions and practices for disease prevention, early detection, control, and management

Figure A2. An Ecological Perspective: Levels of Influence (67).

Appendix B: Questionnaires

Questionnaire B1: Anthropometric measurements form

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ANTHROPOMETRIC MEASUREMENTS FORM **(AMF)**

Name : Identification number : ☐☐ - ☐☐☐☐ ☐☐

FPS : Interview date : D D M M Y Y Y Y

Interviewer # : ☐☐☐

	1st measure	2nd measure	3rd measure (if difference ≥ 0.5 cm)	Coding (mean of two values – nearest)
Height In centimetres, round at 0.1 cm				

Refusal ☐

	1st measure	2nd measure	3rd measure (if difference > 0.5 kg)	Coding (mean of two values – nearest)
Weight In kilograms, round at 0.5 kg				

Refusal ☐

	1st measure	2nd measure	3rd measure (if difference ≥ 0.5 cm)	Coding (mean of two values – nearest)
Waist circumference In centimetres, round at 0.1 cm				

Refusal ☐

Admission weight (kg)	Coding
RADAR	
Medical chart on admission	

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Questionnaire B2: Questionnaire completed by the interviewer

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Participant ID #: | | | - | | | | - | | |

Name : _____

FPS : _____

Institution : _____

Date of birth: | D | D | M | M | Y | Y | Y | Y |

Interview Date: | D | D | M | M | Y | Y | Y | Y |

Age at the Interview: _____

Sex : ☐ 0 Male ☐ 1 Female

Marital status: ☐ 1 Single ☐ 2 Married/common law ☐ 3Divorced/separated ☐ 4 Widower/widow

Aboriginal status : ☐ 1 Aboriginal ☐ 2 Métis ☐ 3 Inuit ☐ 0 Non Aboriginal

Ethnicity ☐ 0 Caucasian ☐ 1 South Asian ☐ 2 Chinese ☐ 3 Black ☐ 4 Filipino ☐ 5 Latin American ☐ 6 Arab ☐ 7 Korean ☐ 8 Southeast Asian ☐ 9 Japanese ☐ 10 West Asian

11Other : _____

Incarcerated since: | D | D | M | M | Y | Y | Y | Y |

Length of incarceration at the time of the the interview: _____

Total length of sentence: _____

Interviewer # : ☐

Section 1- Sleeping Habits

1. It can be difficult to sleep in prison, do you sleep well here?

$_0$○ No $_1$○ Yes $_8$ ○ Don't know $_9$ ○ Refusal

2. On average, how many hours do you sleep at night?

_____ hours $_8$ ○ Don't know $_9$ ○ Refusal

2a. Typically, is your sleep continuous or interrupted?

$_1$ ○ Continuous
$_2$ ○ Interrupted → 2b. On average, how many times do you wake up during the night ? _____ times
$_8$ ○ Don't know
$_9$ ○ Refusal

$_8$ ○ Don't know
$_9$ ○ Refusal

2c. Why do you wake up?_____

$_8$ ○ Don't know
$_9$ ○ Refusal

3. On average how many hours do you sleep during the day?

_____ hours $_8$ ○ Don't know $_9$ ○ Refusal

Section 2- Smoking Status and Substance Abuse

4. Incarceration forces many lifestyle changes, were you a smoker before your incarceration?

$_0$ ○ No
$_1$ ○ Yes → 4a.How many cigarettes did you smoke per day prior to incarceration?
____ cigarettes per day $_8$ ○ Don't know $_9$ ○ Refusal

$_8$ ○ Don't know
$_9$ ○ Refusal

5. Did you have substance abuse problems before your incarceration?

0 ○ No
1 ○ Yes → 5a. Which substance?
  1 ○ Alcohol- Specify: _____
  2 ○ Drugs/Medication – Specify: _____
  3 ○ Other – Specify: _____
  8 ○ Don't know
  9 ○ Refusal
8 ○ Don't know
9 ○ Refusal

6. How much alcohol did you consume prior to your incarceration?

_____ drinks per day or _____drinks per week

8 ○ Don't know
9 ○ Refusal

Section 3- Diet

7. Are you on a special diet here (in prison)?

0 ○ No
1 ○ Yes → 7a. What type of diet?
  1 ○ Religious – Specify _____
  2 ○ Therapeutic – Specify _____
  3 ○ Weight Loss
  4 ○ Vegetarian
  5 ○ Food Allergy diet- Specify _____
  6 ○ Other − Specify _____
  8 ○ Don't know
  9 ○ Refusal
8 ○ Don't know
9 ○ Refusal

8. Most people in this institution eat from (specify feeding system)
Which feeding system do you eat from?

1 ○ Tray
2 ○ Cafeteria
3 ○ Small Group Meal Plan (SGMP)
8 ○ Don't know
9 ○ Refusal

9. On average, which meal(s) do you eat from Food Services per day?

0 ○ None
1 ○ Breakfast
2 ○ Lunch
3 ○ Dinner
8 ○ Don't know
9 ○ Refusal

10. Typically how much of your meals do you eat?

	10a. Breakfast	10b. Lunch	10c. Dinner
0% (nothing)	1	1	1
25% (a quarter)	2	2	2
50% (half)	3	3	3
75% (three quarters)	4	4	4
100% (all)	5	5	5
N/A	6	6	6
Don't know	8	8	8
Refusal	9	9	9

11. What do you eat off the tray?

0 ○ Nothing
1 ○ Vegetables
2 ○ Fruit
3 ○ Grains
4 ○ Meat
5 ○ Dairy
6 ○ Other - Specify _____
8 ○ Don't know
9 ○ Refusal

12. What do you leave behind?

0 ○ Nothing
1 ○ Vegetables
2 ○ Fruit
3 ○ Grains
4 ○ Meat
5 ○ Dairy
6 ○ Other - Specify _____
8 ○ Don't know
9 ○ Refusal

13. Food frequency questionnaire: How many portions of these do you eat?

Food	Per day	Per week	Per month	Never	Don't know	Refusal
Water						
Skim milk powder						
2% or lactose free milk						
Soy beverage						
Regular pop						
Diet pop						
Sports drinks						
Pure fruit juice						
Fruit drinks or cocktail						
Fruits						
Vegetables						
Potatoes						
Poultry						
Red meat (beef, pork)						
Eggs						
Peanut butter						
Fish						
Legumes (beans, tofu, lentils)						
Bread						
Cereal						
Pasta/Rice						
Pasteries/Cookies/Chips						
Chocolat bars						
Nuts or seeds						
Ice cream						
Table salt						

14. What type of foods do you typically purchase from canteen?

0 ○ Nothing
1 ○ Junk foods (eg., : chocolate bars, chips, cakes…)
2 ○ Healthy food (eg., : yogurt, fruit, nuts, tuna, oats...)
3 ○ Beverages
4 ○ Supplements
5 ○ Other - Specify _____
8 ○ Don't know
9 ○ Refusal

15. How long does it take to eat your meal?

_____ minutes

8 ○ Don't know
9 ○ Refusal

16. Do you feel rushed to eat at meals?

0 ○ No
1 ○ Yes → 16a. Why do you feel rushed?
8 ○ Don't know
9 ○ Refusal

_____
_____

Section 4- Physical Activity and Screen Time

17. On average, how much time do you spend engaging in moderate to vigorous physical activity (e.g: vigorous walking, riding a stationary bike or working out at the gym)?

_____ minutes/day or _____ minutes/week

8 ○ Don't know
9 ○ Refusal

18. What type of physical activity do you typically do? (e.g: vigorous walking, riding a stationary bike, working out at the gym or other)?

_____
_____

8 ○ Don't know
9 ○ Refusal

19. On average, how many hours per day or per week do you normally spend watching TV or using a computer, playing video games or other screen?

_____ hours/day or _____ hours/week

8 ○ Don't know
9 ○ Refusal

20. Categorize your screen time in order of frequency (watching TV, using the computer or playing video games)? 1- most often, 2- less often 3- rarely 4- never

TV	
Computer	
Video games	
Other: specify:	

8 ○ Don't know
9 ○ Refusal

Section 5- Social Network

21. How many friends (or people you can count on) do you have in prison?

_____ friends

8 ○ Don't know
9 ○ Refusal

22. How many visitors and phone calls do you get a month?

a. _____ visits

b. _____ calls

8 ○ Don't know
9 ○ Refusal

Section 6- Body Weight and Body Image

23. How much do you normally weight?

_____ pounds (1) *or* _____ kilogrammes(2)

8 ○ Don't know
9 ○ Refusal

24. How much did you weight when you were first incarcerated?

_____ pounds (1) *or* _____ kilogrammes(2)

8 ○ Don't know
9 ○ Refusal

25. Do you get made fun of because of your size or your appearance?

0 ○ No
1 ○ Yes
8 ○ Don't know
9 ○ Refusal

26. Do you consider your size to be a problem?

0 ○ No
1 ○ Yes → 26a. How is your size a problem?
8 ○ Don't know
9 ○ Refusal

1 ○ Too big
2 ○ Too small
3 ○ Other – Specify _____
8 ○ Don't know
9 ○ Refusal

Section 7- Health Status

27. Do you have diabetes?

0 ○ No
1 ○ Yes
8 ○ Don't know
9 ○ Refusal

28. Have you been screened for diabetes here?

0 ○ No
1 ○ Yes
8 ○ Don't know
9 ○ Refusal

29. Check medical chart for the following health problems:

A – On admission *I – At the time of the interview*	**No**	**Yes (A)**	**Yes (I)**
A. Hypertension ? (HTN)	0	1	2
B. Diabetes (Type 2) ? (DM)	0	1	2
C. Cardiovascular disease? (CVD)	0	1	2
D. Cancer ? (CA)	0	1	2
E. Osteoarthritis ? (OS)	0	1	2
F. Gout ? (G)	0	1	2
G. Sleep apnea ? (SA)	0	1	2
H. Dyslipidemia ? (Lip)	0	1	2
I. Non-alcoholic fatty liver? (Hep)	0	1	2
J. Gastro Esophageal Reflux Disease (GERD)?	0	1	2
K. Diagnosed Food Allergy Specify allergy :	0	1	2
L. Other relevant health problem? ***Specify :***	0	1	2

30. Check medical chart: use of psychotropic medication?

0 ○ No
1 ○ Yes → 30a. Number: _____

30b. Attach a copy of the list of medication to this questionnaire

Section 8- Sociodemographic Characteristics

31. What is your highest level of education?

Secondary school not completed (no High school diploma)	1
Secondary school completed (High school diploma)	2
Post-secondary education (partial or completed)	3
Don't know	8
Refusal	9

32. Did you have employment before incarceration (or 'on the outside')?

0 ○ No
1 ○ Yes → 32a. What was your job? _____
8 ○ Don't know
9 ○ Refusal

33. Do you have employment now?

0 ○ No
1 ○ Yes → 33a. What is your job? _____
8 ○ Don't know
9 ○ Refusal

33b. What is the level of pay (RADAR)?

1 ○ A
2 ○ B
3 ○ C
4 ○ D

34. What is your first language?

1 ○ English
2 ○ French
3 ○ Other – Specify : _____
8 ○ Don't know
9 ○ Refusal

35. What is your preferred language?

1 ○ English
2 ○ French
3 ○ Other – Specify : _____
8 ○ Don't know
9 ○ Refusal

36. What language did you speak most often at home before your incarceration?

1 ○ English
2 ○ French
3 ○ Other – Specify : _____
8 ○ Don't know
9 ○ Refusal

37. Which language do you speak most often during your incarceration?

1 ○ English
2 ○ French
3 ○ Other – Specify : _____
8 ○ Don't know
9 ○ Refusal

Ask question 38 if first or preferred language is not English:

38. Would you like to have access to more services in French during your incarceration?

0 ○ No
1 ○ Yes → 38a. Which services?
8 ○ Don't know
9 ○ Refusal

1 ○ Health Services
2 ○ Food Services
3 ○ Parole office Services
4 ○ Officers
5 ○ Chaplaincy Service
6 ○ Other - Specify _____
8 ○ Don't know
9 ○ Refusal

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Questionnaire B3: Questionnaire for chart review

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Participant ID #: | | | - | | | | - | | | - | 2 |

Name : _____

FPS : _____

Institution : _____

Anthropometric measurements	Coding
Weight in RADAR (Kg)	
Admission weight in medical chart (Kg)	
Current weight (Kg) date:	
Height in RADAR (cm)	
Body Mass Index (BMI) (kg/m$^{2)}$	

Date of birth: | D | D | M | M | Y | Y | Y | Y |

Chart review Date: | D | D | M | M | Y | Y | Y | Y |

Age at chart review: _____

Sex : $_0$ Male $_1$ Female

Marital status: ☐ $_1$ Single ☐ $_2$ Married/common law ☐ $_3$Divorced/separated ☐ $_4$ Widower/widow

Aboriginal status : ☐ $_1$ Aboriginal ☐ $_2$ Métis ☐ $_3$ Inuit ☐ $_0$ Non Aboriginal

Ethnicity ☐ $_0$ Caucasian ☐ $_1$ South Asian ☐ $_2$ Chinese ☐ $_3$ Black ☐ $_4$ Filipino ☐ $_5$ Latin American ☐ $_6$ Arab ☐ $_7$ Korean ☐ $_8$ Southeast Asian ☐ $_9$ Japanese ☐ $_{10}$ West Asian

$_{11}$Other : _____

Incarcerated since:

D	D	M	M	Y	Y	Y	Y

Length of incarceration at the time of the chart review: _____

Total length of sentence: _____

8. What is the feeding system at the institution?

1 ○ Tray
2 ○ Cafeteria
3 ○ Small Group Meal Plan (SGMP)

29. Check medical chart for the following health problems:

A – On admission *I – At the time of the interview*	**No**	**Yes (A)**	**Yes (I)**
29a. Hypertension ? (HTN)	0	1	2
29b. Diabetes (Type 2) ? (DM)	0	1	2
29c. Cardiovascular disease? (CVD)	0	1	2
29d. Cancer ? (CA)	0	1	2
29e. Osteoarthritis ? (OS)	0	1	2
29f. Gout ? (G)	0	1	2
29g. Sleep apnea ? (SA)	0	1	2
29h. Dyslipidemia ? (Lip)	0	1	2
29i. Non-alcoholic fatty liver? (Hep)	0	1	2
29j. Gastro Esophageal Reflux Disease (GERD)?	0	1	2
29k. Diagnosed Food Allergy Specify allergy :	0	1	2
29l. Other relevant health problem? ***Specify :***	0	1	2
29m. Diet order from medical chart (OSCAR):	0	1	2
29n. Diet order from Food Services (FSIMS):	0	1	2

30. Check medical chart: use of psychotropic medication?

0 ○ No
1 ○ Yes → 30a. Number: _____

2 ○ No medication on file

30b. Attach a copy of the complete list of medication to this questionnaire

33. Does the participant have employment as indicated in RADAR?

0 ○ No
1 ○ Yes → 33b. What is the level of pay (RADAR)?
8 ○ Don't know

1 ○ A
2 ○ B
3 ○ C
4 ○ D
5 ○ Allowance

35. What is the participant's preferred language as indicated in RADAR?

1 ○ English
2 ○ French
3 ○ Other – Specify : _____
8 ○ Don't know

Appendix C: Copyright Transfer

Copyright Transfer 07.12.2018

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Confirmation of your Copyright Transfer

Dear Author,

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