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.

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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 $5,0 \pm 8,3$ 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 <i>N</i> (%)	Sex (%)		<i>p</i> value	Age (%)				
		Male	Female		18 ≤ 24 years	≥ 25 ≤ 34 years	≥ 35 ≤ 44 years	≥ 45 ≤ 64 years	≥ 65 years
All <i>N</i> (%)	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, <i>N</i> = 570									
Walk or yoga	228 (40)	38	64	<0.0001*	21	22	35	64	67
No walk	342 (60)	62	36		79	78	65	36	33
or yoga									
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

	<i>p</i> value	Region (%)		<i>p</i> value	Ethnicity (%)				<i>p</i> value
		Atlantic	Ontario		Caucasian	Black	Aboriginal	Other	
All <i>N</i> (%)		311 (41)	443 (59)		470 (62)	124 (16)	106 (14)	54 (7)	
Physical activity duration per day	<0.0001*			0.25					0.89
0		27	23		28	17	19	19	
> 0 ≤ 30 min		17	18		19	16	18	13	
> 30 ≤ 60 min		23	28		24	28	29	28	
> 60 min		33	31		29	39	34	41	

Table 1 (continued)

Physical activity type, <i>N</i> = 570											
	40	40	40	0.0001*	40	40	48	15	43	32	<0.0001*
	60	60	60		60	60	52	85	57	68	
	33	33	42	<0.0001*	42	42	32	45	44	59	0.0001*
	67	67	58		58	58	68	55	56	41	
	63	63	63	<0.0001*	63	63	56	83	62	70	<0.0001*
	37	37	37		37	37	44	17	38	30	
	22	22	17	<0.0001*	17	17	15	30	17	23	0.0009*
	78	78	83		83	83	85	70	83	77	
Screen time during the day	3	5	5	0.0367*	5	5	4	2	7	4	0.10
	13	9	9		9	9	10	6	13	13	
	12	14	14		14	14	15	10	8	19	
	47	38	38		38	38	43	43	13	31	
Sleep during the night	25	35	35		35	35	28	39	34	33	
	47	55	55	<0.0001*	55	55	51	53	52	57	0.89
	46	41	41		41	41	43	42	43	41	
	6	5	5		5	5	6	5	5	2	
Sleep during the day	67	53	53	0.0125*	53	53	61	48	62	56	0.08
	25	35	35		35	35	29	43	25	31	
	9	11	11		11	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), <i>N</i> (%)			<i>p</i> value	Waist circumference, <i>N</i> (%)		<i>p</i> 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 ($\text{BMI} \geq 30 \text{ kg/m}^2$) 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)	<i>p</i> value	Median BMI change (kg/m ²) (CI)	<i>p</i> value	Annual weight change (kg/year) (CI)	<i>p</i> 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
Sleep duration at night	> 300 min	+ 0.01 (− 0.07, 0.08)	0.8811	+ 0.01 (− 0.06, 0.07)	0.8609
	< 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 ($7 \leq 9$ 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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