

Health Reports

Sleep duration, sleep quality and obesity in the Canadian Armed Forces

by Heather Gilmour, Diane Lu and Jane Y. Polsky

Release date: May 17, 2023



Statistics
Canada

Statistique
Canada

Canada

How to obtain more information

For information about this product or the wide range of services and data available from Statistics Canada, visit our website, www.statcan.gc.ca.

You can also contact us by

Email at infostats@statcan.gc.ca

Telephone, from Monday to Friday, 8:30 a.m. to 4:30 p.m., at the following numbers:

- | | |
|---|----------------|
| • Statistical Information Service | 1-800-263-1136 |
| • National telecommunications device for the hearing impaired | 1-800-363-7629 |
| • Fax line | 1-514-283-9350 |

Standards of service to the public

Statistics Canada is committed to serving its clients in a prompt, reliable and courteous manner. To this end, Statistics Canada has developed standards of service that its employees observe. To obtain a copy of these service standards, please contact Statistics Canada toll-free at 1-800-263-1136. The service standards are also published on www.statcan.gc.ca under “Contact us” > “[Standards of service to the public](#).”

Note of appreciation

Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued co-operation and goodwill.

Published by authority of the Minister responsible for Statistics Canada

© His Majesty the King in Right of Canada as represented by the Minister of Industry, 2023

All rights reserved. Use of this publication is governed by the Statistics Canada [Open Licence Agreement](#).

An [HTML version](#) is also available.

Cette publication est aussi disponible en français.

Sleep duration, sleep quality and obesity in the Canadian Armed Forces

by Heather Gilmour, Diane Lu and Jane Y. Polsky

[DOI: https://www.doi.org/10.25318/82-003-x202300500001-eng](https://www.doi.org/10.25318/82-003-x202300500001-eng)

ABSTRACT

Introduction

Research has identified an association between sleep and obesity in the general population. It is also important to examine this association in a military population.

Methods

Data from the 2019 Canadian Armed Forces Health Survey (CAFHS) were used to estimate the prevalence of sleep duration, sleep quality characteristics, overweight and obesity for Regular Force members. The relationship of sleep duration and sleep quality with obesity was assessed with multivariable logistic regression that controlled for sociodemographic, work and health characteristics.

Results

Females were significantly more likely than males to report meeting recommended sleep duration (7 hours to less than 10 hours; 48.7% vs. 40.4%), trouble falling or staying asleep (32.3% vs. 23.5%), or that sleep was not refreshing (64.0% vs. 57.7%). Difficulty staying awake did not differ significantly between males and females (6.3% vs. 5.4%). Obesity, but not being overweight, was significantly more prevalent among those who had short (less than 6 hours) or borderline (6 hours to less than 7 hours) sleep duration, or poor sleep quality. Compared with recommended sleep duration, short sleep duration (adjusted odds ratio [AOR] 1.3; 95% confidence interval [CI]: 1.2 to 1.6) and borderline sleep duration (AOR 1.2; 95% CI: 1.1 to 1.4) were associated with obesity for males, but not females, in fully controlled models. Sleep quality indicators were not independently associated with obesity.

Discussion

This study adds to the body of evidence that identifies an association between sleep duration and obesity. The results emphasize the importance of sleep as one of the components of the Canadian Armed Forces Physical Performance Strategy.

Keywords

sleep disturbances, sleep quality, sleep duration, Canadian Armed Forces, obesity, cross-sectional study, insomnia, overweight, body mass index

AUTHORS

Heather Gilmour and Jane Y. Polsky are with the Health Analysis Division at Statistics Canada. Diane Lu is with the Department of National Defence, Ottawa

What is already known on this subject?

- While sleep disturbance and sleep duration have been associated with obesity in the general population, the association warrants study in the Canadian Armed Forces context.
- Sleep duration and sleep quality are linked concepts and may have some overlap, but they are not synonymous with each other. Evidence from recent studies demonstrates their differential and independent effects on health outcomes.

What does this study add?

- When sociodemographic, work, and health characteristics were considered, short and borderline sleep duration was significantly associated with obesity compared with recommended sleep duration for males, but not for females.
- Sleep quality indicators were not independently associated with obesity.
- Findings support the importance of sleep as part of the Canadian Armed Forces Physical Performance Strategy.

Sleep problems are prevalent among military populations, in particular during deployments.¹ Sleep has recently been identified as one of the pillars of physical performance in the Canadian Armed Forces (CAF),² as well as in the U.S. military.³ While studies regarding sleep have tended to focus on challenges experienced during deployment, sleep is important throughout the military career. It can affect readiness for deployment and quality of life during non-deployment periods^{1,4} and is a risk factor for chronic conditions.^{5,6} Sleep health potentially affects obesity through physiological, hormonal and food-related behavioural changes.⁷ For example, short sleep duration or poor sleep quality may result in increased food intake and more opportunities to eat, biological changes in hormones related to hunger and appetite, or decreased physical activity and energy expenditure attributable to lethargy and daytime sleepiness.⁷ Obesity, in turn, affects the risk of many chronic conditions, such as diabetes, cardiovascular disease, some types of cancer, asthma, back pain, osteoarthritis, and gallbladder disease.⁸⁻¹¹ It also increases the risk of injury.¹²

While sleep disturbance and sleep duration have been associated with obesity in the general population,¹³⁻¹⁸ the association warrants study in a military setting. The armed forces differ from the general population in occupational demands, such as deployments and frequent and regular postings; requirements for physical training, testing and maintenance of physical levels; and a unique workforce culture.⁶

Sleep health encompasses multiple dimensions of sleep beyond sleep duration, which are sometimes examined individually in relation to obesity. Three dimensions of sleep health—trouble falling or staying asleep, difficulty staying awake, and sleep not being refreshing—are referred to in this study as measures of sleep quality. Sleep duration and sleep quality are linked concepts and may have some overlap, but they are not synonymous with each other. Evidence from recent studies demonstrates their differential and independent effects on

health outcomes, and supports considering both aspects together.¹⁹⁻²¹ While few population health studies contain measures of both sleep duration and sleep quality, the 2019 Canadian Armed Forces Health Survey (CAFHS) does. Based on CAFHS data, this study presents the prevalence of overweight, obesity, sleep duration and measures of sleep quality in the Regular Force (RF) population. In addition, the independent associations of sleep duration and sleep quality with obesity are examined. A secondary objective was to assess the independent association of sociodemographic, work and health-related covariates other than sleep duration or quality with obesity in the CAF population. Because of evidence showing different associations between measures of sleep and body mass by sex,^{5,22,23} males and females were analyzed separately.

Methods

Data source

The voluntary cross-sectional 2019 CAFHS collected information related to health status, health care service use, lifestyle and social conditions of actively serving Department of National Defence CAF members from both the RF and the Reserve Force (classes A and B). Data were collected using an electronic questionnaire between January and June 2019. The overall response rate was 38.4%. The response rate was 39.9% for the RF and 26.4% for the Reserve Force. The focus of this analysis is the RF population. RF members are employed full time in the CAF and make up the bulk of personnel employed domestically and abroad on operations. Primary reservists are members who have other full-time civilian employment or who attend school, and who work with the CAF on a part-time basis.

The analytical sample consists of 13,039 RF members aged 18 years and older (9,616 males, and 3,423 females). Responses were weighted to represent the entire RF population of 56,400.

Adjustments were made to the survey weights to reduce potential non-response bias. Additional information on the survey can be found at <https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5259>.

Definitions

Sleep variables

Sleep duration: Responses to the question “How long do you usually spend sleeping each night?” were provided in categorical ranges: less than 2 hours, 2 hours to less than 3 hours, 3 hours to less than 4 hours, and so on up to 12 hours or more. Based on the National Sleep Foundation (NSF) guidelines,²⁴ responses were grouped into short sleep duration (less than 6 hours), borderline short sleep duration (6 hours to less than 7 hours), and recommended sleep duration (7 hours to less than 10 hours) that approximates the NSF 7- to 9-hour recommended sleep range (Table 1), as well as that of the Canadian 24-hour Movement Guidelines for Adults.²⁵ Those who were categorized as having a long sleep duration (10 hours or more) were too few to be reported and could not logically be combined with one of the other sleep duration categories. Thus, they were excluded from the analytical sample (17 males, and 8 females).

Sleep quality: Respondents were also asked three questions about their sleep quality:

1. “How often do you have trouble going to sleep or staying asleep?”
2. “How often do you find your sleep refreshing?”
3. “How often do you find it difficult to stay awake when you want to?”

Those who responded “most of the time” or “all of the time” to the first and third questions versus “sometimes,” “rarely,” or “never” were considered to have trouble falling or staying asleep, or to have difficulty staying awake. Those who responded “never” or “rarely” to the second question were considered to find that their sleep was not refreshing.

Obesity

Height (without shoes on) and weight were self-reported. The body mass index (BMI) of respondents was calculated as the weight (kg) divided by the square of the height (m). The weight status of respondents (except pregnant women) was classified as underweight (less than 18.50), normal weight (18.50 to

24.99), overweight (25.00 to 29.99) or obese (30.00 or over).^{26,27}

Sociodemographic characteristics

Sex at birth was categorized as male or female. Age was categorized into groups for bivariate analyses (18 to 29 years, 30 to 39 years, 40 to 49 years, and 50 years and older) and used continuously in multivariable analyses.

Three marital status categories were used: married or common law; widowed, separated or divorced; and single.

Respondents’ highest level of education was dichotomized as having a bachelor’s degree or higher versus less than a bachelor’s degree.

Work characteristics

The ranks of RF members were grouped as Junior Non-Commissioned Members (NCMs), Senior NCMs, and Junior or Senior Officers. An NCM has the skills, knowledge and hands-on experience in trade specialties that are required to conduct CAF operations domestically and abroad. A commissioned officer has successfully completed a postgraduate degree and their responsibilities include planning, organizing, commanding, directing, controlling and evaluating, the operations of their organization in relation to established objectives. The three service elements represented were air (Royal Canadian Air Force), land (Canadian Army) and sea (Royal Canadian Navy).

Health characteristics

The Canadian Physical Activity Guidelines recommend at least 150 minutes of moderate-to-vigorous physical activity per week for adults.²⁸ Based on the total number of minutes a respondent engaged in active transportation and moderate-to-vigorous recreational and other physical activities in the previous seven days, RF members were categorized as those whose physical activity level was at or above the guidelines, those whose physical activity level was below guidelines, or those who reported no physical activity. Respondents were categorized as daily, occasional, or former smokers, or as never having been smokers.

Respondents were categorized into five groups based on responses to the question, “On a typical day at work, how much time per day do you spend sitting down?”: 3 hours or less, more than 3 hours to 4 hours, more than 4 hours to 5 hours, more than 5 hours to 6 hours and more than 6 hours. These groups correspond to the survey response categories.

Table 1
National Sleep Foundation guidelines for sleep duration

Age	Hours of sleep		
	Recommended	May be appropriate	Not recommended
18 to 25 years	7 to 9	6 10 to 11	Less than 6 More than 11
26 to 64 years	7 to 9	6 10	Less than 6 More than 10

Source: Adapted from: Hirshkowitz 2015.

Those who reported that most days were “quite a bit” or “extremely” stressful were considered to have high self-perceived stress, while those who reported “not at all,” “not very,” or “a bit” stressful were considered to have low self-perceived stress.

Table 2
Percentage distribution of sociodemographic, work and health-related characteristics, by sex, Regular Force members, Canadian Armed Forces, 2019

Characteristics	Both sexes			Males			Females		
	%	95% Confidence interval		%	95% Confidence interval		%	95% Confidence interval	
		from	to		from	to		from	to
Total	100.0	...	...	100.0	...	...	100.0	...	...
Sociodemographic									
Age group (years)									
18 to 29	24.2	23.9	24.6	24.8	24.4	25.2	20.7 †	20.1	21.3
30 to 39	39.5	39.1	39.8	39.6	39.2	40.0	38.5 †	38.0	39.0
40 to 49	24.6	24.4	24.9	23.9	23.6	24.2	28.9 †	28.4	29.3
50 and older	11.7	11.6	11.8	11.7	11.5	11.8	12.0	11.7	12.2
Marital status									
Married or common law	69.5	68.6	70.4	70.0	68.9	71.0	66.6 †	65.1	68.2
Separated, widowed or divorced	8.2	7.7	8.7	7.5	6.9	8.1	12.2 †	11.2	13.3
Single	22.4	21.6	23.2	22.6	21.7	23.5	21.1	19.8	22.5
Highest level of education									
Bachelor's degree or higher	32.5	31.6	33.4	30.8	29.8	31.8	42.4 †	40.9	43.9
Less than a bachelor's degree	67.5	66.6	68.4	69.2	68.2	70.2	57.6 †	56.1	59.1
Work characteristics									
Rank									
Junior Non-Commissioned Member	43.1	42.2	44.0	43.8	42.8	44.8	39.0 †	37.5	40.5
Senior Non-Commissioned Member	25.2	24.5	25.9	25.5	24.6	26.3	23.6 †	22.4	24.8
Senior Officer or Junior Officer	31.7	30.8	32.6	30.7	29.8	31.7	37.4 †	35.9	38.9
Service element									
Air	33.2	32.4	33.9	32.2	31.4	33.1	38.8 †	37.3	40.2
Land	50.7	50.0	51.5	51.9	51.1	52.8	43.8 †	42.2	45.3
Sea	16.1	15.6	16.6	15.9	15.3	16.5	17.5 †	16.4	18.6
Health									
Canadian Physical Activity Guidelines									
At or above the guidelines	71.9	71.0	72.8	72.4	71.4	73.4	68.8 †	67.2	70.3
Below the guidelines	21.8	21.0	22.7	21.4	20.4	22.3	24.6 †	23.2	26.1
No physical activity reported	6.3	5.8	6.8	6.2	5.7	6.8	6.6	5.9	7.4
Smoking									
Daily	9.5	9.0	10.1	9.6	9.0	10.3	9.1	8.2	10.1
Occasional	7.4	6.9	7.9	7.7	7.1	8.3	5.7 †	5.0	6.5
Former	42.1	41.1	43.0	42.7	41.6	43.8	38.3 †	36.7	39.8
Never	41.0	40.0	42.0	40.0	38.9	41.2	46.9 †	45.3	48.5
Number of hours sitting down on a typical day at work									
3 hours or less	21.5	20.7	22.3	23.0	22.1	23.9	12.9 †	11.9	14.1
More than 3 hours to 4 hours	15.0	14.3	15.7	15.6	14.8	16.4	11.6 †	10.6	12.7
More than 4 hours to 5 hours	19.1	18.3	19.9	19.2	18.3	20.1	18.2	17.0	19.5
More than 5 hours to 6 hours	20.9	20.1	21.7	20.1	19.3	21.0	25.3 †	23.9	26.8
More than 6 hours	23.5	22.7	24.3	22.1	21.2	23.0	31.9 †	30.5	33.4
Self-perceived life stress									
High	23.6	22.8	24.4	22.6	21.7	23.6	29.4 †	27.9	30.9
Low	76.4	75.6	77.2	77.4	76.4	78.3	70.6 †	69.1	72.1
Alcohol use in the past 12 months									
Once per week or less, or non-drinker	62.4	61.4	63.4	61.5	60.4	62.6	67.7 †	66.2	69.1
Two to three times per week	25.4	24.6	26.3	26.0	25.0	27.0	21.9 †	20.7	23.3
Four times per week or more	12.2	11.5	12.8	12.5	11.7	13.2	10.4 †	9.4	11.4
Chronic conditions									
Joint pain (past 30 days) or arthritis									
Yes	63.4	62.4	64.4	63.1	62.0	64.2	65.0 †	63.5	66.5
No	36.6	35.6	37.6	36.9	35.8	38.0	35.0 †	33.5	36.5
Chronic obstructive pulmonary disease									
Yes	0.5	0.4	0.7	0.5	0.4	0.7	0.6	0.4	0.9
No	99.5	99.3	99.6	99.5	99.3	99.6	99.4	99.1	99.6
Back problems, excluding fibromyalgia and arthritis									
Yes	29.6	28.7	30.5	29.8	28.8	30.8	28.6	27.2	30.0
No	70.4	69.5	71.3	70.2	69.2	71.2	71.4	70.0	72.8
Mental disorder									
Yes	21.3	20.6	22.1	20.4	19.5	21.3	26.7 †	25.3	28.1
No	78.7	77.9	79.4	79.6	78.7	80.5	73.3 †	71.9	74.7
Sleep apnea									
Yes	9.5	9	10.1	10.5	9.9	11.2	3.8 †	3.2	4.4
No	90.5	90	91.0	89.5	88.8	90.1	96.2 †	95.6	96.8

... not applicable

† significantly different from estimate for males (p < 0.05)

Source: Canadian Armed Forces Health Survey, 2019.

Table 3
Percentage distribution of body mass index classification, sleep duration and sleep quality, by sex, Regular Force members, Canadian Armed Forces, 2019

Characteristics	Both sexes			Males			Females		
	%	95% Confidence interval		%	95% Confidence interval		%	95% Confidence interval	
		from	to		from	to		from	to
Body mass index (kg/m²)									
Underweight (<18.50)	0.5	0.4	0.6	0.3 [‡]	0.2	0.5	1.4 [‡]	1.1	1.9
Normal (18.50 to 24.99)	27.6	26.7	28.5	24.9	23.9	25.9	44.0 [‡]	42.4	45.7
Overweight (25.00 to 29.99)	43.6	42.7	44.6	45.4	44.3	46.6	32.6 [‡]	31.1	34.2
Obese classes I, II and III (≥ 30.00)	28.3	27.4	29.2	29.3	28.4	30.3	21.9 [‡]	20.5	23.3
Sleep duration									
Short	24.4	23.6	25.2	24.9	23.9	25.8	21.5 [‡]	20.2	22.9
Borderline	34.0	33.1	34.9	34.7	33.7	35.8	29.7 [‡]	28.2	31.3
Recommended	41.6	40.6	42.6	40.4	39.3	41.5	48.7 [‡]	47.1	50.4
Trouble falling or staying asleep									
Yes	24.8	24.0	25.6	23.5	22.6	24.4	32.3 [‡]	30.9	33.9
No	75.2	74.4	76.0	76.5	75.6	77.4	67.7 [‡]	66.1	69.1
Difficulty staying awake									
Yes	5.6	5.1	6.0	5.4	4.9	6.0	6.3	5.6	7.1
No	94.4	94.0	94.9	94.6	94.0	95.1	93.7	92.9	94.4
Refreshment from sleep									
Not refreshing	58.6	57.6	59.6	57.7	56.6	58.8	64.0 [‡]	62.4	65.5
Refreshing	41.4	40.4	42.4	42.3	41.2	43.4	36.0 [‡]	34.5	37.6

[‡] use with caution

[‡] significantly different from estimate for males (p < 0.05)

Note: Body mass index was calculated based on self-reported height and weight.

Source: Canadian Armed Forces Health Survey, 2019.

Alcohol use in the past 12 months was grouped into three categories: never or once per week or less, two to three times per week, and four times per week or more.

Chronic conditions examined in this study included joint pain (excluding back and neck) in the past 30 days, and the following conditions that are expected to last or have already lasted six months or more and have been diagnosed by a health professional: arthritis, back pain (excluding fibromyalgia and arthritis), mental disorder (mood disorder, anxiety disorder and, post-traumatic stress disorder) and sleep apnea.

Analytical techniques

Weighted frequencies and cross-tabulations were calculated to examine estimates of BMI classification, sleep duration and sleep quality characteristics. Multivariable logistic regression was used to determine which sleep duration and quality factors (included simultaneously in models) were independently associated with obesity (classes I, II, and III combined) versus none (underweight, normal and overweight), first controlling for age (Model 1) and, additionally, after accounting for sociodemographic, work and health characteristics (Model 2). All analyses were stratified by sex. To investigate whether results differed when sleep duration and sleep quality were not included in the same models, a sensitivity analysis repeated models 1 and 2, separately modelling sleep duration and each of the three sleep quality variables.

Variance inflation factors (2.9 and over) and tolerance estimates (0.2 and under) demonstrated that multicollinearity was not a problem. In all analyses, bootstrap weights were applied in

SAS-callable SUDAAN version 11.0 to account for underestimation of standard errors resulting from the complex survey design.²⁹

Results

Tables 2 and 3 present the weighted percentage distribution of covariates, BMI classification and sleep characteristics among the RF population.

Of the RF members in this analysis, 50.7% served in land, 33.2% in air and 16.1% in sea service elements (Table 2). Males made up 85.5% of the sample; mean age was 37 years for males and 38 years for females. Among RF members, 32.5% had a bachelor’s degree or higher, 69.5% were married or living common-law, and 31.7% were Officers (Table 2).

Self-reported height and weight were used to determine BMI, and 43.6% of all RF members were classified as overweight and 28.3% as obese (Table 3). Males were significantly more likely than females to be classified as overweight (45.4% vs. 32.6%) or obese (29.3% vs. 21.9%).

Females were significantly more likely than males to report usual sleep duration in the recommended range (48.7% vs. 40.4%), and to report trouble falling or staying asleep (32.3% vs. 23.5%) or that sleep was not refreshing (64.0% vs. 57.7%). Difficulty staying awake was less frequently reported and did not differ significantly between females and males (6.3% vs. 5.4%).

Table 4
Prevalence of overweight and obesity by sleep characteristics and selected sociodemographic, work and health characteristics, Regular Force members, Canadian Armed Forces, 2019

Characteristics	Males						Females					
	Overweight			Obese			Overweight			Obese		
	%	95% Confidence interval		%	95% Confidence interval		%	95% Confidence interval		%	95% Confidence interval	
		from	to		from	to		from	to		from	to
Total	45.4	44.3	46.5	29.4	28.4	30.4	32.5	31.0	34.1	21.9	20.6	23.3
Sleep duration												
Short	44.1	42.0	46.3	35.8 *	33.8	38.0	33.3	30.0	36.7	27.6 *	24.5	30.9
Borderline	45.8	44.0	47.7	30.6 *	28.9	32.4	33.1	30.4	35.9	23.3 *	20.9	26.0
Recommended [†]	45.8	44.0	47.6	24.3	22.8	25.8	31.9	29.6	34.2	18.4	16.6	20.4
Trouble falling or staying asleep												
Yes	43.9	41.6	46.2	34.7 *	32.5	36.9	34.4	31.7	37.1	25.6 *	23.1	28.2
No [†]	45.8	44.6	47.1	27.7	26.6	28.9	31.6	29.7	33.6	20.1	18.5	21.9
Difficulty staying awake												
Yes	41.7	36.9	46.7	34.8 *	30.3	39.6	35.8	29.6	42.4	26.1	20.8	32.1
No [†]	45.6	44.5	46.8	29.0	28.0	30.0	32.3	30.7	33.9	21.7	20.3	23.1
Refreshment from sleep												
Not refreshing	45.6	44.1	47.1	31.8 *	30.5	33.2	32.7	30.8	34.7	24.5 *	22.7	26.3
Refreshing [†]	45.1	43.4	46.8	25.9	24.4	27.4	32.1	29.7	34.7	17.4	15.3	19.7
Sociodemographic												
Age group (years)												
18 to 29 [†]	45.2	42.7	47.8	19.9	18.1	22.0	29.5	26.0	33.3	19.6	16.5	23.2
30 to 39	43.2	41.2	45.1	30.0 *	28.2	31.8	32.1	29.7	34.6	18.6	16.6	20.8
40 to 49	46.8	44.8	48.9	35.4 *	33.4	37.4	33.7	30.9	36.6	26.0 *	23.5	28.7
50 and older	50.4 *	47.9	52.9	34.9 *	32.5	37.3	35.9 *	32.0	39.9	26.0 *	22.3	30.0
Marital status												
Married or common law [†]	46.4	45.0	47.7	31.6	30.4	32.8	33.0	31.1	34.9	21.7	20.1	23.4
Separated, widowed or divorced	46.4	42.5	50.4	30.0	26.5	33.7	35.8	31.5	40.5	19.2	15.8	23.2
Single	41.8 *	39.3	44.3	22.7 *	20.7	24.8	29.1	25.9	32.6	24.1	21.0	27.5
Highest level of education												
Bachelor's degree or higher [†]	45.8	43.8	47.9	21.9	20.3	23.6	29.9	27.5	32.3	17.1	15.2	19.1
Less than bachelor's degree	45.0	43.6	46.4	32.8 *	31.6	34.1	34.5 *	32.4	36.6	25.4 *	23.6	27.4
Work characteristics												
Rank												
Junior non-commissioned member [†]	43.2	41.4	45.1	30.0	28.4	31.6	34.0	31.5	36.6	24.9	22.5	27.4
Senior non-commissioned member	47.2 *	45.1	49.4	36.5 *	34.5	38.5	36.0	33.0	39.2	25.9	23.1	28.9
Senior officer or junior officer	46.9 *	44.9	48.9	22.5 *	20.9	24.3	28.7 *	26.2	31.4	16.2 *	14.3	18.4
Service element												
Air [†]	45.1	43.3	46.9	27.4	25.9	28.9	32.7	30.2	35.3	20.7	18.6	23.0
Land	46.5	44.9	48.2	29.5 *	28.1	30.9	33.9	31.6	36.4	20.3	18.2	22.5
Sea	42.2	39.4	45.0	33.0 *	30.3	35.8	28.8	25.3	32.5	28.8 *	25.4	32.5
Health												
Canadian physical activity guidelines												
At or above the guidelines [†]	46.4	45.1	47.7	28.2	27.1	29.4	33.1	31.3	35.0	20.4	18.8	22.0
Below the guidelines	43.5 *	41.1	46.0	31.1 *	28.9	33.3	31.4	28.3	34.6	26.2 *	23.4	29.3
No physical activity reported	40.1 *	36.0	44.4	37.3 *	33.4	41.3	31.0	25.6	37.0	22.4	17.5	28.2
Smoking												
Daily [†]	43.0	39.4	46.7	26.5	23.5	29.7	29.8	25.0	35.1	25.1	20.7	30.2
Occasional	46.9	42.7	51.1	30.8	27.0	34.8	41.7 *	35.3	48.4	20.1	15.2	26.1
Former	46.5	44.7	48.2	31.1 *	29.6	32.7	35.0	32.5	37.6	22.2	20.2	24.4
Never	44.4	42.6	46.3	28.0	26.4	29.6	30.0	27.8	32.3	21.2	19.2	23.4
Time sitting down on a typical day at work												
3 hours or less [†]	47.0	44.5	49.4	25.2	23.1	27.4	35.3	31.2	39.6	16.3	13.1	20.0
More than 3 hours to 4 hours	45.9	43.1	48.9	30.5 *	28.0	33.2	30.7	26.2	35.5	24.0 *	19.7	28.9
More than 4 hours to 5 hours	45.8	43.4	48.1	29.5 *	27.3	31.7	33.4	29.7	37.2	20.7	17.7	24.1
More than 5 hours to 6 hours	43.7	41.3	46.1	31.1 *	28.9	33.3	32.7	29.6	35.9	24.0 *	21.3	26.9
More than 6 hours	44.7	42.3	47.1	31.2 *	29.2	33.4	31.5	28.8	34.3	22.5 *	20.2	25.0
Self-perceived life stress												
High [†]	45.2	43.0	47.5	32.9 *	30.8	35.1	33.1	30.3	35.9	22.1	19.7	24.6
Low [†]	45.3	44.1	46.6	28.4	27.3	29.5	32.3	30.4	34.2	21.9	20.2	23.6
Alcohol use in the past 12 months												
Once per week or less, or non-drinker [†]	42.9	41.5	44.4	31.6	30.3	32.9	31.6	29.7	33.5	23.3	21.6	25.1
Two to three times per week	49.6 *	47.4	51.7	25.3 *	23.5	27.2	35.8 *	32.6	39.2	18.8 *	16.2	21.6
Four times per week or more	49.0 *	45.8	52.2	26.5 *	23.7	29.4	31.8	27.2	36.8	19.6	15.9	23.9
Chronic conditions												
Joint pain (past 30 days) or arthritis												
Yes	45.6	44.2	47.0	32.3 *	31.0	33.6	33.6	31.8	35.5	24.7 *	23.0	26.4
No [†]	45.1	43.2	47.0	24.2	22.7	25.9	30.6	28.0	33.3	16.7	14.6	19.2
Back problems, excluding fibromyalgia and arthritis												
Yes	45.9	43.9	47.9	34.1 *	32.2	36.0	35.9 *	33.0	38.8	26.8 *	24.3	29.5
No [†]	45.2	43.8	46.5	27.4	26.2	28.6	31.2	29.3	33.1	19.9	18.3	21.5
Mental disorder												
Yes	41.3 *	39.0	43.7	38.3 *	36.0	40.8	33.4	30.4	36.5	29.4 *	26.5	32.4
No [†]	46.5	45.2	47.8	27.0	25.9	28.1	32.2	30.4	34.1	19.2	17.7	20.8
Sleep apnea												
Yes	32.7 *	29.7	35.7	59.7 *	56.4	63.0	29.5	22.2	38.1	55.3 *	46.8	63.5
No [†]	44.7	43.7	45.7	25.8	24.8	26.8	32.7	31.1	34.3	20.7	19.3	22.1

* significantly different from reference category (p < 0.05)

[†] reference category

Notes: Body mass index was calculated based on self-reported height and weight. The underweight category was excluded because of small numbers. Obese classes I, II, and III were combined into the obese category.

Source: Canadian Armed Forces Health Survey, 2019.

In bivariate analyses, obesity, but not overweight, was significantly more prevalent among those who had less than recommended sleep duration, had trouble falling or staying asleep, or found that sleep was not refreshing, for both males and females (Table 4). Difficulty staying awake was associated with obesity for men but not for women.

Having shorter than recommended sleep duration and reporting that sleep was not refreshing were significantly associated with increased odds of being obese for both males and females in models that controlled for sleep duration and sleep quality indicators in addition to age (Table 5, Model 1). The association between shorter than recommended sleep duration and obesity

Table 5
Adjusted odds ratios relating sleep and other selected characteristics to obesity,¹ by sex, Regular Force members, Canadian Armed Forces, 2019

Characteristics	Males						Females					
	Model 1		Model 2				Model 1		Model 2			
	Odds ratio	95% Confidence interval		Odds ratio	95% Confidence interval		Odds ratio	95% Confidence interval		Odds ratio	95% Confidence interval	
	ratio	from	to	ratio	from	to	ratio	from	to	ratio	from	to
Sleep duration												
Short	1.5 *	1.3	1.7	1.3 *	1.2	1.6	1.4 *	1.1	1.8	1.2	0.9	1.6
Borderline	1.3 *	1.1	1.5	1.2 *	1.1	1.4	1.2 *	1.0	1.5	1.2	1.0	1.5
Recommended [†]	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Trouble falling or staying asleep												
Most of the time or all of the time	1.1	1.0	1.3	1.0	0.8	1.1	1.0	0.8	1.2	0.9	0.8	1.2
Never, rarely or sometimes [†]	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Difficulty staying awake												
Most of the time or all of the time	1.2	0.9	1.5	1.0	0.8	1.2	1.2	0.8	1.6	1.0	0.7	1.4
Never, rarely or sometimes [†]	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Sleep not refreshing												
Most of the time or all of the time	1.2 *	1.0	1.3	1.0	0.9	1.1	1.3 *	1.1	1.7	1.2	0.9	1.5
Never, rarely or sometimes [†]	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Sociodemographic												
Age (continuous)	1.03 *	1.02	1.03	1.02 *	1.01	1.02	1.02 *	1.01	1.03	1.02 *	1.01	1.03
Marital status												
Married or common law [†]	1.0	...	...	...	...	...	1.0	...	...
Separated, widowed or divorced	...	...	...	1.2 *	1.1	1.4	...	...	...	1.4 *	1.1	1.7
Single	...	...	...	1.0	1.0	1.0	...	...	...	1.0	1.0	1.0
Highest level of education												
Bachelor's degree or higher	...	...	...	1.4 *	1.1	1.6	...	...	...	1.2	0.9	1.6
Less than bachelor's degree	...	...	...	1.0	...	...	...	...	...	1.0	...	...
Work characteristics												
Rank												
Junior non-commissioned member [†]	1.3 *	1.1	1.6	...	...	...	1.5 *	1.1	2.0
Senior non-commissioned member	...	...	...	1.2	0.9	1.4	...	...	...	1.2	0.8	1.7
Senior officer or junior officer	...	...	...	1.0	...	...	...	...	...	1.0	...	...
Service element												
Air [†]	1.0	...	...	...	...	...	1.0	...	...
Land	...	...	...	1.1	1.0	1.2	...	...	...	0.9	0.8	1.1
Sea	...	...	...	1.3 *	1.1	1.5	...	...	...	1.6 *	1.2	2.0
Health												
Canadian physical activity guidelines												
At or above the guidelines [†]	1.0	...	...	...	...	...	1.0	...	...
Below the guidelines	...	...	...	1.1	1.0	1.3	...	...	...	1.3 *	1.1	1.6
No physical activity reported	...	...	...	1.3 *	1.1	1.6	...	...	...	0.9	0.6	1.3
Smoking												
Daily	...	...	...	0.7 *	0.6	0.9	...	...	...	0.9	0.7	1.2
Occasional	...	...	...	1.1	0.9	1.4	...	...	...	0.8	0.5	1.2
Former	...	...	...	1.1	1.0	1.2	...	...	...	0.9	0.8	1.1
Never [†]	1.0	...	...	...	...	...	1.0	...	...
Minutes sitting down on a typical day at work (continuous)												
...	...	...	...	1.001 *	1.000	1.001	...	...	...	1.001 *	1.000	1.001
Self-perceived life stress												
High	...	...	...	1.0	0.9	1.2	...	...	...	0.9	0.7	1.1
Low [†]	1.0	...	...	...	...	...	1.0	...	...
Alcohol use in the past 12 months												
Once per week or less, or non-drinker [†]	1.0	...	...	...	...	...	1.0	...	...
Two to three times per week	...	...	...	0.8 *	0.7	0.9	...	...	...	0.8	0.7	1.0
Four times per week or more	...	...	...	0.7 *	0.6	0.9	...	...	...	0.8	0.6	1.1
Chronic conditions²												
Joint pain (past 30 days) or arthritis	...	...	...	1.1 *	1.0	1.3	...	...	...	1.3 *	1.1	1.6
Back problems, excluding fibromyalgia and arthritis	...	...	...	1.0	0.9	1.1	...	...	...	1.1	0.9	1.4
Mental disorder	...	...	...	1.2 *	1.1	1.4	...	...	...	1.4 *	1.1	1.7
Sleep apnea	...	...	...	3.4 *	2.9	3.9	...	...	...	3.0 *	2.0	4.6

... not applicable

* significantly different from reference category (p < 0.05)

[†] reference category; for chronic conditions, the reference category is the absence of the condition

1 Body mass index was calculated based on self-reported height and weight. Obese classes I, II and III were combined into the obese category and compared with the non-obese category (underweight, normal or overweight).

2 The reference group is the absence of the condition.

Source: Canadian Armed Forces Health Survey, 2019.

was attenuated for both males and females and lost significance for women in models that controlled for additional sociodemographic, work and health characteristics (Table 5, Model 2). The association between reporting that sleep was not refreshing and obesity was not significant for either males or females in Model 2.

In multivariable models, Junior NCMs had increased odds of obesity compared with Officers, as did those in the sea service element compared with those in the air service element and those with more minutes sitting at work. Males who reported no physical activity and females whose physical activity was below the guidelines also had increased odds of obesity. Several chronic conditions were independently associated with increased odds of obesity, including joint pain and arthritis, mental disorders, and sleep apnea.

Appendix A demonstrates very similar outcomes when models 1 and 2 were run with sleep duration or each of the sleep quality variables one at a time, with the exception of “sleep not refreshing,” which was significant for both men and women when it was the only sleep variable in the model.

Discussion

Less than half (41.6%) of RF members reported the recommended hours of sleep based on the 2019 CAFHS. However, what constitutes short sleep duration lacks consistency between published studies, making comparisons challenging. The recommended sleep duration classification used in this study is based on the NSF guidelines²⁴ of “recommended” or “may be appropriate” ranges for adults (7 hours to less than 10 hours). Some studies define a shorter range of 7 to 8 hours of sleep as the recommended range. For example, two U.S. studies in military populations reported that 27.7% and 29.9% of military personnel had 7 to 8 hours of sleep.^{5,30} Finding that sleep was not refreshing (58.6%) or having trouble falling or staying asleep (24.8%) was also quite prevalent in this study’s RF population, while difficulty staying awake was much less so (5.6%).

The proportion of RF members classified as obese (28.3%) is comparable to the 26.8% of the general population of Canadian adults.³¹ However, a higher proportion of RF members (44.6%) were classified as overweight than in the general population (36.3%).³¹ While in the general population BMI tends to be underreported,³² this may be less of an issue in a military population. This group undergoes frequent physical testing, including measurement of weight, and thus may be more able to accurately report their weight. A high muscle mass in the RF population may result in increased BMI and overestimation of overweight or obesity.³³⁻³⁵

Short and borderline sleep durations were independently associated with increased odds of obesity in multivariable analysis for male CAF members, but were not significant for female CAF members in models that fully controlled for a range of sociodemographic, work and health covariates. Previous studies of short sleep duration and obesity in the general

population have found associations for both males and females,^{22,37} while others have not.^{23,38} One study in a military population reported a significant association between short sleep duration and overweight or obesity but did not stratify results by sex.⁶

None of the sleep quality variables were significantly associated with obesity in full models that controlled for all sleep variables simultaneously. Sensitivity analyses that modelled each of the three quality sleep variables separately revealed results that were highly consistent with those of the main analyses. The exception was the “sleep not refreshing” variable; its effect was similar in magnitude to the main analyses but reached statistical significance for both men and women in the fully adjusted models. Not having refreshing sleep can be related to sleep duration. However, results of models combining all sleep variables suggest that sleep duration may have the more powerful association with obesity in the CAF population.

This study is cross-sectional and thus cannot infer causality or directionality. Systematic reviews and meta-analyses have concluded that short sleep is a risk factor for weight gain, although evidence is stronger for children than for adults.³⁹⁻⁴¹ Bi-directionality is possible, such that short duration sleepers may gain more weight over time, but excess body weight can also lead to poor sleep.^{42,43} However, it has been suggested that the direction is mainly sleep to obesity.⁴⁴

Several other covariates of note remained significantly associated with obesity in multivariable analysis, such as rank, service element, physical activity and sleep apnea. Junior NCMs had higher odds of obesity compared with Officers, similar to findings in the U.S. military.¹ The U.S. Navy has been shown to have increased risk of obesity.⁴⁵ Obesity may be more prevalent in the sea service element because of factors such as physical space constraints on vessels, disrupted sleep schedules and lack of natural light.

Reporting no physical activity for males or physical activity below Canadian Physical Activity Guidelines for females was associated with obesity independent of the impact of sleep duration. A study of Canadian adults found that the association between trouble sleeping and BMI varied by physical activity level, such that it was almost null for those with a high level of physical activity.¹³ While that study examined trouble sleeping and not sleep duration, future studies may shed light on whether the association between sleep duration and obesity similarly varies by physical activity level. This may be of particular interest in a military population, where physical training and activity are a mandatory part of the occupation.

Military populations have also been reported to have a higher prevalence of sleep apnea than the general population.⁶ In this study, male RF members were significantly more likely ($p < 0.05$) than men in the general population aged 18 years and older⁴⁶ to have sleep apnea (10.5% vs. 9.3%), while female RF members were significantly less likely to have sleep apnea (3.8% vs. 4.9%) compared with females in the general population. Both male and female RF members with sleep apnea had approximately three times the odds of being obese;

these findings are consistent with evidence that sleep apnea is an established risk factor for obesity.^{43,47} However, shorter sleep duration remained associated with obesity for males independent of sleep apnea.

Because sleep affects energy balance, eating and physical activity behaviours, it has been identified as a potential tool to aid in the management of obesity.⁴⁸ This study identified a cross-sectional association between sleep and obesity but cannot draw any conclusions about the efficacy of sleep interventions in changing sleep patterns or treating obesity. Sleep interventions have had some success in a military population in improving sleep health. For example, a German study found that a workplace sleep-health program can improve objective and self-reported measures of sleep in an armed forces population.⁴⁹ While these findings are encouraging, there is no clear evidence that changes in sleep health can improve weight management or obesity outcomes.⁴¹ Interventional studies, especially in military populations, are needed.

Strengths

Among the strengths of this analysis are a large, representative sample and control for a wide range of sociodemographic, work and health covariates. This study is also among the few to examine multiple dimensions of sleep health (both sleep duration and measures of sleep quality) together, enabling assessment of which aspect may be most important in relation to obesity.

Additionally, because the CAF population is generally excluded from national population health surveys, this study provides data on a unique and understudied military population.

Limitations

It is not possible to determine the direction of the association between sleep variables and obesity because of the cross-sectional study design, emphasizing the need for future intervention studies and studies with longitudinal data. Additionally, sleep questions are based on one point in time, and the duration of sleep problems could not be assessed.

Data are not available on some factors that could influence sleep or obesity, such as eating behaviour and caloric intake, shift work and work hours, specific job occupations, or medications that might increase risk of sleep problems or obesity.

Categorical response options for sleep duration result in some loss of information. Thus, it was not possible to calculate mean hours of sleep or use sleep duration as a continuous variable in models.

The Reserve Force component of the CAFHS is small, and the response rate was relatively low; thus, analysis was limited to only RF members. It is not known whether associations would differ in the Reserve Force population.

Sleep, weight and height, and covariates were self-reported and not verified by another source.

It is known that there are limitations in the application of BMI estimates for certain subgroups, such as young adults who have not attained full growth, those with a very lean build or who are very tall or short, and certain ethnic groups.³⁶

Conclusion

Shorter than recommended sleep duration, poor sleep quality, and obesity are prevalent among the CAF Regular Force and are a concern for the long-term health, well-being and deployment readiness of this population.

Results of this study suggest that sleep health is associated with obesity in a military population. In particular, short and borderline sleep duration remained independently associated with obesity among males; thus, differences by sex warrant further investigation. These findings support the importance of sleep as part of the Canadian Armed Forces Physical Performance Strategy. Longitudinal or intervention studies are needed to better understand the potential role of healthy sleep practices in obesity management, particularly in military populations.

Appendix Table A

Adjusted odds ratios relating sleep duration and sleep quality individually to obesity,¹ by sex, Regular Force members, Canadian Armed Forces, 2019

Characteristics	Males						Females					
	Model 1			Model 2			Model 1			Model 2		
	Odds ratio	95% Confidence interval		Odds ratio	95% Confidence interval		Odds ratio	95% Confidence interval		Odds ratio	95% Confidence interval	
		from	to		from	to		from	to		from	to
Sleep duration												
Short	1.7 *	1.5	1.9	1.4 *	1.2	1.6	1.6 *	1.3	2.0	1.3	1.0	1.6
Borderline	1.3 *	1.2	1.5	1.3 *	1.1	1.4	1.3 *	1.1	1.6	1.2	1.0	1.5
Recommended [†]	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Trouble falling or staying asleep	1.1 *	1.0	1.3	1.0	0.9	1.2	1.3 *	1.1	1.5	1.1	0.9	1.3
Difficulty staying awake	1.3 *	1.1	1.6	1.1	0.9	1.4	1.3	0.9	1.7	1.0	0.7	1.5
Sleep not refreshing	1.3 *	1.2	1.5	1.1 *	1.0	1.3	1.5 *	1.3	1.8	1.3 *	1.0	1.5

... not applicable

* significantly different from reference category (p < 0.05)

† reference category; if not otherwise indicated, the reference category is the absence of the condition

1. Body mass index was calculated based on self-reported height and weight. Obese classes I, II and III were combined into the obese category and compared with the non-obese category (underweight, normal or overweight).

Notes: Model 1 includes the specified sleep variable (without the other sleep variables) plus age. Model 2 includes the specified sleep variable (without the other sleep variables) plus age, marital status, highest level of education, rank, service element, Canadian Physical Activity Guidelines, smoking status, minutes sitting on a typical day at work, self-perceived life stress, alcohol use in past six months, joint pain or arthritis, back problems, mental disorder, and sleep apnea.

Source: Canadian Armed Forces Health Survey, 2019.

References

1. Troxel WM, Shih RA, Pedersen E, et al. Sleep in the military. Promoting Healthy Sleep among U.S. Service members. 2015. *RAND Corporation*, Santa Monica, California.
2. Department of National Defence–Canadian Armed Forces. Balance: The Canadian Armed Forces Physical Performance Strategy. 2018. Available at: https://www.cafconnection.ca/getmedia/d244a0e1-3e52-4177-9649-3e19637f5173/BALANCE-Book_E.pdf.aspx
3. Lentino CV, Purvis DL, Murphy KJ, Deuster PA. Sleep as a Component of the Performance Triad: The Importance of Sleep in a Military Population. *The United States Army Medical Department Journal* 2013; Oct-Dec: 98–108.
4. Good CH, Brager AJ, Capaldi VF, Mysliwiec V. Sleep in the US military. *Neuropsychopharmacology* 2020; 45:176–19. <https://doi.org/10.1038/s41386-019-0431-7>
5. Mysliwiec V, McGraw L, Pierce R, et al. Sleep disorders and associated medical comorbidities in active duty military personnel. *Sleep* 2013; 36(2): 167–174.
6. Hruby A, Lieberman HR, Smith TJ. Self-reported health behaviors, including sleep, correlate with doctor-informed medical conditions: data from the 2011 Health Related Behaviors Survey of U.S. Active Duty Military Personnel. *BMC Public Health* 2018; 18: 853. <https://doi.org/10.1186/s12889-018-5781-2>
7. Ogilvie RP, Patel SR. The epidemiology of sleep and obesity. *Sleep Health* 2017; 3(5): 383–388. <https://doi.org/10.1016/j.sleh.2017.07.013>
8. Guh DP, Zhang W, Bansback N, et al. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. *BMC Public Health* 2009; 9: 88. <https://doi.org/10.1186/1471-2458-9-88>
9. Abdullah A, Peeters A, de Courten M, Stoelwinder J. The magnitude of association between overweight and obesity and the risk of diabetes: a meta-analysis of prospective cohort studies. *Diabetes Research and Clinical Practice* 2010; 89(3): 309–19. <https://doi.org/10.1016/j.diabres.2010.04.012>
10. Ackerman SE, Blackburn OA, Marchildon F, Cohen P. Insights into the Link Between Obesity and Cancer. *Current Obesity Reports* 2017; 6(2): 195–203. <https://doi.org/10.1007/s13679-017-0263-x>
11. Aune D, Norat T, Vatten LJ. Body mass index, abdominal fatness and the risk of gallbladder disease. *European Journal of Epidemiology* 2015; 30(9): 1009–19. <https://doi.org/10.1007/s10654-015-0081-y>
12. Grier, T, Dinkeloo E, Reynolds M, Jones BH. Sleep duration and musculoskeletal injury incidence in physically active men and women: A study of U.S. Army Special Operation Forces soldiers. *Sleep Health* 2020; 6(3): 344–349.
13. Sampasa-Kanyinga H, Chaput JP. Associations among self-perceived work and life stress, trouble sleeping, physical activity, and body weight among Canadian adults *Preventive Medicine* 2017; 96: 16–20. <http://dx.doi.org/10.1016/j.ypmed.2016.12.013>
14. Reutrakul S, Van Cauter E. Sleep influences on obesity, insulin resistance, and risk of type 2 diabetes. *Metabolism: Clinical and Experimental* 2018; 84: 56–66. <https://doi.org/10.1016/j.metabol.2018.02.010>
15. Broussard J., Van Cauter E. Disturbances of sleep and circadian rhythms: novel risk factors for obesity. *Current Opinion in Endocrinology, Diabetes and Obesity* 2016; 23(5): 353–9. <https://doi.org/10.1097/MED.0000000000000276>
16. Cappuccio FP, Taggart FM, Kandala NB, et al. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep* 2008; 31(5): 619–26.
17. Muscogiuri G, Tuccinardi D, Nicasastro V, et al. Sleep disturbances: one of the culprits of obesity-related cardiovascular risk? *International Journal of Obesity Supplements* 2020; 10: 62–72. Available at <https://doi.org/10.1038/s41367-020-0019-z>
18. Krueger PM, Reither EN, Peppard PE, et al. Cumulative exposure to short sleep and body mass outcomes: a prospective study. *Journal of Sleep Research* 2015; 24 (6): 629–38. <https://doi.org/10.1111/jsr.12327>
19. Seow LSE, Tan XW, Chong SA, et al. Independent and combined associations of sleep duration and sleep quality with common physical and mental disorders: Results from a multi-ethnic population-based study. *PLOS ONE* 2020; 15(7): e0235816. <https://doi.org/10.1371/journal.pone.0235816>
20. Bin YS. Is Sleep Quality More Important than Sleep Duration for Public Health? *Sleep* 2016; 39(9): 1629–30. <https://doi.org/10.5665/sleep.6078>
21. Clark A, Clark AJ, Salo P, et al. Onset of impaired sleep and cardiovascular disease risk factors: a longitudinal study. *Sleep* 2016; 39: 1709–18.
22. Mezick EJ, Wing RR, McCaffery JM. Associations of self-reported and actigraphy-assessed sleep characteristics with body mass index and waist circumference in adults: moderation by gender. *Sleep Medicine* 2014; 15(1): 64–70. <https://doi.org/10.1016/j.sleep.2013.08.784>
23. St-Onge MP, Perumean-Chaney S, Desmond R, et al. Gender Differences in the Association between Sleep Duration and Body Composition: The Cardia Study. *International Journal of Endocrinology* 2010; 2010: 726071. Available at: <https://doi.org/10.1155/2010/726071>
24. Hirshkowitz, M, Whiton K, Albert SM, et al. National Sleep Foundation’s sleep time duration recommendations: methodology and results summary. *Sleep Health* 2015; 1: 40–43. <http://dx.doi.org/10.1016/j.sleh.2014.12.010>
25. Canadian Society for Exercise Physiology. Canadian 24-Hour Movement Guidelines: An Integration of Physical Activity, Sedentary Behaviour, and Sleep. Available at: <https://csepguidelines.ca>
26. World Health Organization. Obesity and overweight. Fact Sheet. World Health Organization; Geneva: 2021. Available at: <https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight>

27. Global BMI Mortality Collaboration, Di Angelantonio E, et al. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. *Lancet* 2016; 388(10046): 776–86. [https://doi.org/10.1016/S0140-6736\(16\)30175-1](https://doi.org/10.1016/S0140-6736(16)30175-1)
28. Tremblay MS, Warburton DEF, Jassen I, et al. New Canadian Physical Activity Guidelines. *Applied Physiology, Nutrition and Metabolism* 2011; 36: 36–46.
29. Rust KF, Rao JNK. Variance estimation for complex surveys using replication techniques. *Statistical Methods in Medical Research* 1996; 5(3): 283–310.
30. Luxton DD, Greenburg D, Ryan J, et al. Prevalence and impact of short sleep duration in redeployed OIF soldiers. *Sleep* 2011; 34(9):1189–1195.
31. Statistics Canada. Overweight and obese adults, 2018. *Health Fact Sheets* 2019. Available at: <https://www150.statcan.gc.ca/n1/pub/82-625-x/2019001/article/00005-eng.htm>
32. Connor Gorber S, Shields M, Tremblay MS, McDowell I. The feasibility of establishing correction factors to adjust self-reported estimates of obesity. *Health Reports* 2008; 19(3): 71–82. Available at: https://www150.statcan.gc.ca/n1/en/pub/82-003-x/2008003/article/10680-eng.pdf?st=_AKVhEU5
33. Heinrich KM, Jitnarin N, Suminski RR, et al. Obesity classification in military personnel: a comparison of body fat, waist circumference, and Body Mass Index measurements. *Military Medicine* 2008; 173(1): 67–73. <https://doi.org/10.7205/MILMED.173.1.67>
34. Grier T, Canham-Chervak M, Sharp M, Jones BH. Does body mass index misclassify physically active young men. *Preventive Medicine Reports* 2015; 11(2): 483–7. <https://doi.org/10.1016/j.pmedr.2015.06.003>
35. Zhu Q, Huang B, Li Q, et al. Body mass index and waist-to-hip ratio misclassification of overweight and obesity in Chinese military personnel. *Journal of Physiological Anthropology* 2020; 39(1): 24. <https://doi.org/10.1186/s40101-020-00236-8>
36. Health Canada. (2003). Canadian Guidelines for Body Weight Classification in Adults. Catalogue no. H49-179/2003E. Available at: http://www.hcsc.gc.ca/fn-an/alt_formats/hpfb-dgpsa/pdf/nutrition/weight_booklivres_des_poidseng.pdf
37. Chaput JP, Després JP, Bouchard C, Tremblay A. Short sleep duration is associated with reduced leptin levels and increased adiposity: Results from the Quebec family study. *Obesity* 2007; 15(1): 253–61. <https://doi.org/10.1038/oby.2007.512>
38. Watanabe M, Kikuchi H, Tanaka K, Takahashi M. Association of short sleep duration with weight gain and obesity at 1-year follow-up: a large-scale prospective study. *Sleep* 2010; 33(2): 161–7. <https://doi.org/10.1093/sleep/33.2.161>
39. Magee L, Hale L. Longitudinal associations between sleep duration and subsequent weight gain: A systematic review. *Sleep Medicine Reviews* 2012; 16(3): 231–241. <https://doi.org/10.1016/j.smrv.2011.05.005>
40. Zhou Q, Zhang M, Hu D. Dose-response association between sleep duration and obesity risk: a systematic review and meta-analysis of prospective cohort studies. *Sleep and Breathing* 2019; 23(4): 1035–1045. <https://doi.org/10.1007/s11325-019-01824-4>
41. Antza C, Kostopoulos G, Mostafa S, et al. The links between sleep duration, obesity and type 2 diabetes mellitus. *Journal of Endocrinology* 2021; 252(2): 125–141. <https://doi.org/10.1530/JOE-21-0155>
42. Muscogiuri G, Barrea L, Annunziata G, et al. Obesity and sleep disturbance: the chicken or the egg? *Critical Reviews in Food Science and Nutrition* 2019; 59(13): 2158–2165. <https://doi.org/10.1080/10408398.2018.1506979>
43. Wolk R, Shamsuzzaman ASM, Somers VK. Obesity, Sleep Apnea, and Hypertension. *Hypertension*. 2003; 42(6): 1067–1074. <https://doi.org/10.1161/01.HYP.0000101686.98973.A3>
44. Madrid-Valero JJ, Martínez-Selva JM, Ordoñana JR. Sleep quality and body mass index: a co-twin study. *Journal of Sleep Research* 2017; 26(4): 461–467. <https://doi.org/10.1111/jsr.12493>
45. Reyes-Guzman CM, Bray RM, Forman-Hoffman VL, Williams J. Overweight and obesity trends among active duty military personnel: a 13-year perspective. *American Journal of Preventive Medicine* 2015; 48(2): 145–153. <https://doi.org/10.1016/j.amepre.2014.08.033>
46. Statistics Canada. 2022. Special tabulation based on 2019 Canadian Community Health Survey – Annual.
47. Gaines J, Vgontzas AN, Fernandez-Mendoza J, Bixler EO. Obstructive sleep apnea and the metabolic syndrome: The road to clinically-meaningful phenotyping, improved prognosis, and personalized treatment. *Sleep Medicine Review* 2018; 42: 211–219. <https://doi.org/10.1016/j.smrv.2018.08.009>
48. Chaput JP, Tremblay A. Adequate sleep to improve the treatment of obesity *CMAJ* 2012; 184(18): 1975–1976. <https://doi.org/10.1503/cmaj.120876>
49. Sauter C, Kowalski JT, Stein M, et al. Effects of a workplace-based sleep health program on sleep in members of the German Armed Forces. *Journal of Clinical Sleep Medicine* 2019; 15(3): 417–429. <https://doi.org/10.5664/jcsm.7666>