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Evidence synthesis

Patterns and motivations of polysubstance use: a rapid review of the qualitative evidence

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Abstract

Introduction: Polysubstance use—the use of substances at the same time or close in time—is a common practice among people who use drugs. The recent rise in mortality and overdose associated with polysubstance use makes understanding current motivations underlying this pattern critical. The objective of this review was to synthesize current knowledge of the reasons for combining substances in a single defined episode of drug use.

Methods: We conducted a rapid review of the literature to identify empirical studies describing patterns and/or motivations for polysubstance use. Included studies were published between 2010 and 2021 and identified using MEDLINE, Embase, PsycINFO and Google Scholar.

Results: We included 13 qualitative or mixed-method studies in our analysis. Substances were combined sequentially to alleviate withdrawal symptoms or prolong a state of euphoria ("high"). Simultaneous use was motivated by an intention to counteract or balance the effect(s) of a substance with those of another, enhance a high or reduce overall use, and to mimic the effect of another unavailable or more expensive substance. Self-medication for a pre-existing condition was also the intention behind sequential or simultaneous use.

Conclusion: Polysubstance use is often motivated by a desire to improve the experience based on expected effects of combinations. A better understanding of the reasons underlying substance combination are needed to mitigate the impact of the current overdose crisis.

Keywords: *polysubstance use, polydrug use, misuse, drug combination, co-use, co-ingestion, rapid review*

Highlights

- The use of multiple substances in a single episode is common, but increases the risk of an acute toxicity event.
- Polysubstance use is driven by people's experience and expectation of substance effects.
- Substances can be combined sequentially to alleviate withdrawal symptoms or prolong a state of euphoria ("high").
- Substances can be used simultaneously to counteract or balance their effect(s), enhance a high, reduce overall use, or mimic the effect of another substance.
- While substances are generally combined to improve the experience, reducing overall use or self-medicating a pre-existing condition are also motivations.

Introduction

Polysubstance use, the consumption of more than one substance close in time, with overlapping effects,[1,2] is increasingly recognized as an urgent public health issue.[3-6] The co-involvement of stimulants, benzodiazepines and alcohol increases the risk of acute opioid toxicity[7] and has been identified as one of the key drivers in the rise in opioid-related mortality in North America.[3-6] In Canada, 22 828 apparent opioid toxicity deaths were recorded between January 2016 and March 2021.[8] Although it is most prevalent among people with problematic use,[6,9-11] polysubstance use is far-reaching and occurs across populations and age groups.[12-16]

Overdose death rates have risen rapidly since the onset of the COVID-19 pandemic.[8] Between April and September 2020, in the 6 months after the implementation of COVID-19 prevention measures, there were 3351 apparent opioid toxicity deaths in Canada, representing a 74% increase over the previous 6 months (1923 deaths between October 2019 and March 2020).[8] Recent evidence suggests that physical distancing measures have contributed to this situation by reducing the availability of treatment and harm reduction services for people who use substances.[17] Although the literature on polysubstance use in the context of COVID-19 is still nascent, findings from recent reports also suggest that self-medication and the effects of abstinence from no longer accessible drugs has resulted in an increase in the number of substances

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used simultaneously.[18] This trend is a concern given that it contributes to multiple dependencies,[19-21] especially when substances are consumed to mitigate a negative symptom, for example, to manage pain.[22]

Studies have shown that people combine substances with the intention of minimizing harm, reducing negative symptoms, increasing pleasurable sensations and enhancing overall experience, despite the risk of acute toxicity inherent to polysubstance use.[23] Qualitative and mixed-method studies have reported various motivators of polysubstance use in specific populations,[24-28] but a comprehensive synthesis of the literature is missing. As studies relying on qualitative data tend to be small, a synthesis of the literature could provide a broader and more complete picture of polysubstance use motivations in the population, help identify common and less common motivating factors, and inform substance-use intervention and prevention programs and policies.

In this review of qualitative evidence, we aim to summarize the current state of knowledge on the way people choose to combine substances in a single episode, either at the same time or sequentially, to achieve desired effects.

Methods

Search strategy

We developed this review using the methods described in the *Rapid Review Guidebook*.[24]

An electronic database search strategy was developed with a librarian based on a prespecified protocol (available from the authors on request). We searched MEDLINE, Embase and PsycINFO databases for peer-reviewed studies published between January 2010 and March 2021. We identified grey literature by searching the Google and Google Scholar databases for governmental reports and webpages of the Organisation for Economic Co-operation (OECD) and of OECD member countries. An ancestry search of all the references cited by all included peer-reviewed articles and a manual search in Google Scholar for key concepts such as pattern of polysubstance use were carried out to capture relevant studies that may not have been indexed in the searched databases.

Studies were eligible for inclusion if they (1) reported on the pattern or motivation of polysubstance use; (2) were qualitative or mixed methods using original data; (3) were conducted in OECD countries; and (4) were written in French or in English. There were no restrictions on study population or context/setting.

Studies were excluded if they (1) reported motivations only for alcohol and/or cannabis and/or tobacco or a combination of these with a non-psychoactive substance because the focus was on combinations associated with more severe problematic use;[25] (2) reported no specific combination(s); (3) relied on data collected before 2005, to capture recent patterns of use; (4) described the probability of combining substances with no mention of motivations; or (5) did not specify a time period of use or described the use as taking place for a period longer than 24 hours.

Study selection and data collection

Two reviewers (MBF, CL) independently screened titles and abstracts and retrieved potentially relevant studies for full-text review. Three reviewers (MBF, GC, GG) independently extracted data from the included studies. Any discrepancies between reviewers at screening and full-text review were resolved via consensus. For all included publications, the study country, objective(s), population, sample size, data collection method, years of data collection, basic demographic data of study participants including age, sex, substances under study and combinations of substances and or classes were extracted. Motivations for combining different substances, and patterns of substance use (simultaneous or sequential), were coded.

Quality appraisal

Three reviewers (MBF, GC, GG) independently assessed the quality of included studies using the Mixed Methods Appraisal Tool (MMAT).[26,27] This tool has been developed and validated to critically appraise the methodological quality of different study designs. The MMAT uses five questions to assess the appropriateness of the study design for the research question, the potential bias and the quality of measurements and analyses, according to design.

Based on "yes," "no" or "can't tell" answers, a five-point quality score was created, assigning one point for each "yes" response. Studies were considered good quality (≥4 "yes" answers); moderate quality (3 "yes" answers); or poor quality (≤2 "yes" answers). Disagreements between reviewers were resolved if any of their answers to the five questions described in the MMAT tool differed. Consensus was reached through discussion between two reviewers, followed by discussions with a third if the disagreement persisted.

No studies were excluded based on their quality. (Details of the complete quality appraisal results of all included studies are available from the authors on request).

Data analysis

We extracted qualitative data on polysubstance use, including the specific substances combined and their class (stimulants, depressant, dissociative, psychedelics, etc.). We defined polysubstance use as the consumption of at least two substances at the same time (simultaneous pattern) or taken one after another within a 24-hour period (sequential pattern).

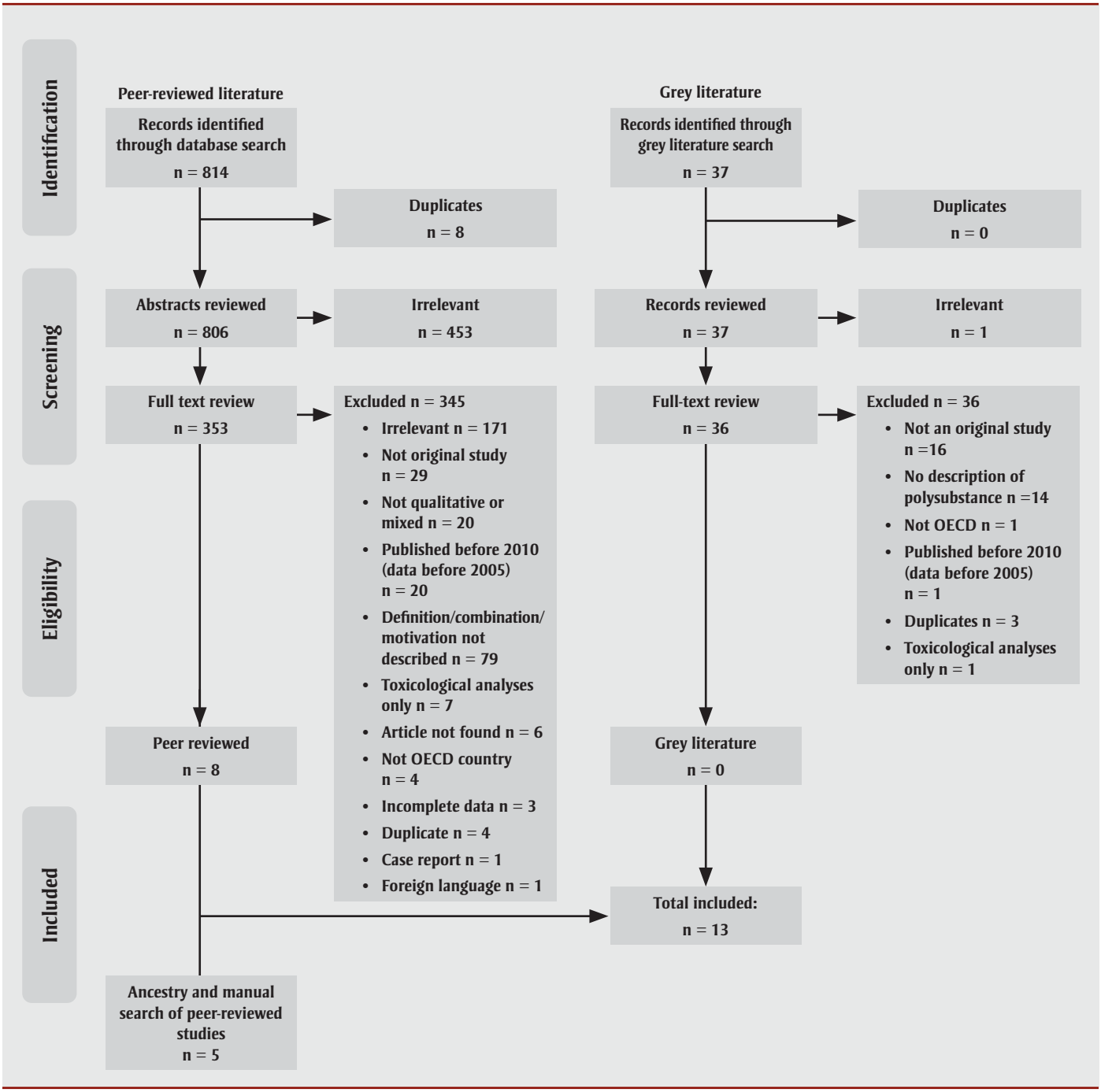
We carried out a thematic content analysis to identify the motivations and patterns of use. We coded qualitative information using a predetermined list of motivations extracted from a published review,[10] allowing for more to emerge. Once the list of motivations stabilized, two reviewers (either MBF and CL, or MBF and GC) coded the verbatims separately and then compared their results. A single quote could be coded under more than one motivation. If the reviewers disagreed as to the motivation to ascribe, they resolved the disagreement through discussion, with a third reviewer joining the discussion if the disagreement persisted.

Results

Study selection and characteristics

The initial electronic database search yielded 814 studies, and the grey literature search 37 records. After the removal of duplicates (n = 8) and ineligible records on the basis of their title and abstract (n = 453), 353 manuscripts underwent full-text review. Of these, 8 studies[28-35] were included in the review (Figure 1). Five more peer-reviewed studies were added through the ancestry and manual searches.[14,36-39]

FIGURE 1
Data identification, selection and extraction process



Eleven of the included studies were conducted in North America[14,28-30,32,34,36-40] and two in Europe.[33,35] Six were qualitative and 7 were mixed methods studies. The characteristics of included studies are summarized in Table 1.

We classified nine of the studies as high quality. Four mixed-methods studies were considered moderate quality, either because they did not provide a clear rationale for using mixed methods or because the quality of the quantitative and/or qualitative research methods could not be assessed based on the reported information.

The median number of participants in the selected studies was 45, with the actual number between 11 and 13 521. The study population was categorized into one of the six following groups: people who attend parties and raves and go to bars; people attracted to the same sex; people attending academic or training institutions; people who inject substances and/or are street involved and/or experiencing homelessness; and people who use substances not otherwise specified.

Ten of the 13 studies were conducted with street-based or socially marginalized populations including people who inject

TABLE 1
Summary of included studies reporting on polysubstance use, 2010–2021

Citation and location	Years of data collection	Study population	Sample size, n	Proportion of males, %	Age, years	Data collection method	Research objective(s)	Substances under study	Quality score, /5
Aikins (2013)[28] United States	2009–2010	University students	41	56	Median: 21 (range: 18–50)	Semistructured interviews, questionnaire (self-administered)	To describe the experiences of students who use drugs for academic purposes	Alcohol, cannabis, nicotine, prescribed stimulants, Strattera, modafinil, salvia or any other nootropic medication taken to increase academic performances	5
Ellis et al. (2018)[29] United States	2011–2017	People newly entering substance abuse treatment programs	13 521	52	Categorical: 18–24 (21.2%) 25–34 (42.7%) 35–44 (20.6%) >45 (15.6%)	Questionnaire (self-administered), open-ended questions	To understand whether use of methamphetamine has increased among opioid users	Methamphetamine, opioids	5
Kecojevic et al. (2015)[36] United States	2012–2013	Young men who have sex with men	25	100	Median: 23 (IQR: 21–26)	In-depth, semistructured interviews and structured quantitative interviews	To explore personal motivations for prescription drug misuse among young men who have sex with men, including the possible connection between misuse and sexual behaviours	Opioids, such as Vicodin and OxyContin, tranquilizers, such as Xanax and Klonapin, and stimulants, such as Adderall and Ritalin	5
Lamonica & Boeri (2012)[30] United States	NR	People who use methamphetamine and former users	16	50	Median: NR (range: 22–51)	Questionnaire (interviewer-administered), in-depth interviews	To describe the patterns of use of prescribed drugs and methamphetamine	Methamphetamine and prescribed drugs (NS)	5
Lankenau et al. (2012)[31] United States	2008–2009	Young people who inject substances	50	70	Mean (SD): 21.4 (NR) (range: 16–25)	Semistructured interviews and participant observation	To understand current patterns of prescription drug misuse: motivations, source of prescription drugs, risks, impact on health and well-being	Prescribed pain medication and other drugs (NS)	4
Motta-Ochoa et al. (2017)[32] Canada	2015	People who use cocaine	50	66	Median: NR (range: 20–60)	Semistructured interviews and participant observations	To understand practices of psychotropic medication use among people who use cocaine	Cocaine and other substances	5
Oliveira et al. (2010)[33] Spain	2005–2006	People who use substances and former users	30	NR (mainly men)	Median: NR (range: 20–40)	In-depth interviews	To understand cocaine use to support the elaboration of intervention strategies that support people who use drugs	Cocaine and other substances	5

Continued on the following page

TABLE 1 (continued)
Summary of included studies reporting on polysubstance use, 2010–2021

Citation and location	Years of data collection	Study population	Sample size, n	Proportion of males, %	Age, years	Data collection method	Research objective(s)	Substances under study	Quality score, /5
Pringle et al. (2015)[34] United States	NR	People who use DXM	52	83	Mean: 23.6 (range: 18–63)	Questionnaire (self-administered), open-ended questions	To describe patterns, preferences and perceptions of DXM use among adult members of an online DXM community	DXM and other substances (NS)	4
Rigg & Ibañez (2010)[37] United States	2008–2009	People who misuse prescription drugs	45	58	Mean: 39 (range: 18–60)	In-depth qualitative interviews (qualitative) and computer-assisted personal interviewing	To determine the motivations for engaging in non-medical use of prescription opioids and sedatives among street-based people who use illegal substances, methadone maintenance patients, and residential drug treatment clients	Opioids and other prescription drugs	5
Roy et al. (2012)[38] Canada	2007–2009	People who use cocaine	64	85	Mean: 38.6 (range: 18–60)	Participant observations and unstructured interviews (qualitative) and self-report questionnaire (quantitative)	To investigate the influence of crack availability on current drug use	Cocaine, opioids and other substances	3
Silva et al. (2013)[39] United States	2008–2009	Young people who misuse prescription drugs	45	84	Mean: 20.9 (range: 16–25)	Semistructured interview (qualitative and quantitative)	To examine the reasons young polydrug users misuse prescription drugs and explore how young users employ risk-reduction strategies to minimize adverse consequences	Opioids, tranquilizers[a] and stimulants[b]	4
Valente et al. (2020)[14] United States	2018–2019	People who inject drugs	45	64	Median: 37 (IQR: 31–41)	Quantitative surveys on sociodemographics, semistructured interviews	To explore patterns, contexts, motivations and perceived consequences of polysubstance use among people who inject drugs	Heroin, fentanyl or another synthetic opioid, cocaine, cannabis, benzodiazepines, alcohol, prescription opioids[c], methamphetamine, prescription stimulants[d] and other drugs	5

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TABLE 1 (continued)
Summary of included studies reporting on polysubstance use, 2010–2021

Citation and location	Years of data collection	Study population	Sample size, n	Proportion of males, %	Age, years	Data collection method	Research objective(s)	Substances under study	Quality score, /5
Van Hout & Bingham (2012)[35] Ireland	2011	People who inject substances using low threshold harm reduction services and who reported injecting mephedrone	11	73	Median: NR (range: 25–40)	In-depth interviews	To describe the experiences of people who were injecting mephedrone prior to the introduction of legislative controls	Mephedrone and other substances (NS)	5

Abbreviations: DXM, dextromethorphan; GHB, gamma-hydroxybutyrate; IQR, interquartile range; NR, not reported; NS, not specified; SD, standard deviation.

[a] Sedatives (often referred to as "tranquilizers"): benzodiazepine, z-drug and barbiturates (e.g. alprazolam, diazepam, clonazepam, lorazepam, zopiclone).[41]

[b] Stimulants: In reference to the central nervous system (CNS), any agent that activates, enhances or increases neural activity; also called psychostimulants or CNS stimulants. Included are amphetamine-type stimulants, cocaine, caffeine, nicotine and others.[41]

[c] Prescribed opioids (also known as painkillers): hydrocodone, oxycodone or opioid therapy (e.g. methadone, supeudol, Suboxone).[41]

[d] Prescribed stimulant: amphetamine (Adderal), dextroamphetamine (Dexedrine), methylphenidate (Ritalin, Concerta, Biphentin), lisdexamfetamine dimesylate (Vyvanse).[41]

drugs, use harm reduction services or are experiencing homelessness.[14,29,30,32,33,35,37-40] The age range varied across the studies, with the overall range 18 to 60 years.

One study examined the reasons for polysubstance use in a population of university students (median of 21 years of age)[28]; one examined the reasons for polysubstance use among people attracted to the same sex (median of 23 years of age)[36]; and one examined the reasons for polysubstance use among people who discuss substance use in online forums (mean of 23 years of age)[34]. Most of the study participants (50–100%) identified as male.

Patterns and motivations for combining substances

The 13 studies included in this rapid review reported a total of 41 different combinations of substances and the motivations for combining substances (Table 2).

We found eight motivations for which we described the temporal patterns of use (simultaneous or sequential) when information was available. Excerpts of quotes from the original studies are duplicated here to better illustrate individuals' motivations for combining substances.

Sequential use

Sequential use refers to the consumption of a substance after the peak effect of another substance. People reported using substances sequentially to alleviate withdrawal symptoms or to prolong a state of euphoria, or "high."

Alleviate withdrawal symptoms

The most frequently reported combinations of substances involve a stimulant with a depressant (e.g. benzodiazepine, alcohol), cannabis or an opioid to either calm down, induce sleep, alleviate anxiety or distress or avoid drug cravings[28,32,35,37,39] produced by the stimulant.

> "Sometimes when you do cocaine, or you get really wired up on the Oxys, we need something to come down, and we would take that Xanax to come down or get some sleep because sometimes in the process of doing these drugs you forget to sleep for a couple of days, and then finally you've got to say, 'Okay, it's time to sleep.'"[37]

Studies reported people using substances within the same class of effect to ease off the effects of the drug. For example, a prescribed stimulant (dexamfetamine) was used to maintain normal functioning after a prolonged session of methamphetamine[36] or cocaine[28]. Similarly, oxycodone was used to ease the pain of heroin withdrawal.[37,40]

> "I kind of like to ride like a stimulant wave, it's very typical for me to after doing crystal all weekend to just do Adderall, to get through the day. Because, again, you're not kind of cranky, you're still up and you're still awake, and you're not tired, and you're able to do super-human things by just keeping going."[36]

> "… Hey, if you're sick, what will help is the Percocet. (…) the withdrawals make me feel really shitty. You know? But the Percocet, it kind of takes away all that. So that's why I use it…I only use it because I will go through withdrawals from the heroin, so I use the Percocet to ease the pain when I can't get heroin."[37]

Prolong a high

The pattern of stimulation sedation can take place in a single day or for longer periods (several days) with stimulants and opioids to prolong a high.[14,38]

> "I would smoke crack and use heroin or fentanyl, what we call landing gear, to come back down. And once you get down, then you'll want to take another hit [of crack] to go back up, and it's just like a cat chasing its tail. It never ends. Go up just to come down, then go up [again]."[14]

Simultaneous use

Simultaneous use is defined here as the consumption of two or more substances at the same time or close in time. The intention of simultaneous use is usually to balance or counteract the effects of one

TABLE 2
Specific motivations for combining substances identified in qualitative or mixed-method studies (N = 13)

Motivation	Combination of classes and substances		Description of specific motivations according to specific substances combined
	Class + (specific substance)	Class + (specific substance)	
Sequential use (proximal time)			
Alleviate withdrawal symptoms	Opioid (heroin)	Opioid (Rx opioids)	To ease pain when coming down from heroin[31,37]
	Opioid (prescribed)	Alcohol	To induce sleep after using an opioid[30]
	Stimulant (mephedrone)	Opioid (heroin and methadone)	To come down off a stimulant[35]
	Stimulant (cocaine)	Antidepressant (trazodone)	To induce sleep after using a stimulant[32]
		Antipsychotic (quetiapine)	To alleviate distress and induce sleep after using a stimulant[32,36]
		Benzodiazepine (clonazepam or lorazepam) with or without alcohol	To cope with anxiety and paranoia, induce sleep and avoid cravings ("jonesing") after using a stimulant[32,37]
		Gabapentinoid (pregabalin)	To reduce anxiety induced by a stimulant[32]
		Stimulant (dexamfetamine)	To come down, avoid "crashing" after the use of a stimulant[28]
		Opioid (methadone)	To calm down after using a stimulant[33]
	Stimulant (methamphetamine)	Benzodiazepine (alprazolam) with or without alcohol	To induce sleep, to calm down and prevent hallucinations after using a stimulant[32]
		Stimulant (dexamfetamine)	To maintain functioning after a prolonged session of stimulant use[36]
		Opioids (NS)	To alleviate withdrawal symptoms[29] and to reduce paranoia induced by a stimulant[30]
	Stimulant (Adderal or MDMA)	Benzodiazepine (alprazolam)	To induce sleep after using a stimulant[39]
	Stimulant (dexamfetamine)	Cannabinoid (cannabis)	To relax, numb physical exhaustion after using a stimulant. To mentally signifying the end of a productive period or the beginning of recreational time[28]
		Alcohol	To achieve a level of soberness after using alcohol[36]
		Benzodiazepine (alprazolam)	To induce sleep after using a stimulant[36]
Prolong a high	Stimulant (cocaine)	Opioid (hydromorphone)	To create a pattern of successive stimulation and sedation[14,42]
Simultaneous use			
Balance effects	Opioid (heroin)	Benzodiazepine (clonazepam)	To avoid being aggravated easily by noise and reduce anxiety[31]
	Stimulant (cocaine)	Opioid (heroin or dilaudid)	To avoid negative experiences ("bad trips"), overpowering sensations[33]; to avoid feeling drowsy ("nodding") when using an opioid[38]
		Opioid (heroin) + Opioid (mephedrone)	To avoid overpowering sensation[35]
		Methamphetamine +/− opioid	To avoid overpowering sensation[29,30]
	Rx stimulant (dexamfetamine)	Alcohol	To calm down[28]
		Cannabis	To calm down and to increase appetite[28]

Continued on the following page

TABLE 2 (continued)
Specific motivations for combining substances identified in qualitative or mixed-method studies (N = 13)

Motivation	Combination of classes and substances		Description of specific motivations according to specific substances combined
	Class + (specific substance)	Class + (specific substance)	
	Stimulant (methamphetamine)	Opioid	To provide energy to offset the sedation from opioids, to calm down after using the stimulant[30]
		Opioid (heroin)	To avoid overpowering sensation[30]
		Rx opioids	To provide energy to offset the sedation from opioids, or to calm down after using the stimulant[30]
		Alcohol	To avoid overpowering sensation[30]
Counteract effects	Stimulant (methamphetamine)	Erectile dysfunction Rx (Cialis, Viagra)	To counteract the effect of a stimulant on sexual performance[36]
	Rx stimulant (dexamfetamine)	Cannabis	To counteract the effect of the stimulant and restore appetite[28]
Enhance a high	Opioid (heroin)	Benzodiazepine (clonazepam)	To enhance the effect of the opioid[31,32]
		Opioid (oxycodone)	To enhance the effect and achieve the desired high with low quality drug[31]
	Opioid (Rx opioid)	Cannabis	To accentuate or enhance the effects of cannabis[37]
	Stimulant (cocaine)	Stimulant (methylphenidate)	To enhance the effect of the stimulant[32]
	Stimulant (dexamfetamine)	Stimulant (clonidine)	To enhance the effect of the stimulant[32]
		Stimulant (caffeine)	To enhance the effect of the stimulant[28]
	Stimulant (methamphetamine)	Opioid	To increase enjoyment of effect[29]
		Rx opioid	To enhance the effect of the stimulant[30]
		CNS depressant (GHB), Dissociative (ketamine)	To enhance sexual experience or self-discovery experiences[14]
	Cocaine	Opioid (NS)	To maximize the effect of one drug or the other[38]
Reduce overall use	Opioid (Rx opioid)	Alcohol	To achieve the same effect while reducing overall use and harm related to alcohol use[39]
Mimic the effect of another substance	Opioid (methadone)	Benzodiazepine	To mimic the effect of heroin[32]
Temporality of use not specified			
Self-medicate	Opioid (heroin)	Rx opioid	To self-medicate pain[14]

Abbreviations: CNS, central nervous system; GHB, gamma-hydroxybutyrate; MDMA, methylenedioxymethamphetamine (ecstasy); NS, not specified; Rx, prescribed medication.

Note: We use the colloquial expression "high" to mean a state of euphoria induced by the taking of the drug(s).

substance by using another substance, to enhance a high, to reduce overall use or to mimic the effect of another substance.

Balance effects

Substances with opposing psychoactive effects were used simultaneously to achieve a desired mental state or to temper undesirable effects. For example, heroin is used to avoid experiencing negative overpowering feelings when using a stimulant.[33]

> "... you no longer think about hallucinations, paranoia, you don't go through a bad trip, it [simultaneous use of heroin and crack cocaine] is the best thing to reduce the effect."[33]

Similarly, a stimulant is used to avoid feeling drowsy when using an opioid or as a depressant.[30,38]

> "I'll take Adderall mainly when I go to the clubs. At nighttime when I'm too drunk, I'll take the Adderall to straighten me up a little bit, open my eyes, be more attentive."[36]

Counteract effects

Substances with complementary effects can be used simultaneously to counteract undesired effects. For example, erectile dysfunction medication is used to counteract the effect of methamphetamine on sexual performance,[36] and cannabis is used to increase appetite when using a stimulant.[28]

> "I smoke the weed to control [the Adderall]. If I get too jittery—too uppity—and I'm grinding [my teeth] way too much, okay, I need to smoke

to calm down some, and let myself know I got to eat something."[28]

Enhance a high

Motivations for polysubstance use included combining drugs to create synergistic psychoactive effects with the intent to potentiate or enhance the effects of another substance. Often, stimulants are used in combination to increase a high.[28,32] People also reported using benzodiazepines[31,32] or prescription opioids[31] with heroin for the same purpose. Opioids and stimulants were also used in combination to maximize the effect of one drug or the other and create a synergy.[38] Substances may also be combined with the specific purpose of enhancing the effect of a low quality drug to achieve the desired high.

> "For crappy dope, I'm gonna try to get some Oxys for free, take those, and do a shot of dope. Or, I'll take a Percocet, start feeling that, and then do a shot of dope, which just intensifies it."[31]

Stimulants are combined simultaneously with GHB (gamma-hydroxybutyrate) and ketamine for added pleasure and to enhance sexual experiences or self-discovery.[14]

> "But then [if] you want to go voyaging off into the universe, do a shot of crystal [crystal meth] and special K [ketamine] in the same shot. It's amazing … I don't know how to explain it. I feel like I've learned a lot about life in those kinds of experiences."[14]

Reduce overall use

Substances can be used simultaneously as a harm reduction strategy to decrease substance consumption. For example, alcohol is used with an opioid to achieve the same effect of alcohol while reducing overall intake.[39]

> "It's usually like, 'Oh, we're going out to the bar, OK, I'll take half a Vicodin and have a couple of drinks, because it makes it that much more intense without having to consume as much.' [That] is my approach to it. I can go out and have two drinks and take half the Vicodin and feel better than going and having four or five drinks that night."[39]

Mimic the effect of another substance

Substances are mixed to help users achieve a desired effect if a preferred substance is not available or only available at a higher price. For instance, participants reported simultaneously using benzodiazepines and methadone to mimic the effects of heroin when that drug is not available.[32]

> "When I take methadone and benzos I nod [laughs] … Nodding is when you are high on heroin. Methadone and benzos make you nod. That's why some doctors don't want to prescribe both. It makes the effect of heroin. Methadone and benzos make you high like heroin."[32]

Pattern not specified

Self-medicate

Self-medication for poorly managed physical or mental health conditions or to alleviate pain was another common reason for using more than one substance. For instance, a participant described using Suboxone for pain and also self-medicating with a benzodiazepine and Ritalin to cope with a pre-existing condition:

> "[I currently use] Suboxone. I also like to use Xanax [benzodiazepine], it calms me down. The Concerta, the Ritalin [prescription stimulants], gives me energy. I mean, of course, the Suboxone, takes away all the [pain]. 'Cause I also have chronic pain, and it does help, and that's mostly (…) just to make it through the day and not be in so much pain."[14]

Complex behaviour and superimposed motivations

During a single episode of polysubstance use, there may be multiple motivations that guide the choices of people who use drugs, and drugs may be used both sequentially and simultaneously to meet these goals. For example, the use of alcohol and cannabis often constitute the baseline on which to build the experience, which can then be followed by a simultaneous use of stimulants, psychedelics and a sedative. The following quote exemplifies a situation where a person combines a stimulant and a gabapentinoid to prolong a high and to alleviate negative symptoms:

> "Sometimes I do Lyricas [pregabalin], I sniff them…the pills, after I do coke. It is a downer and the other, the coke, is an upper… I want Lyrica just to keep my buzz. [When] I wake up in the morning…I'm good this way, it's cool, it's quiet, I'm less anxious."[32]

Discussion

We identified and summarized eight motivations of polysubstance use and their temporality of use. Building on previous reviews that looked more widely at polysubstance use,[10] our work intentionally puts a narrow focus on overlapping use and described preferred combinations based on the person's experience and expectations of substance pharmacological effects.

Our results show that there are distinct motivations for using drugs sequentially and simultaneously in a single episode. The use of over five substances in an episode is common and preferred substances vary across groups,[14,15,43] making it difficult to capture general patterns of use.

While the object of our review was intentional polysubstance use, we acknowledge that substance combinations are not always a matter of choice. In illicit markets, preferred substances may be contaminated with other substances without the knowledge of the purchaser. In some instances, the progression and maintenance of use happen as a result of dependence, where the use of one substance triggers the use of another.[22] Other circumstantial factors can be at play; the emergence of new substances in the illegal local markets, the ease of access to traditional substances and price variations influence patterns of use.[44] When a substitute for a drug becomes cheaper, more available or of better quality, people will likely favour it. In North America, the increasing availability and quality of methamphetamine along with its decreased price have led to it being substituted for other stimulants[45,46] and to what has been described as the "twin epidemics" of methamphetamine and opioid use.[47] A similar pattern is currently being observed in Europe where cocaine quality and affordability have been steadily increasing and so has its use.[45]

The choice of substances that are used in combination also depends on the context in which they are used to fulfill specific functions.[44] For example, studies that include people who go to parties and bars tend to report combinations of "club drugs" including ecstasy/MDMA (methylenedioxymethamphetamine), amphetamines, ketamine, cocaine, GHB, psychedelics, cannabis and alcohol.[43,48,49] Club drugs are used to

increase feelings of euphoria, desirability, self-insight and sociability.[50] In other cases, substance combinations can involve non-psychoactive substances that are used to improve the overall experience. For example, a beta blocker can be used to offset tachycardia or omeprazole to avoid stomach pain when using stimulants.[7] Studies that focus on people who are attracted to the same sex often describe the use of wide combinations of club drugs[15,51] along with erectile dysfunction medication and alkyl nitrite (or "poppers") for sensation seeking, enhancing the sexual experience and fitting in.[52] Studies have also examined the use of prescription stimulants to enhance cognitive performance[28,53] and prescription drugs, including benzodiazepine and opioids, to alleviate distress among college and university students.[54,55]

Changes in the legal status of psychoactive substances are also expected to influence people's behaviour. As a result of legislative changes, the use of synthetic cathinones such as mephedrone, which was very prevalent a few years ago,[35] has fallen drastically.[7] A similar pattern of substitution has been observed for fentanyl, where traditional opioids such as heroin were successively substituted with fentanyl and fentanyl analogs[56] and, more recently, with non-fentanyl analogs, with effects similar to fentanyl, and analogs such as the nitazenes.[57] Designer benzodiazepines such as etizolam are increasingly used as a replacement for their traditional counterparts.[58] These changes in the market are expected to be reflected in substance combinations.

While the effects of the new combinations of emerging substances are often unpredictable, analogs are designed to provide legal alternatives to controlled substances and often have similar effects.[7] Furthermore, the motivations for using and combining new substances remain similar to their classical counterparts;[59] hence the relevance of characterizing and monitoring typical patterns of polysubstance use based on the preferences of people who choose to combine substances.

Strengths and limitations

An important strength of this rapid review is its focal and targeted scope. We reviewed evidence on an explicit and narrow definition of polysubstance use, which allows for a better understanding of combinations potentially involved in acute toxicity events. We defined an episode within a period of 24 hours, but we acknowledge that an episode of use can take place over several days and even weeks.[60] Our review focused on articles published in the last decade to highlight patterns that may underlie the current overdose crisis. Qualitative data allowed us to create a richer portrait by characterizing the motivations for combining substances.

Certain limitations should be acknowledged. All included studies relied on self-reports that can be inaccurate because participants are not always aware of the content of a product, especially when using illegal substances.[61] We did not explore the mode of substance use, although this could be a determinant of expected effect. Furthermore, some relevant studies may not have been identified by our search strategy given the broad nature of the concept of polysubstance use; thus the combinations reported only represent an overview.

The context in which people use substances is known to influence their behaviour,[44] but published information on different settings with patterns of polysubstance use is limited. Finally, while no studies were excluded on the basis of sex/gender or identity of participants, the included work does not reflect the broad scope and diversity of experiences lived by people who use drugs.

Conclusion

While contextual factors such as changes in the illegal drug supply and availability of substance remain major drivers of behaviour, individual motivations significantly affect patterns of use. Putting a greater emphasis on the reasons why people choose to combine substances is a key factor in understanding polysubstance use patterns associated with higher risks of overdose. In doing so, we can better tailor harm reduction messaging to the complex reality of people who use substances.

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Conflict of interest

The authors have no conflicts of interest to declare.

Authors' contributions and statement

MBF – conceptualization of search strategy, screening of identified works for inclusion, data extraction, analysis and interpretation of data, and manuscript preparation

GC – data extraction, analysis and interpretation of data, and manuscript preparation

GG – data extraction, analysis and interpretation of data, and manuscript preparation

CL – review of search strategy, screening of identified works for inclusion, analysis and interpretation of data, and manuscript preparation

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Original quantitative research

Suicide and drug toxicity mortality in the first year of the COVID-19 pandemic: use of medical examiner data for public health in Nova Scotia

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Abstract

Introduction: The COVID-19 pandemic and governmental responses have raised concerns about any corresponding rise in suicide and/or drug toxicity mortality due to exacerbations of mental illness, economic issues, changes to drug supply, ability to access harm reduction services, and other factors.

Methods: Data were obtained from the Nova Scotia Medical Examiner Service. Case definitions were developed, and their performance characteristics assessed. Pre-pandemic trends in monthly suicide and drug toxicity deaths were modelled and the observed numbers of deaths in the pandemic year compared to expected numbers.

Results: There was a significant reduction in suicide deaths in the first year of the COVID-19 pandemic in Nova Scotia, with about 21 fewer non-drug toxicity suicide deaths than expected in March 2020 to February 2021 (risk ratio = 0.82). No change in drug toxicity mortality was detected. Case definitions were successfully applied to free-text cause of death statements and cases where cause and manner of death remained under investigation.

Conclusion: Processes for case classification and monitoring can be implemented in collaboration with medical examiners and coroners for timely, ongoing public health surveillance of suicide and drug toxicity mortality. Medical examiners and coroners are the stewards of a wealth of data that could inform the prevention of further deaths; it is time to engage these systems in public health surveillance.

Keywords: *coroners, medical examiners, public health surveillance, COVID-19, suicide, drug overdose, mortality*

Highlights

- Unintended consequences of the COVID-19 pandemic and the resulting regulations and policies may include increased suicide and/or drug toxicity mortality.
- Suicide mortality decreased during the first year of the pandemic, a finding that was in agreement with international findings and was not related to reporting lags.
- There was no change in numbers of drug toxicity deaths in the first year of the pandemic in Nova Scotia.
- Ongoing public health surveillance with timely reporting is required to detect and respond to any changes over time

Introduction

Medical examiners and coroners investigate deaths that are unexplained or unexpected or that occur by violence, including domestic homicides, suicides, drug overdose deaths and motor vehicle collision deaths. Their offices are valuable sources of information that can be mobilized to inform policies and programs aiming to prevent future harms. Although these offices have been recognized as essential sources of data for informing public health surveillance[1,2,3], their legislative position (typically in justice and public safety) means that they sit outside of the health system, and the exchange of data is sometimes problematic. Routine monitoring and interpretation, where it occurs at all, is typically limited and conducted only once case investigations are closed, which can be up to two years after a death. This inherent time-lag translates to official vital statistics data.

There are concerns that further COVID-19 pandemic "waves" and the responses to mitigate the spread of disease could result in a rise in adverse outcomes related to exacerbated mental illness, social isolation, economic issues or burnout.[4] Cross-sectional studies have detected significant increases in the prevalence of symptoms of depression, anxiety, psychological distress and COVID-related fears following the declaration of the pandemic and implementation of restrictions on public life.[5,6] Negative outcomes could include increases in deaths by suicide or drug

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toxicity; there have already been numerous reports in North America of increases in drug overdose events.[7-11] Early reports found no increase in suicide in the early months of the pandemic in many countries, but emphasize the importance of staying alert to both emerging and known risk factors for suicide as the consequences of the pandemic and associated policies evolve.[12,13] Researchers in Japan have reported an increase in suicide deaths coinciding with the second wave of the pandemic there, a phenomenon that appears to be most marked among women and children.[14] The unintended consequence of increased suicide is not necessarily inevitable;[4,15] timely data are required to allow for timely and targeted interventions.

There are two main barriers to the use of data from coroners and medical examiners in public health surveillance: the first is administrative and the second is practical. The first barrier is a lack of a natural pathway for data to flow between these agencies and public health, so that formal partnerships must be newly established. The second barrier is the length of time—often several months—it takes for medicolegal death investigations to conclude, potentially diminishing the value of information for use in real-time public health interventions.

The need to detect and respond to any impact the COVID-19 pandemic and associated policies have had on suicide and drug toxicity mortality has led to the health and justice departments in Nova Scotia collaborating for timely information sharing. Epidemiological principles were applied for systematic classification of fatalities referred to the Nova Scotia Medical Examiner Service. Cases were classified by characteristics that depended on whether the cause of death was certified or remained under investigation.

In this study, we assessed whether there was a change in suicide or drug toxicity deaths in the year after the introduction of measures to prevent the spread of COVID-19 in Nova Scotia.

Methods

Data source

All deaths that may be due to drug intoxication or suicide fall within the legislative mandate of the Nova Scotia Medical Examiner Service (NSMES). The NSMES uses an electronic application to collect and store case investigation information, including cause and manner of death. As standard practice, the medical examiners include the generic names of the drugs causing or contributing to death in the cause of death statement. Through a private service provider, the medical examiners have access to toxicology testing that covers a broad scope of pharmaceutical and nonpharmaceutical drugs.

Data for deaths occurring between January 2009 and February 2021 were extracted on 1 March 2021.

Case definitions: Suicide deaths and deaths due to drug toxicity

We mapped investigative workflow and timelines for key stages (e.g. toxicology results available, cause of death certified; details available on request from the authors). We had access to mortality data from investigative files and death certificates, which included various free text fields (and no International Classification of Diseases coding). We assessed deaths that had a final cause and manner of death recorded in the database against confirmed case definitions. Confirmed deaths by suicide were those for which manner of death was classified as suicide on the death certificate. Confirmed drug toxicity deaths were detected through text mining of immediate and antecedent cause of death fields on the death certificate as described here,[16] similar to others,[17] and currently in use for public reporting.[10,16] Probable case classifications were applied to cases still under investigation, with cause of death not yet certified. Understanding the performance of the case definitions was required to validate their usefulness in monitoring for trends, particularly when assessing recent months of mortality when many death investigations remain ongoing and cause and manner of death are not yet certified. It also allowed for a sensitivity analysis of findings to provide evidence that trends tested were not affected by the time lag in death certification.

Case definitions are summarized in Table 1.

Analysis

We analyzed data using STATA version 15.1 (StataCorp LP, College Station, TX, US). We classified cases and calculated performance characteristics, including sensitivity, specificity, positive predictive value (PPV; true positives/all cases that met probable case definitions) and negative predictive value (NPV; true negatives/all cases that did not meet probable case definitions) of probable case definitions against confirmed case definitions, the reference standard.

TABLE 1
Case definitions of drug toxicity and/or suicide deaths for public health surveillance

Drug toxicity deaths	
Confirmed drug toxicity death (reference standard)	• Death occurred in Nova Scotia AND • Cause of death was certified as drug toxicity
Probable drug toxicity: Definition A	• Death occurred in Nova Scotia AND • Cause of death remains under investigation AND • Preliminary classification of death event was "drug related"
Probable drug toxicity: Definition B	• Death occurred in Nova Scotia AND • Cause of death remains under investigation AND • Preliminary classification of death event was "drug related" or "medical" or "undetermined" AND • Postmortem toxicology findings included detection of one or more drugs[16] AND • Age at death >14 and <75 years[a]
Suicide deaths – total	
Confirmed suicide death (reference standard)	• Death occurred in Nova Scotia AND • Manner of death was certified as suicide
Suicide deaths excluding drug toxicity	
Confirmed suicide death excluding drug toxicity suicide deaths (reference standard)	• Death occurred in Nova Scotia AND • Manner of death was certified as suicide AND • Cause of death does not meet drug toxicity death case definition

[a] Excluding cases outside of this age range improved positive predictive value and decreased risk of report of misclassified deaths in age groups where drug toxicity is a rare event.

To assess case definitions, we applied probable case definitions to historic data in the manner they would have been applied in real time. In other words, even though cause and manner for historic cases had since been certified, we reviewed the case notes and, if the death was not certified at the time of autopsy (within 3 days of report of death), the cause of death was considered "under investigation" and probable definitions were applied. Classifications dependent on cases remaining under investigation post-autopsy required manual review for historic cases; as such, fewer years of data were included for performance characteristics for related definitions.

The modelling approach described by Pirkis et al.[12] was applied. Models for monthly case frequencies were fit using Poisson regression with time as a linear predictor. Pairs of sine and cosine functions were added to improve model fit as a seasonal trend was observed when suicide data were plotted. Sine and cosine functions were removed from drug toxicity models, as they did not significantly improve the model fit as per the likelihood ratio test for significant difference between competing models.

From the model, we estimated the expected number of deaths in the year after the first cases of COVID-19 were detected in Nova Scotia, and compared this number with the number of deaths observed in that time period. We calculated risk ratios with 95% confidence intervals (CIs). We called the time period between January 2011 and February 2020 the pre-pandemic period and the March 2020 to February 2021 time frame the pandemic period.

We conducted sensitivity analyses based on historic sensitivity and PPV of case definitions. Models were run with cases in the pre-pandemic time period equal to the cases detected multiplied by the sensitivity of each definition (cases × 0.92 for suicide excluding drug toxicity, and cases × 0.96 for drug toxicity), and observed cases in the pandemic period were equal to the cases detected multiplied by the PPV of each definition (confirmed cases × 1 and probable cases × 0.669 for drug toxicity).

Results

There were no significant differences in the sex or age group distributions of cases between the pre-pandemic and pandemic periods (see Table 2 for case characteristics).

There was a significant decrease in suicide mortality in the pandemic year compared to the pre-pandemic period, with 30 fewer suicide deaths (excluding drug toxicity deaths) than expected (Table 3). A sensitivity analysis suggests this decrease may more likely be 21 fewer deaths than expected in the pandemic period, with borderline statistical significance (CI: 0.67–1.00). There was no significant change in frequency of drug toxicity death in the pandemic period compared to the pre-pandemic period (Table 3).

A small proportion of suicide deaths (a mean of 2 per month) were caused by drug toxicity (Table 2; Figure 1). A review of workflow and timelines determined that over 90% of suicide deaths not caused by drug toxicity were certified within 3 days of the first report of death. Deaths related to drug toxicity, whether accident or suicide, always required more time to investigate (>1 month) because of ancillary testing. We therefore implemented surveillance of both (1) non-drug toxicity suicide deaths, without the need for an interim probable suicide case definition, and (2) drug toxicity deaths, including probable cases but regardless of manner of death.

The performance parameters of the case definitions against the reference standards are shown in Tables 4a-d. While the PPV of probable definition A for drug toxicity was found to be very high (93.4%), the sensitivity was lower (85.1%) than desired (Table 4a). Use of this definition alone would underestimate drug toxicity deaths, potentially resulting in missing a chance to detect an important event or trend.

Probable definition B on its own has a lag time related to toxicology testing and would not include cases within probable definition A that have a very high probability of certification of cause of death due to drug toxicity (Table 4b). However, probable definition B is useful for ongoing monitoring of toxicity deaths by specific drug/drug type. For monitoring of all drug toxicity deaths, confirmed cases and cases meeting either probable definition A and/or B were classified as probable drug toxicity deaths.

Figures 1 and 2 present monthly counts of deaths by suicide and drug toxicity over time. The lag in certification of drug toxicity deaths is apparent in Figure 2, where underestimation of cases (as per probable classifications) is most evident in the most recent six months to data extraction.

Discussion

One year into the COVID-19 pandemic, a decrease was noted in the number of non-drug toxicity suicide deaths in Nova Scotia compared to the pre-pandemic period. This decrease was not explained by a lag in certification, as most of these deaths were certified within 3 days. The sensitivity analysis that accounted for the performance of the case definitions applied showed about 21 fewer deaths in the first 12-month period of the pandemic, with borderline statistical significance (upper confidence limit of 1.00).

Suicide findings are consistent with a recent report where 12 of 21 high income and upper-middle income countries (or areas of countries) had a decrease in suicide deaths in the early months of the pandemic while the remainder continued to have numbers within the expected range.[12] There was no evidence of a difference in the demographics of those dying by suicide during the pandemic compared to before the pandemic; nor was there a detectable change in drug toxicity deaths, which included probable and confirmed cases to mitigate the lag in certification.

Increases in drug toxicity mortality during the pandemic have been observed in other Canadian jurisdictions.[7,9,10] Factors contributing to these increases—including a shifting and increasingly harmful drug supply and greater barriers to harm reduction approaches—have been less prominent in Nova Scotia to date but can change quickly and must be considered when pandemic policies are implemented to avoid preventable death.

An emerging collaboration between the NSMES and public health authorities in Nova Scotia initially focused on drug toxicity deaths and deaths by suicide, both recognized as major public health issues in Canada and North America, and both identified as in need of monitoring for prompt response in the context of potential unintended consequences of the COVID-19 pandemic.[4,8,13] The case definitions that have been implemented had

TABLE 2
Demographic characteristics of decedents, pre-pandemic, January 2011–February 2020, and during the first year of the pandemic, March 2020–February 2021, Nova Scotia

Characteristics	Pre-pandemic n (%)	First pandemic year n (%)	Chi square *p* value
Suicide deaths – total			
Total	1174 (mean of 128 per 12-month period)	111	–
Sex			
Male	891 (75.9)	89 (80.2)	0.310
Female	283 (24.1)	22 (19.8)	
Age, years			
<20	68 (5.8)	7 (6.3)	0.143
20–29	165 (14.1)	8 (7.2)	
30–39	136 (11.6)	14 (12.6)	
40–49	245 (20.9)	27 (24.3)	
50–59	277 (23.6)	21 (18.9)	
60–69	169 (14.4)	19 (17.1)	
70–79	74 (6.3)	13 (11.7)	
80+	40 (3.4)	2 (1.8)	
Suicide deaths excluding drug toxicity			
Total	945 (mean of 103 per 12-month period)	93	–
Sex			
Male	778 (82.3)	77 (82.8)	0.910
Female	167 (17.7)	16 (17.2)	
Age, years			
<20	65 (6.9)	7 (7.5)	0.079
20–29	150 (15.9)	8 (8.6)	
30–39	116 (12.3)	12 (12.9)	
40–49	195 (20.6)	24 (25.8)	
50–59	213 (22.5)	17 (18.3)	
60–69	122 (12.9)	14 (15.0)	
70–79	55 (5.8)	11 (11.8)	
80+	29 (3.1)	0	
All drug toxicity deaths			
Total	859 (mean of 94 per 12-month period)	104	–
Sex			
Male	533 (62.1)	69 (66.4)	0.393
Female	326 (37.9)	35 (33.6)	
Age, years			
<20	21 (2.4)	3 (2.9)	0.427
20–29	108 (12.6)	21 (20.2)	
30–39	160 (18.6)	22 (21.1)	
40–49	183 (21.3)	18 (17.3)	
50–59	225 (26.2)	20 (19.2)	
60–69	108 (12.6)	14 (13.5)	
70–79	38 (4.4)	4 (3.8)	
80+	16 (1.9)	2 (1.9)	

high sensitivity and specificity when applied to historical data, suggesting that events of interest will not go undetected and excluded cases are unlikely to be certified as drug toxicity or suicide deaths when the case investigations are closed. Monitoring provisional trends in drug toxicity deaths as well as suicide deaths ensures timely surveillance of both types of fatalities, taking into account drug specificity and manner of death. It also satisfies concerns around differences in classification of manner of death and a suggested need to consider both suicide poisoning and accidental toxicity together as a group of deaths due to self-intoxication.[18,19]

The approach to case classification described here does not increase the workload of members of the death investigation team and does not require time-consuming manual review of cases. It does rely upon common certification practices on the part of the medical examiners; existing guidelines from the United States for the certification of drug toxicity deaths have been helpful in this regard. One of these guidelines recommends naming the specific (parent) drug(s) that contributed to death by their generic names in Part I of the death certificate.[20]

Coroner/medical examiner offices across Canada differ markedly in the way they are resourced, staffed and administered, and they are not subject to national practice guidelines of any type. The impact of this variance in death investigation practice on the quality of mortality data has not been studied. Common approaches would allow for better comparability in this area. In the interim, presumptive case classifications are assigned in various jurisdictions in different ways (e.g. based on scene evidence, medical and social history collected by investigating coroners for suspected drug toxicity[8,9]; preliminary coroner statistics[7] and police-reported statistics for suspected deaths by suicide[14]).

The longer-term trend of an increasing population suicide rate in Nova Scotia pre-pandemic is also evident in vital statistics data as presented in the Nova Scotia suicide framework.[21] The two-year lag in data availability shows that collaboration with the death investigation system is required to detect any early warning signals and classify cases (including presumptive cases) to monitor them in real time.

TABLE 3
Observed and expected numbers of suicides in the first year of the pandemic, March 2020–February 2021, Nova Scotia

Category	Observed	Expected[a]	Risk ratio (95% CI)
Suicide deaths excluding drug toxicity	93	123	0.75 (0.62–0.92)
Suicide deaths excluding drug toxicity – sensitivity analysis	93	114	0.82 (0.67–1.00)
All drug toxicity deaths	104	91	1.15 (0.95–1.39)
All drug toxicity deaths – sensitivity analysis	96	87	1.11 (0.91–1.36)

Abbreviation: CI, confidence interval.
[a] Estimates from modelling of pre-pandemic data.

Furthermore, drug toxicity and suicide data available through routine processes for gathering vital statistics in Canada may be affected by information bias that could be mitigated through classification of probable cases and more frequent updates from source data or a live connection. As the complexity of the investigation to determine suicide intent and the lag time of toxicology results can lead to a longer investigation, time frames for capturing a vital statistics dataset and publishing it as "final" means that a proportion of deaths are classified in the "Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified" category. This can result in significant underestimation in frequencies and population rates; the effect of this underestimation on drug toxicity surveillance in the USA has been noted.[22]

In summary, vital statistics data are affected by timeliness as well as accuracy for suicide and drug toxicity deaths. This, coupled with the richness of the contextual information collected through the death investigation, which is distilled out when coded to ICD,[1,17] makes the coroner/medical examiner office both the source of truth about non-natural deaths and the source of data and evidence to inform action.

Efforts to prevent deaths can be informed by an understanding of the context in which fatalities occur (e.g. different actions are warranted in response to deaths from pharmaceutically formulated fentanyl patches than to fentanyl powders produced outside of the controls of the pharmaceutical industry), and when considered alongside other evidence (e.g. mental health surveys, non-fatal harms, etc.). Pan-Canadian toxicity mortality data are publicly released every quarter, with a six-month delay in providing evidence essential for drug policy.[23]

At the local level, evidence-based interventions can be rapidly implemented to prevent additional drug toxicity deaths in a targeted setting, similar to what happens when the source of infection is identified and removed to contain infectious disease outbreaks. While the removal of causative agents such as nonpharmaceutical fentanyl or methamphetamine from the local environment has proven not to be feasible, there are effective interventions for preventing death. Similarly, rapid targeted suicide prevention strategies can be deployed[4,15] when warranted in addition to established population-based prevention strategies.

Setting up routine data collection for key pieces of information for routine and/or ad-hoc analysis can provide a basis for quickly assessing a situation (e.g. occupational groups affected by suicide during versus prior to the pandemic, such as health care providers). Although the investigative files are rich in detail, they could be made more useful by standardizing the collection of minimum datasets.[1] In the interim, cases can be reviewed to abstract key information, but this is time consuming and should be driven by the need for information for action. Ongoing collaboration between the death investigation system and public health is fundamental for this surveillance system to function, with iterative review of objectives, analysis, reporting, and related programs/policies.[22]

Strengths and limitations

There are limitations to this work. For some cases, cause of death remained

FIGURE 1
Number of suicide deaths including and excluding drug toxicity as cause of death, by month, Nova Scotia, January 2011–February 2021

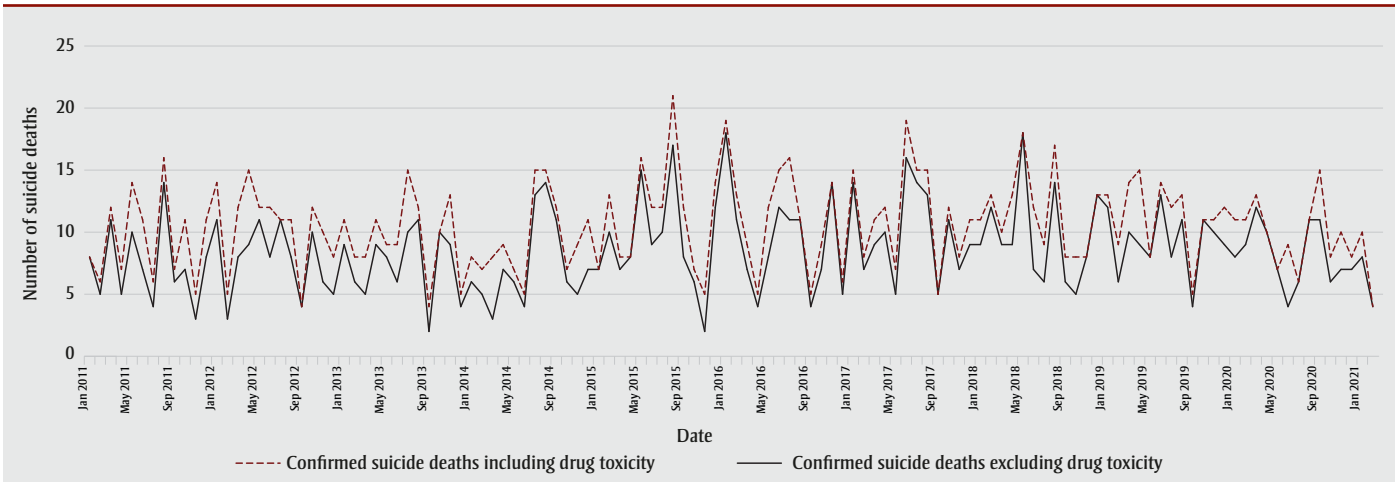


TABLE 4a
Performance of probable drug toxicity – definition A[a], NSMES, January 2009–February 2018 (n = 9897)

Category	Cause of death, n		PPV/NPV
	Drug toxicity (n = 785)	Not drug toxicity (n = 9112)	
Probable definition A met	668	47	PPV = 93.4%
Probable definition A not met	117	9065	NPV = 98.7%
Sensitivity/specificity	Sensitivity = 85.1%	Specificity = 99.5%	N/A

Abbreviations: NPV, negative predictive value; NSMES, Nova Scotia Medical Examiner Service; PPV, positive predictive value.
[a] Defined as death that occurred in Nova Scotia AND cause of death remains under investigation AND preliminary classification of death event was "drug related."

TABLE 4b
Performance of probable drug toxicity – definition B[a], NSMES, January 2017–February 2018 (n = 1353)

Category	Cause of death, n		PPV/NPV
	Drug toxicity (n = 114)	Not drug toxicity (n = 1239)	
Probable definition B met	105	52	PPV = 66.9%
Probable definition B not met	9	1187	NPV = 99.3%
Sensitivity/specificity	Sensitivity = 92.1%	Specificity = 95.8%	N/A

Abbreviations: NPV, negative predictive value; NSMES, Nova Scotia Medical Examiner Service; PPV, positive predictive value.
[a] Defined as death that occurred in Nova Scotia AND cause of death remains under investigation AND preliminary classification of death event was "drug related" or "medical" or "undetermined" AND postmortem toxicology findings included detection of one or more drugs AND age at death >14 and <75 years.

TABLE 4c
Performance of probable drug toxicity – definition A[a] and/or B[b], NSMES, January 2017–February 2018 (n = 1353)

Category	Cause of death, n		PPV/NPV
	Drug toxicity (n = 114)	Not drug toxicity (n = 1239)	
Probable definition A or B met	109	54	PPV = 66.9%
Probable definition A and B not met	5	1185	NPV = 99.6%
Sensitivity/specificity	Sensitivity = 95.6%	Specificity = 95.6%	N/A

Abbreviations: NPV, negative predictive value; NSMES, Nova Scotia Medical Examiner Service; PPV, positive predictive value.
[a] Defined as death that occurred in Nova Scotia AND cause of death remains under investigation AND preliminary classification of death event was "drug related."
[b] Defined as death that occurred in Nova Scotia AND cause of death remains under investigation AND preliminary classification of death event was "drug related" or "medical" or "undetermined" AND postmortem toxicology findings included detection of one or more drugs AND age at death >14 and <75 years.

TABLE 4d
Suicide deaths confirmed post-autopsy, excluding drug toxicity deaths, NSMES, 2019 (n = 1094)

Category	Manner of death, n		PPV/NPV
	Suicide (n = 110)	Not suicide (n = 984)	
Confirmed post-autopsy	101	0	PPV = 100%
Not confirmed post-autopsy (longer investigation)	9	984	NPV = 99.0%
Sensitivity/specificity	Sensitivity = 92.0%	Specificity = 100%	N/A

Abbreviations: NPV, negative predictive value; NSMES, Nova Scotia Medical Examiner Service; PPV, positive predictive value.

outstanding at the time of assessing historical probable cases against the reference standard. Still, this proportion was small (3.5%) and classification as case/not case would not change the findings. Medical examiners in Nova Scotia have broad consensus on the structure of cause of death statements for drug toxicity deaths and the level of evidence to classify a death as suicide, but there could still be some inter- and intra-observer variability in how deaths are classified.

Because Nova Scotia has a highly centralized death investigation system, the approach we describe here may not be generalizable across all Canadian or international jurisdictions, precluding direct replication of this approach. The scope of this collaboration could be widened to include all non-natural deaths. However, surveillance of natural causes of death, such as heart or lung disease, requires access to all-cause mortality data: extension of our approach to these other categories of death will require an extension of the collaboration to other agencies.

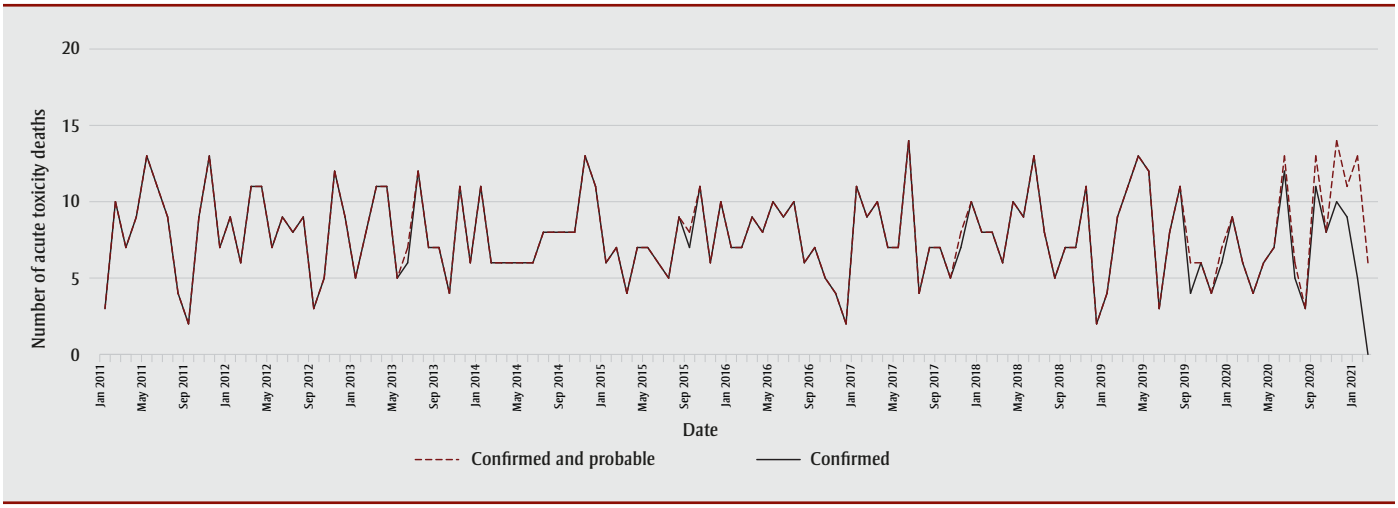
Investing in real-time mortality surveillance systems and improving the accuracy of death certification are essential for understanding and acting on trends in mortality by cause.[24,25] Some simple measures, such as guidelines for death certification,[20] implementing electronic death certificates,[26] and standardization of cause of death statements easily implementable in electronic systems,[1] allows for timely and inexpensive monitoring of all causes of death.

Conclusion

Timely surveillance data need not be perfect in terms of sensitivity and specificity to provide evidence of a need for action or iteratively inform an ongoing public health response (and associated programs and policies). Assigning cases according to definitions of public health interest is the first step prior to any descriptive or analytic analyses, whether measuring direct or indirect effects of pandemic or related restrictions at the individual level (e.g. changes to mental health during lockdown, changes to employment, disruption to drug supply) or the ecological level (e.g. timelines of changes to policies).

Nova Scotia has not experienced increases in suicide or drug toxicity deaths during the first year of the pandemic. As the

FIGURE 2
Number of probable plus confirmed drug toxicity deaths by month (probable definitions A[a] and B[b] applied to cases without cause of death certified), Nova Scotia, January 2011–February 2021



[a] Definition A: Death that occurred in Nova Scotia AND cause of death remains under investigation AND preliminary classification of death event was "drug related."

[b] Definition B: Death that occurred in Nova Scotia AND cause of death remains under investigation AND preliminary classification of death event was "drug related" or "medical" or "undetermined" AND postmortem toxicology findings included detection of one or more drugs AND age at death >14 and <75 years.

factors that contribute to non-natural deaths can quickly shift during pandemic response, countermeasures and rapid intervention are important. Death investigation systems are the source of truth for preventable non-natural deaths that have the potential to arise as unintended consequences. These systems are the stewards of a wealth of data that could inform the prevention of further deaths; it is time to engage these systems in public health surveillance.

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Conflict of interest

The authors declare that they have no conflict of interest.

Statement

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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Original quantitative research

Trends in gender and socioeconomic inequalities in adolescent health over 16 years (2002–2018): findings from the Canadian Health Behaviour in School-aged Children study

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This article has been peer reviewed.

Abstract

Introduction: Monitoring health inequalities in adolescents informs policy approaches to reducing these inequalities early in the life course. The purpose of this study was to investigate trends in gender and socioeconomic inequalities in six health domains.

Methods: Data were from five quadrennial survey cycles of the Health Behaviour in School-aged Children (HBSC) study in Canada (pooled n = 94 887 participants). Differences in health between socioeconomic groups (based on material deprivation) and between genders were assessed using slope and relative indices of inequality in six health domains: daily physical activity, excess body weight, frequent physical symptoms, frequent psychological symptoms, low life satisfaction, and fair or poor self-rated health.

Results: Over a 16-year period, adolescents in Canada reported progressively worse health in four health domains, with those at the lowest socioeconomic position showing the steepest declines. Socioeconomic differences increased in excess body weight, physical symptoms, low life satisfaction, and fair or poor health. Gender differences also increased. Females showed poorer health than males in all domains except excess body weight, and gender differences increased over time in physical symptoms, psychological symptoms and low life satisfaction.

Conclusion: Socioeconomic and gender inequalities in health are persistent and widening among adolescents in Canada. Policies that address material and social factors that contribute to health disparities in adolescence are warranted.

Keywords: *socioeconomic inequalities, socioeconomic position, gender, mental health, physical health, adolescents, HBSC, Canada*

Highlights

- Five survey cycles of the Canadian HBSC study revealed increasing health inequalities between socioeconomic and gender groups from 2002 to 2018.
- The burden of ill health shifted towards socioeconomically disadvantaged adolescents in terms of excess body weight, physical symptoms, low life satisfaction, and fair or poor health.
- Gender inequalities also increased in physical and psychological symptoms and low life satisfaction, resembling trends in Canadian adults and in European adolescents.
- Monitoring health inequalities among adolescents informs policy approaches to reducing these gaps early in the life course.

Introduction

Social disadvantage in childhood and adolescence (i.e. income poverty, low parental education, housing instability) increases the risk of lower earnings, less education and poorer health in adulthood, perpetuating an intergenerational cycle of poverty and ill health.[1] Research has shown that individuals in lower socioeconomic positions (SEP) have poorer health.[2] Also, females are at a health disadvantage relative to males.[3] Both types of social inequalities in health—socioeconomic and gender—are socially constructed early in the life course and define health inequalities throughout life.[4] Therefore, evidence on adolescent health inequalities between socioeconomic and gender groups can be useful for predicting health inequalities in the adult population.

Using social policy to redress health inequalities requires robust evidence on their trends over time. Unfortunately, the evidence shows that little to no progress has been made in reducing health inequalities in Canada with regard to unintentional injury, chronic diseases, social conditions, well-being and health behaviours.[5,6] Similar trends were found in Europe.[7,8] Research has also found that socioeconomic differences in health (e.g. self-rated mental health and smoking) among Canadian adults have widened over time and that inequalities in health status (measured using the Health Utility Index and the Frailty Index) have increased more among females than males.[5,6]

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Evidence from the Health Behaviour in School-aged Children (HBSC) study suggests that Canadian adolescents have increasing socioeconomic and gender inequalities in frequent psychosomatic symptoms (i.e. two or more of the following in the past 6 months: headache, stomach ache, feeling low, irritable or bad tempered, feeling nervous, difficulty in getting to sleep and/or feeling dizzy).[9-11] We built upon this evidence by examining secular trends in these plus four other health domains (daily physical activity, excess body weight, life satisfaction and self-rated health) over a longer period. We chose these domains to broadly represent mental and physical health and well-being because they were consistently measured in the Canadian HBSC study and because they relate to current and future health problems.

Psychosomatic symptoms vary in severity from minor health complaints to clinical symptoms, and can develop into more serious conditions such as anxiety and depression.[12,13] Daily physical activity is associated with better physical and psychological health in terms of cardiometabolic outcomes (blood pressure, cholesterol and insulin resistance), cardiovascular fitness and quality of life.[14] Excess body weight in adolescence predicts poor social and psychological functioning and metabolic diseases in adulthood;[15] most adolescents with excess body weight continue to have excess weight in adulthood, which is associated with chronic diseases (e.g. type 2 diabetes, hypertension) and mortality.[16] Life satisfaction is positively associated with mental health in adolescence[17,18] and reduced risk of depression and other adverse health conditions later in life.[19] Self-rated health is a subjective measure of health status with links to risk of various health conditions, school dropout, physical inactivity and poorer psychosocial functioning and work integration.[20]

Previous research found that adolescents at lower SEP (compared to those at higher SEP) and female adolescents (compared to males) reported less physical activity,[21] higher body weight,[22] poorer self-rated health,[3] lower life satisfaction[23] and a greater number of physical and psychological health complaints.[9,11,24] International research using HBSC data has revealed significant heterogeneity in these trends across countries and health outcomes and few common trends.[25,26] Therefore, our analyses focused on trends in health inequalities between SEP and gender among Canadian adolescents. Given that adolescent health is positively associated with SEP and that socioeconomic differences in health may have widened due to increasing economic inequality,[5,9,11] we hypothesized that socioeconomic differences in all health domains grew from 2002 to 2018. We also hypothesized, based on previous findings, that gender inequalities in health also widened, with female adolescents reporting progressively worse health than their male counterparts.[10,27]

Methods

Sample

The HBSC study is a cross-national school-based survey that is carried out in Canada and Europe every four years under the auspices of the World Health Organization.[28] It aims to understand associations between adolescents' health and health behaviours with social contextual factors. The questionnaire is completed during school hours in classroom settings. Additional details about the HBSC study and design are available elsewhere online.[29,30]

We used Canadian HBSC data from five quadrennial survey cycles from 2001/02 to 2017/18. These data were collected from nationally representative samples of 11- to 15-year-olds using random, two-stage cluster sample of schools.[30] The survey used both active and passive consent approaches depending on school board requirements, and student participation rates were from 74% to 77%.

Ethics approval was granted by the General Research Ethics Board of Queen's University (#601236) and either the Public Health Agency of Canada or Health Canada.

Characteristics of the sample are summarized in Table 1. The increase in sample sizes from 2010 onwards was due to oversampling in some provinces and territories.

Physical and mental health measures (dependent variables)

Daily physical activity was measured with the question "Over the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day?" with responses from 0 to 7. Adolescents who spent 60 minutes engaging in physical activity, every day, over the past 7 days were considered physically active as per the *Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep*.[31]

Standardized body mass indices (BMI) were calculated from self-reported weight and height and converted to body mass index Z (zBMI) scores that represented deviations from age- and gender-adjusted international norms according to World Health Organization child growth standards.[32] We determined excess body weight (overweight or obesity) based on zBMI values above 1. Adolescents with a zBMI below −2 (7.5% of the sample) or who had missing weight or height (26.1% of the sample) were omitted from the weight status analyses as these categories represent health risks other than excess body weight.[33-35] The proportion of missing weight and height in these data are consistent with findings from a review on missing weight, height and BMI information among adolescents.[36]

Physical symptoms and psychological symptoms

Participants were asked to identify symptoms by responding to the question, "In the last 6 months, how often have you had the following [headache; stomach ache; backache; feeling low (depressed); irritability or bad temper; feeling nervous; difficulties in getting to sleep; feeling dizzy]?" The response options were "about every day," "more than once a week," "about every week," "about every month" or "rarely or never." The HBSC symptom checklist has proven to be a valid measure of adolescents' health complaints, with a test-retest reliability of 0.79.[37]

In line with previous HBSC reporting, adolescents who reported two or more physical symptoms (headache; stomach ache; backache; feeling dizzy) more than once a week in the last 6 months were considered to have frequent physical symptoms.[28] Those who reported two or more psychological symptoms (feeling low; feeling irritable; feeling nervous; difficulties in getting to sleep) more than once a week in the last 6 months were considered to have frequent psychological symptoms.[28]

TABLE 1
Sample characteristics of Health Behaviour in School-aged Children study participants, Canada, 2002–2018 (n = 94 887)

Characteristic	Weighted percent per survey cycle, %						Total count, n	χ^2	*p* value
	2002 (n = 7235)	2006 (n = 9717)	2010 (n = 26 078)	2014 (n = 30 107)	2018 (n = 21 750)	Total			
Total sample	20.0	20.0	20.0	20.0	20.0	100.0	94 887		
Gender									
Female	53.4	52.9	50.8	50.9	52.5	52.1	48 199	42.3	0.163
Male	46.6	47.1	49.2	49.1	47.5	47.9	45 971		
Total	100	100	100	100	100	100	94 170		
Family structure									
Two-parent family	84.9	78.9	77.7	78.0	81.3	80.2	70 725		
One-parent family	13.8	18.2	18.7	17.6	16.3	16.9	16 641	623.6	<0.001
Other	1.2	2.8	3.6	4.4	2.3	2.9	3634		
Total	100	100	100	100	100	100	91 000		
Daily physical activity									
No	77.7	76.8	77.2	76.0	75.0	76.6	71 189	46.5	0.029
Yes	22.3	23.2	22.8	24.0	25.0	23.4	21 693		
Total	100	100	100	100	100	100	92 882		
Excess body weight									
Normal	80.3	78.6	78.6	75.0	77.0	77.9	47 881	121.3	<0.001
High	19.7	21.4	21.4	25.0	23.0	22.1	15 092		
Total	100	100	100	100	100	100	62 973		
Two or more physical symptoms									
No	75.6	72.5	73.2	74.0	74.6	74.0	69 504	59.2	0.002
Yes	24.4	27.5	26.8	26.0	25.4	26.0	25 383		
Total	100	100	100	100	100	100	94 887		
Two or more psychological symptoms									
No	61.9	57.8	58.7	59.1	57.3	58.9	55 467	100.5	<0.001
Yes	38.1	42.2	41.3	40.9	42.7	41.1	39 420		
Total	100	100	100	100	100	100	94 887		
Low life satisfaction									
No	85.7	85.1	83.1	82.9	82.1	83.8	75 654	125.0	<0.001
Yes	14.3	14.9	16.9	17.1	17.9	16.2	15 838		
Total	100	100	100	100	100	100	91 492		
Low self-rated health (fair or poor)									
No	87.1	84.1	83.8	82.9	82.9	84.2	76 843	161.4	<0.001
Yes	12.9	15.9	16.2	17.1	17.1	15.8	15 805		
Total	100	100	100	100	100	100	92 648		
Socioeconomic position									
Mean (SD)	0.5 (0.29)	0.5 (0.29)	0.5 (0.29)	0.5 (0.29)	0.5 (0.31)	0.5 (0.30)	89 290		

Abbreviation: SD, standard deviation.

Note: Chi-squares and *p*-values show whether there are significant differences ($p<0.05$) between survey cycles.

Life satisfaction

Life satisfaction was measured using Cantril's analog scale,[38] with adolescents shown an image of a ladder and asked, "In general, where on the ladder do you feel you stand at the moment?" The scale runs from 0 (worst possible life) to 10 (best possible life).[38] The measure has been found to be a valid measure of life satisfaction among adults and adolescents.[17] Adolescents who reported a score of 5 or less were considered to have low life satisfaction.[28]

Self-rated health

Self-rated health was measured using the question "Would you say your health is: excellent, good, fair, or poor?" This measure is a stable construct over time, and the score is low when well-being is low.[39] We used fair or poor health as a dichotomous measure of self-rated health.

Socioeconomic position and gender measures (independent variables)

SEP was estimated using the HBSC Family Affluence Scale, a multi-item measure of material assets (number of cars, having own bedroom, number of computers, number of bathrooms, family holidays in the past year, and having a dishwasher).[40] The number of items increased from four to six in 2014 with the addition of number of bathrooms in the home and ownership of a dishwasher to the list in the measure. The total score was harmonized in the form of a reversed proportional rank (ridit score) of material deprivation, which yields a continuous score from 0 (least deprived or highest SEP) to 1 (most deprived or lowest SEP).[41] This transformation supported the use of a slope index of inequality (SII), which represented the rate difference in health between highest and lowest SEP (or between males and females).[42] Sample weights were applied to the transformation to support an accurate interpretation of the distribution of SEP, which had a mean of 0.5 points and a theoretical range of 1 point.

Gender was assessed using the question "Are you male or female?" with the answer options "male" or "female."

Statistical analyses

Summary statistics for the sample consisted of frequencies, counts and chi-square tests for categorical variables and mean and standard deviation (SD) estimates for continuous variables, across each of the survey cycles. We also assessed the prevalence of the health outcomes at each survey cycle by gender. For each variable and survey cycle, we used logistic regressions to estimate rate differences in health between highest and lowest SEP and between gender groups, while controlling for age and family structure (coded as two-parent family, one-parent family or other), and then multiplied this value by 100 to represent the predicted rate difference per 100 cases.

We tested interactions of SEP and gender across each survey cycle to assess trends in health inequality over time and graphed predicted values of the health measures at the lowest, mean and highest SEP across the survey cycles and for males and females across the survey cycles. All analyses used standardized weights and accounted for the sampling design effect of school clusters using the *svy* toolkit in STATA statistical software version 16.0 (StataCorp LP, College Station, TX, US). Data weights were applied, first within provincial or territorial samples to ensure balanced representations of regions and school types (e.g. public vs. Catholic school boards), then nationally to ensure that representation of the Canadian population was balanced. We also applied post-stratification weights to equalize the importance of each survey cycle to the analysis. The level of significance was set at $p < 0.05$.

Results

Females and males participated equally in the survey (52.1% vs. 47.9%), and the mean (SD) age was 14.0 (1.4) years (see Table 1 for a summary of the characteristics of Canadian participants in the HBSC study from 2002 to 2018). More adolescents reported living in a two-parent family (80.2%) than a one-parent family (16.9%) or other arrangement (2.9%). Three-quarters (76.6%) of adolescents reported no daily physical activity, 22.1% had excess body weight, 26.0% reported physical complaints, 41.1% reported psychological complaints, 16.2% reported low life satisfaction and 15.8% reported low self-rated health (Table 1).

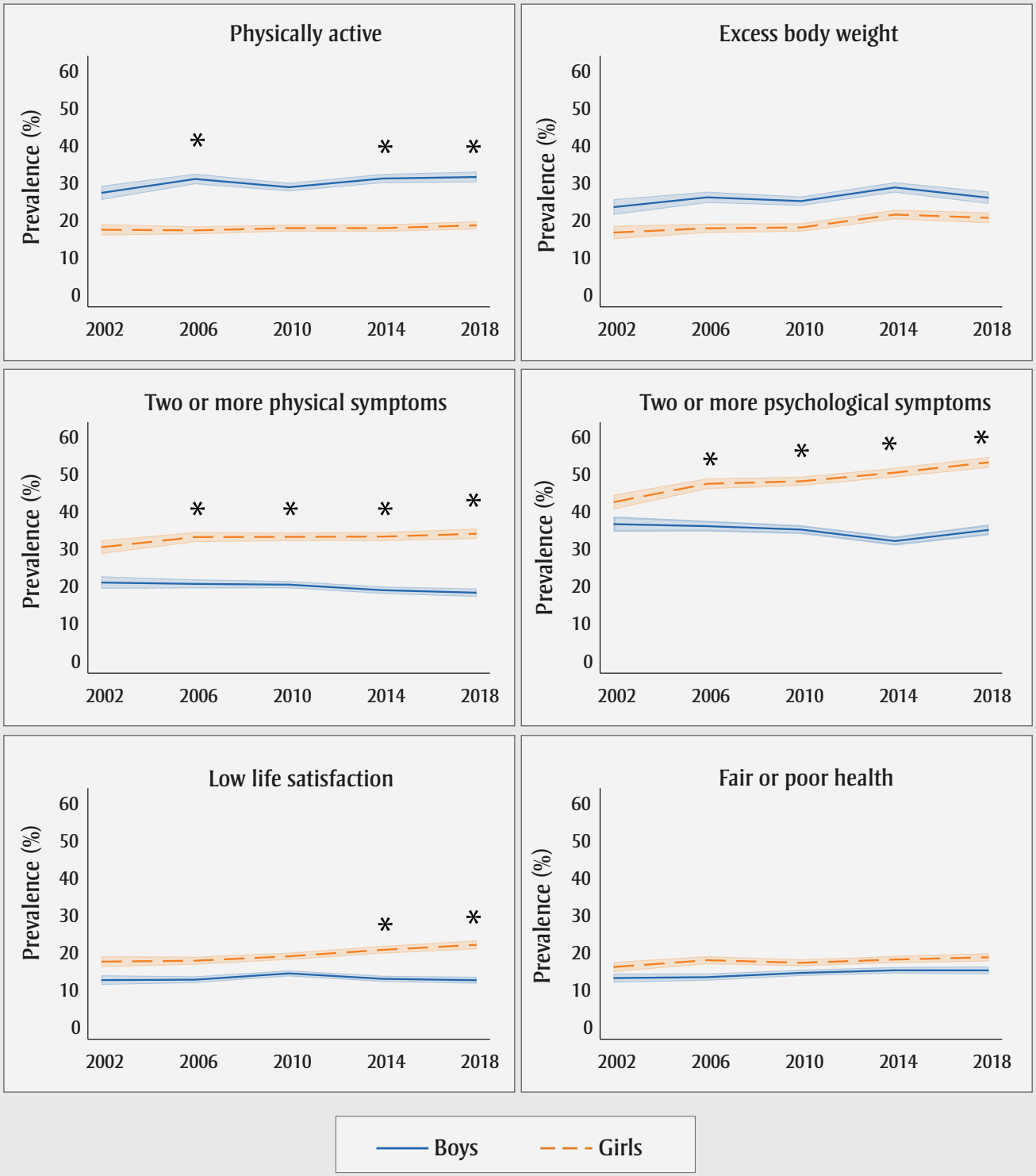
Relative to males, females reported worse health in all of the six health domains measured in the HBSC except excess body weight, which was more prevalent among males (see Figure 1). Gender gaps in trends in health were mostly consistent over time, although differences in physical and psychological symptoms and low life satisfaction widened in later survey cycles.

Relative to males in 2002, females reported higher prevalence of two or more physical symptoms and two or more psychological symptoms at each survey year, with this relative prevalence increasing over time (see Table 2). In 2018, females relative to their male counterparts in 2002 were less active by 3.06%. Also, 6.32% more females reported physical symptoms, 12.17% more females reported psychological symptoms and 4.53% more females reported low life satisfaction. More females also reported low life satisfaction, relative to their male counterparts in 2002, in 2014 (2.82%) and 2018 (4.53%), with the gender gap also widening for this health domain. Relative to their male counterparts in 2002, fewer females reported meeting daily physical activity in 2006 (3.88%), 2014 (3.40%) and 2018 (3.06%). The prevalence of excess body weight and low self-rated health did not significantly differ between gender groups.

Figure 2 shows the prevalence estimates of the six health domains across the range of SEP. Significant differences were found in five health domains, with adolescents at the highest SEP having higher odds than their peers at the lowest SEP of daily physical activity and lower odds of excess body weight, psychological symptoms, low life satisfaction, and fair or poor health. The prevalence of physical symptoms did not differ between socioeconomic groups. In addition, health inequalities widened between the lowest and highest SEP groups in four domains: excess body weight, physical symptoms, low life satisfaction, and fair or poor health. In Figure 2, these trends are reflected as a fanning out of prevalence estimates over time.

Relative to adolescents at the highest SEP in 2002, their counterparts at the lowest SEP had higher prevalence of excess body weight in 2014 and 2018; two or more physical symptoms in 2018; low life satisfaction in 2014; and low self-rated health in 2014 and 2018 (Table 3). Adolescents at the lowest SEP in the most recent survey cycles (2014 and 2018) show that the SEP gap widened in three health domains over

FIGURE 1
Gender differences in six health domains among Health Behaviour in School-aged Children study participants, Canada, 2002–2018 (n = 94 887)



Notes: The lines represent linear trends over time.

Prevalence estimates were weighted and adjusted for age, socioeconomic position and family structure (two parent, one parent or other). Asterisks indicate a significantly larger gender difference in that survey cycle compared to 2002.

TABLE 2
Percent differences in health outcomes[a] across gender per survey cycle among Health Behaviour in School-aged Children study participants, Canada, 2002–2018

Survey cycle	% (95% CI)					
	Daily physical activity	Excess body weight	Two or more physical symptoms	Two or more psychological symptoms	Low life satisfaction	Low self-rated health
2002 (Ref.) × Male (Ref.)	–	–	–	–	–	–
2006	−3.88* (−6.85, −0.91)	−1.49 (−4.84, 1.87)	3.07* (0.03, 6.10)	5.45** (1.99, 8.92)	0.13 (−2.22, 2.49)	1.60 (−0.67, 3.87)
2010	−1.09 (−3.91, 1.73)	−0.25 (−3.47, 2.96)	3.34* (0.46, 6.22)	7.03*** (3.74, 10.31)	−0.35 (−2.64, 1.94)	−0.24 (−2.39, 1.90)
2014	−3.40* (−6.21, −0.53)	−0.44 (−3.75, 2.87)	4.89** (2.00, 7.78)	12.42*** (9.11, 15.74)	2.82* (0.51, 5.14)	−0.07 (−2.24, 2.11)
2018	−3.06* (−6.08, 0.00)	1.44 (−2.08, 4.95)	6.32*** (3.29, 9.34)	12.17*** (8.68, 15.65)	4.53*** (2.10, 6.96)	0.55 (−1.77, 2.87)
Linear trend	−0.01 (−0.01, 0.00)	0.00 (0.00, 0.01)	0.01*** (0.01, 0.02)	0.03*** (0.02, 0.04)	0.03** (0.01, 0.05)	0.00 (−0.01, 0.00)
Number of observations	85 821	58 298	87 241	87 241	85 266	86 155

Abbreviations: CI, confidence interval; Ref., reference.

[a] Shown as beta coefficients of the interaction between survey cycle and gender associated with each health measure. Regression models controlled for the main effects of socioeconomic position, age, family structure (two parent, one parent or other), survey cycle and gender.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

time. This indicates that gaps in social inequalities become apparent slowly over time. The prevalence of daily physical activity and psychological symptoms did not significantly differ across SEP.

Discussion

Socioeconomic and gender inequalities in health among children and adolescents track into adulthood yet remain a neglected area in health policy.[4] Our analysis of data from the Canadian HBSC study examined health inequalities over 16 years across six consistently measured health domains in nationally representative samples of adolescents. We found that health inequalities in socioeconomic and gender groups either increased or remained stable in multiple health domains. Specifically, females and adolescents at lower SEP experienced worse health indicators at several survey cycles, relative to male and more affluent counterparts, respectively. These trends point to the potential for persisting or worsening health inequalities in the adult population in the future.

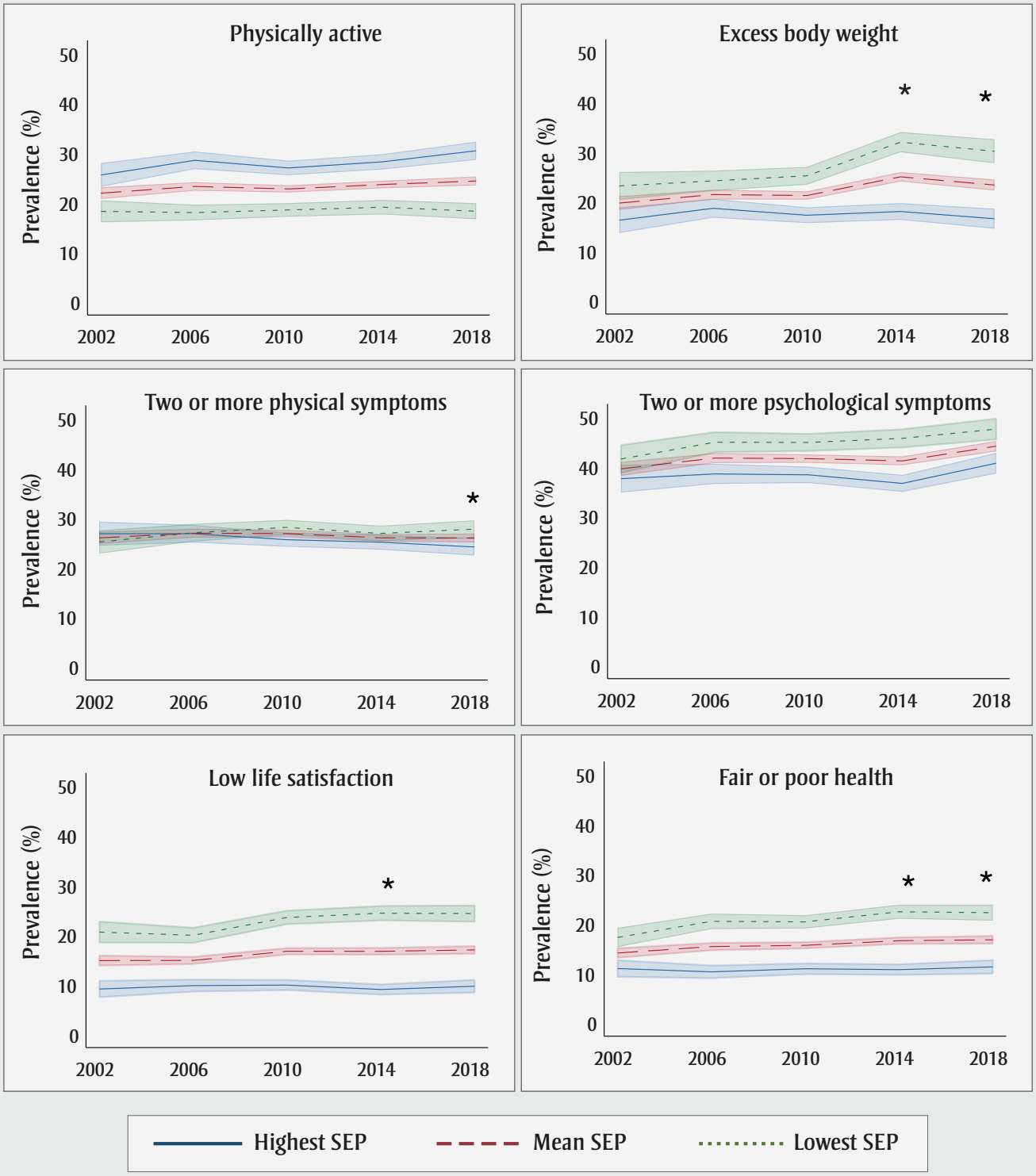
These trends had been previously established for overall health among adults in Canada,[8] for psychological symptoms among adolescents in Canada[10] and, recently, for mental health among adolescents across over 70 countries.[28,43,44] Our study added to the literature with the observation that gender differences and inequalities were widening over time among Canadian adolescents in terms of daily physical activity, physical and psychological symptoms, and low life satisfaction. The increase in psychological symptoms among females is thought to stem from earlier physical maturation, greater stress and greater social pressures perceived by females.[45,46]

We found that socioeconomic inequalities had increased in excess body weight, physical symptoms, low life satisfaction and poor/fair self-rated health among adolescents in Canada. International reports on adolescent and adult health have also shown that socioeconomic inequalities are associated with worsening and widening socioeconomic gaps in overall health[5-7,26] and mental health or psychological symptoms.[8,10,47] Evidence suggests that stress, health behaviours and psychosocial factors drive these social patterns, in part. The social cause theory of health disparities argues that social inequalities in health are the result of social conditions.[48,49] For instance, in their editorial, Link and Phelan[48] proposed that low SEP influences multiple disease outcomes through numerous risk factors as well as by limiting access to health care.[48]

These health differences among adolescents are a concern for population health, policy and practice. There is strong evidence to support strategic investments in programs that identify the unique social challenges and stressors experienced by adolescent girls. Programs that promote gender equity among adolescents can help reduce gender disparity in health, especially when they leverage multisectoral initiatives and community partnerships.[50,51]

We also support interventions similar to universal basic income (i.e. regular, unconditional payments made to individuals or households) as new evidence shows their positive effects on health.[52] Interventions that address the social, economic and physical environments using a cross-sectoral approach are working for adults,[53] but more evidence is needed on effective population-level interventions that address socioeconomic inequalities among adolescents.[54]

FIGURE 2
Socioeconomic differences in six health domains among Health Behaviour in School-aged Children study participants, Canada, 2002–2018 (n = 94 887)



Abbreviation: SEP, socioeconomic position.

Notes: The lines represent linear trends over time.

Prevalence estimates were weighted and adjusted for age, gender and family structure (two parent, one parent or other). Asterisks indicate significantly larger socioeconomic difference in that survey cycle compared to 2002.

TABLE 3
Percent differences in health outcomes[a] across SEP per survey cycle among Health Behaviour in School-aged Children study participants, Canada, 2002–2018

Survey cycle	Rate (95% CI)					
	Daily physical activity	Excess body weight	Two or more physical symptoms	Two or more psychological symptoms	Low life satisfaction	Low self-rated health
2002 (Ref.) × Highest SEP	–	–	–	–	–	–
2006	−3.19 (−8.07, 1.68)	−1.38 (−7.12, 4.36)	1.87 (−3.23, 6.97)	2.42 (−3.53, 8.36)	−1.33 (−5.30, 2.63)	3.91 (0, 7.82)
2010	−1.12 (−5.75, 3.51)	1.04 (−4.44, 6.51)	4.17 (−0.62, 8.95)	2.55 (−3.07, 8.18)	2.15 (−1.65, 5.94)	3.19 (−0.52, 6.89)
2014	−1.80 (−6.50, 2.90)	7.06* (1.43, 12.69)	3.45 (−1.38, 8.30)	5.10 (−0.60, 10.80)	3.90* (0.071, 7.74)	5.41** (1.69, 9.13)
2018	−4.85 (−9.77, 0.71)	6.67* (0.67, 12.67)	5.27* (0.20, 10.33)	2.90 (−3.10, 8.92)	3.16 (−0.89, 7.21)	4.65* (0.67, 8.62)
Linear trend	−0.01 (−0.02, 0.00)	0.02** (0.01, 0.04)	0.01* (0.00, 0.02)	0.01 (0.00, 0.02)	0.01* (0.00, 0.02)	0.01* (0.00, 0.02)
Number of observations	85 821	59 298	87 241	87 241	85 266	86 155

Abbreviations: CI, confidence interval; Ref., reference; SEP, socioeconomic position.

[a] Shown as beta coefficients of the interaction between survey cycle and SEP associated with each health measure. Regression models controlled for the main effects of gender, age, family structure (two parent, one parent or other), survey cycle and SEP.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

Strengths and limitations

Strengths of this study include a large representative sample from across Canada. Rather than using subjective measures of perceived wealth, as done in previous studies,[11] we used an objective measure of material assets in the home and standardized the scores across survey years.[41,42] We used a wide array of physical and mental health measures, which nevertheless all pointed to the same conclusion: that there are gender and socioeconomic inequalities in health, and some are widening over time. Our use of the slope index of health inequality (SII) to measure SEP is important because it takes into consideration increasing affluence (i.e. inflation) over the survey cycles and because the index highlights differences in health between the highest and lowest SEP groups.[41]

Interpretations of these findings should take into account the limitations of this study. First, we used subjective, self-report measures of health. This is a valid approach for many health domains, including height and weight (used for zBMI estimates).[55] However, there was a large percentage of missing zBMI and, as a result, we recommend caution when interpreting inequalities in excess body weight.

Second, although these results are representative of adolescents in Canada, the global generalizability of the findings is limited because this report used a probability sample of Canadian adolescents. Third, the repeated, cross-sectional design did not allow for the investigation of early-life experiences that may influence health.

Fourth, gender was measured using a binary variable (female versus male) from 2002 to 2010, which may have miscategorized individuals who identify as nonbinary. The HBSC study added a third option for gender (answer option: "neither describes me") in 2018.[56]

Fifth, the Family Affluence Scale collects data that are granular and less sensitive to socioeconomic differences among more affluent adolescents and therefore may produce estimates of health inequality that differ from those measured using household income, parental occupation or other SEP indicators.[41]

Lastly, we did not include race/ethnicity in our analyses as this characteristic was unavailable for the 2006 survey cycle and it was inconsistently measured in the other survey cycles. This is a limitation as there are systematic inequalities in health associated with race/ethnicity that are interconnected with SEP.[57]

Conclusion

There are persistent and widening health inequalities across SEP and gender among adolescents in Canada. Adolescent females reported more physical and psychological symptoms as well as lower life satisfaction and lower daily physical activity, relative to their male counterparts. Adolescents at the lowest SEP were most likely to experience excess body weight, frequent physical and psychological symptoms, low life satisfaction and fair or poor health. Future research may consider the intersectional role of gender and SEP and their association with health outcomes. To address social inequalities in health during this formative stage of the life course, policies directed at basic income and disparities in health, gender and social conditions are of utmost importance.

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Conflicts of interest

The authors declare no conflicts of interest.

Authors' contributions and statement

NH interpreted the results and undertook writing of the original draft.

NH and FE conceptualized the study and conducted the formal analysis and visualizations.

FE provided ideas and thoughts for discussion.

MADS contributed to the data curation.

FE and MADS revised the manuscript for important intellectual content and supported NH in writing – reviewing and editing.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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Original quantitative research

Patterns and determinants of adherence to colorectal cancer primary and secondary prevention recommendations in the BC Generations Project

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Abstract

Introduction: Adherence to cancer prevention recommendations can greatly reduce colorectal cancer risk. This study explored patterns and determinants of adherence to these recommendations by participants (n = 26 074) at baseline in a cohort study in British Columbia, Canada.

Methods: Adherence to five colorectal cancer primary prevention behaviours derived from Canadian Cancer Society/World Cancer Research Fund recommendations (nonsmoking, body mass index (BMI), physical activity, alcohol consumption and fruit and vegetable consumption) was measured, and a composite score constructed based on their sum. The definition of secondary prevention adherence was based on the Canadian Task Force on Preventive Health Care recommendations for colorectal cancer screening.

Results: Adherence to primary prevention guidelines ranged from 94.8% (nonsmoking) to 44.2% (healthy BMI). Median composite score was 4. Higher composite scores were associated with being female, being married and with a higher educational attainment. Colorectal cancer screening adherence was 62.4%. Older age, chronic conditions, a recent medical examination and higher income were associated with greater odds of adherence to screening.

Conclusion: Adherence to some colorectal cancer prevention behaviours was high, consistent with findings that British Columbia has low rates of many risky health behaviours. However, there was a clustering of poorer adherence to prevention behaviours with each other and with other risk factors. Screening adherence was high but varied with some sociodemographic and health factors. Future work should evaluate targeted interventions to improve adherence among those in the lowest socioeconomic status and health groups. A better understanding is also needed of the barriers to access and engagement with colorectal cancer screening that persist even in the Canadian public health care system.

Keywords: *CRC, lifestyle, screening, health behaviours, guideline adherence*

Highlights

- Adherence to colorectal cancer primary prevention guidelines ranged from 94.8% to 44.2% according to the targeted behaviours.
- Adherence to individual colorectal cancer primary prevention guidelines varied with demographic factors. For example, women were significantly more adherent to nonsmoking, fruit and vegetable consumption and body mass index guidelines, but significantly less adherent to alcohol and physical activity recommendations.
- Adherence across all primary prevention recommendations was higher among women, those who were married and those who had more education.
- Adherence to screening guidelines was 62.4%.
- Older participants, those with chronic conditions, higher income and more recent medical exams were more likely to undertake colorectal cancer screening.

Introduction

In 2019, 26 300 Canadians were diagnosed with colorectal cancer, making it the third most common cancer in the country.[1] According to the World Cancer Research Fund (WCRF), over a third of all cancers, including colorectal cancer, are preventable through adherence to healthy behaviours: being physically active, maintaining a healthy body mass index (BMI), avoiding smoking and excessive alcohol consumption, and eating a diet high in fruit and vegetables and low in processed and red meat.[2] The WCRF developed a set of guidelines to inform cancer primary prevention policy.[3] Several other bodies, including the Canadian Cancer Society, have produced similar recommendations.[4]

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Secondary prevention (i.e. screening*) of colorectal cancer has also proved to be effective at reducing colorectal cancer mortality.[5] Screening for colorectal cancer in asymptomatic adults through fecal occult blood tests (FOBT) every 2 years or flexible sigmoidoscopy every 10 years has been shown to reduce mortality by approximately 30% as the disease is identified at an early, more treatable stage.[6] The Canadian Taskforce on Preventive Health Care (CTFPHC) recommends colorectal cancer screening for all average-risk adults between the ages of 50 and 74 years using these testing modalities.[6] Behaviour is key to the success of screening programs as these require consistent engagement to achieve the high levels of participation necessary for effective population-level prevention and early detection.

Despite the weight of evidence demonstrating the importance of health behaviours in both primary and secondary prevention of colorectal cancer, adherence to health behaviour recommendations is suboptimal. In Canada, only 17.6% of adults met physical activity guidelines in 2015,[7] and 15% of the overall population report daily or occasional smoking.[8] Direct measurements of BMI in a 2012–2013 national survey found that 62% of Canadians were in either the overweight or obese category,[9] and in 2016, between 7.2% and 16.2% of Canadians (depending on the province) exceeded low-risk drinking guidelines.[10] The most recent figures from the Canadian Community Health Survey (CCHS) also indicate that, depending on the province, between 41.3% and 67.2% of Canadians targeted for colorectal cancer screening adhere to CTFPHC guidelines.[11]

Given this low adherence to recommendations, public health intervention is needed to reduce colorectal cancer risk and mortality. For interventions to be successful, they must be grounded in an understanding of the target populations. While data concerning patterns and predictors of specific risk factors are important, it is also useful to examine overall lifestyle to generate risk profiles.[12]

Some research has attempted to generate risk profiles by constructing composite scores based on adherence to multiple individual health behaviours. Through our population cohort-based cross-sectional analysis, we built on this work by examining (1) the prevalence of adherence to individual colorectal cancer primary prevention behaviours; (2) overall adherence to colorectal cancer primary prevention behaviours; and (3) adherence to colorectal cancer secondary prevention behaviours (i.e. screening guidelines).

We also explored factors associated with these three objectives that would improve the understanding of patterns of adherence to colorectal cancer prevention behaviours in British Columbia, and inform interventions to improve adherence in the province.

Methods

Data

We obtained baseline study data from the BC Generations Project (BCGP),[13] a regional longitudinal cohort of the Canadian Partnership for Tomorrow's Health (CanPath), Canada's largest health cohort study.[14] Recruitment of 28 825 participants to the BCGP occurred between 2009 and 2016, with follow-up planned for 50 years. A questionnaire was administered at baseline, along with self-reported or objective physiological measures and biological samples. Recruitment was restricted to those aged 35 to 69 years, and invitation to participate was via mailed or emailed personal letters. Ethics approval for the analyses reported here was received from the University of British Columbia's Research Ethics Board (H17-03561). All analyses were conducted using R version 3.6.2.[15]

Analytic samples

Of the 28 825 participants, 2751 were excluded because they had a diagnosis of cancer (other than non-melanoma skin cancer) recorded on the BC Cancer Registry prior to enrolment. The remaining 26 074 were assessed for colorectal cancer prevention behaviour adherence. All dependent variables, and most covariates, had missing data, between 0% (for age and sex) and 20.6% (for BMI). Some observations were missing because participants failing to respond to particular questions. It was unlikely responses were "missing completely at random" and results would be biased if a complete case analysis were performed;[16] in addition, a large number of participants (n = 9687) would be excluded.

As "missing at random" was a more plausible assumption in our scenario, we imputed values for missing data on dependent and covariates of interest using a multiple imputation by chained equations (mice) approach.[17] A total of 20 imputation datasets was created, with 10 iterations per imputation in line with literature recommendations.[18] We estimated the parameters of interest in each imputed dataset individually. The results from these 20 imputed datasets were combined (i.e. pooled) using Rubin's rules.[19] All analyses were performed using the R mice package.[20]

As dependent variables were imputed, we used a multiple imputation then deletion (MID) approach, as outlined by von Hippel.[21] According to the MID approach, all dependent variables are included in the imputation process, but cases with missing outcome data are removed before conducting the pooled analysis. As a result, the number of cases available for regression analysis for each dependent variable differed, ranging from 14 583 for colorectal cancer screening to 25 746 for non-smoking. The analysis of the composite score (detailed below) was restricted to cases with outcome data for all five colorectal cancer primary prevention behaviours (n = 18 233). The analysis of colorectal cancer secondary prevention behaviours was limited to participants meeting colorectal cancer screening criteria with complete colorectal cancer screening data (n = 14 583).

Study variables

Primary prevention outcome variables

We reviewed the Canadian Cancer Society and WCRF recommendations for cancer prevention strategies to define the binary outcome variables for adherence to each colorectal cancer primary prevention behaviour (see Table 1), using data from participants with complete data for all primary prevention outcomes.

* Colorectal cancer screening can function as both primary prevention (removal of precancerous polyps) and secondary prevention (removal of adenomas). We use "screening" interchangeably with "secondary prevention" to distinguish between life-long primary prevention behaviours and periodic colorectal cancer screening behaviours, in keeping with how these terms are usually used in the literature.

TABLE 1
The Canadian Cancer Society and World Cancer Research Fund recommendations on colorectal cancer prevention and translation to adherence score in the BCGP

Prevention behaviour	CCS risk reduction recommendations	WCRF cancer prevention recommendations	Operationalization	BCGP adherence score	Adherent, n (%)	Missing, n (%)
Smoking	Live smoke-free	Not smoking/using any form of tobacco Avoiding exposure to tobacco smoke	Current nonsmoker/past smoker	1	24 348 (93.3)	328 (1.26)
			Daily or occasional smoker	0		
BMI	Have a healthy body weight	Keep your weight as low as you can within the healthy range throughout life (BMI = 18.5–24.9)	BMI = 18.5–25 kg/m^2	1	9149 (35.1)	5365 (20.6)
			BMI ≠ 18.5–25 kg/m^2	0		
Physical activity	Be less sedentary and move more throughout the day	Be at least moderately physically active and follow or exceed national guidelines Limit sedentary habits	≥600 MET-minutes[a] per average week	1	19 301 (74.0)	4431 (17.0)
			<600 MET-minutes[a] per average week	0		
Alcohol consumption	If you choose to drink, keep it to less than 1 drink a day for women and less than 2 drinks a day for men	For cancer prevention, it's best not to drink alcohol If you do consume alcohol, do not exceed national guidelines	≤2 drinks a day for men, ≤1 drink a day for women	1	22 265 (85.4)	585 (2.2)
			>2 drinks a day for men, >1 drink a day for women	0		
Diet	Eat well	Eat a diet high in all types of plant foods including at least 5 portions or servings (at least 400 g or 15 oz in total) of a variety of non-starchy vegetables and fruit every day Consume a diet that provides at least 30 g per day of fibre from food Include foods containing wholegrains, non-starchy vegetables, fruit and pulses in most meals	≥5 servings of fruits and vegetables per average day	1	16 729 (64.2)	208 (0.8)
			<5 servings of fruits and vegetables per average day	0		
	–	Do not consume sugar-sweetened drinks High-dose dietary supplements are not recommended for cancer prevention If you eat red meat, limit consumption to no more than 3 portions per week Consume very little, if any, processed meat	Not included			

Abbreviations: BCGP, BC Generations Project; BMI, body mass index; CCS, Canadian Cancer Society; MET, metabolic equivalent minutes; WCRF, World Cancer Research Fund.

[a] Metabolic equivalent of task multiplied by the number of minutes engaging in said task, summed across the week.

The definition of adherence to low alcohol consumption was based on average drinks per day and participant sex. The definition of nonsmoking adherence was based on current smoking status; never smokers and past smokers were classed as adherent. The definition of adherence to fruit and vegetable consumption was based on fruit, vegetable and 100% fruit juice consumption daily. BMI adherence was based on health practitioner–measured BMI when available and self-reported BMI otherwise. The definition of physical activity was based on responses to either the short- or long-form *International Physical Activity Questionnaire* (IPAQ),[22] depending on which version participants had completed, in metabolic equivalent minutes.

Composite adherence score for colorectal cancer primary prevention outcome variables

We calculated a composite score by summing participant adherence to each of the five individual colorectal cancer primary prevention adherence variables, that is, fruit and vegetable consumption, BMI, alcohol, physical activity and nonsmoking. This was computed using data from participants with complete primary prevention outcome data.

Colorectal cancer secondary prevention outcome variables

Adherence to secondary prevention behaviours was limited to all participants with complete data for colorectal cancer screening who met CTFPHC standard screening criteria. Participants were coded as adherent if they had undergone an FOBT within the previous 2 years or flexible sigmoidoscopy/colonoscopy within the previous 10 years. Different versions of the BCGP questionnaire asked about flexible sigmoidoscopy and colonoscopy, either separately or as the same item, so we used a combined measure of undergoing either procedure.

Covariates of interest

The variables used to examine adherence to primary prevention behaviours were age, sex, marital status, highest level of education, household income, perceived health, time since last routine medical

check-up, family history of colorectal cancer, personal history of colorectal cancer-related conditions, ethnicity and chronic conditions. The same variables were examined for association with secondary prevention (i.e. screening guidelines) adherence with the exception of family history of colorectal cancer and personal history of colorectal cancer-related conditions. Primary prevention behaviours were also examined for association with secondary prevention adherence.

Analysis

For adherence to individual primary prevention behaviours, we compared the characteristics of those with complete data for the outcome variables (n = 18 233) based on adherence to different behaviours using chi-square tests. Following the MID approach, we conducted multivariable logistic regressions to calculate the association between each covariate of interest and each colorectal cancer primary prevention behaviour. Adjusted linear regression models were also completed for the composite adherence score measure and the covariates.

We used descriptive statistics to examine the characteristics of the sample assessed for colorectal cancer secondary prevention (i.e. screening guidelines; n = 14 583). A multivariable logistic regression was conducted for each covariate of interest and colorectal cancer screening.

Results

Descriptive statistics

Colorectal cancer primary prevention sample covariates

Most participants in the sample with complete primary prevention data were women (68.5%), and the mean (SD) age was 55 (8.9) years. The majority (76.8%) were married and White (84.3%) and had post-high school education (81.6%) and an annual household income of CAD 75 000 to 150 000 (39.8%). The majority (94.4%) described their health as good, very good or excellent. A third of participants (32.7%) reported one chronic condition, and 29.1% had two or more chronic conditions. Over a quarter (28.0%) were overweight, and 15.3% were obese.

Colorectal cancer primary prevention outcomes

Most participants adhered to primary prevention advice on smoking (94.8%), alcohol (86.6%) and physical activity (88.9%). Adherence to diet and weight–related variables was lower: just 44.2% of participants had a healthy BMI (18.5–24.9 kg/m^2), and 66.7% met recommended fruit and vegetable consumption intake guidelines. Many of the demographic and health variables differed significantly between participants who were adherent and nonadherent to colorectal cancer primary prevention behaviours (see Table 2).

Composite colorectal cancer primary prevention adherence score

The median composite score was 4. The mean (SD) value was 3.8 (0.9), and 25% of participants had the maximum score of 5.

Colorectal cancer secondary prevention covariates.

Participants in the colorectal cancer secondary prevention behaviour sample were mostly women (68.0%), and the mean (SD) age was 59 (5.5) years. The majority were married (74.9%) and White (88.1%) and had post-high school education (79.0%). The most common household income range was CAD 75 000–150 000 (38.8%).

Participants were healthy; 94.2% described their health as good, very good or excellent. Chronic conditions were more common than in the colorectal cancer primary prevention sample; 33.4% of participants reported one chronic condition, and 31.8% had two or more chronic conditions. Nearly a third of participants (28.9%) were overweight and 15.9% were obese (data not shown).

Colorectal cancer secondary prevention outcomes

Adherence to secondary prevention behaviours was 62.4%; 43.4% of participants had undergone an FOBT in the previous 2 years, and 36.4% had undergone a flexible sigmoidoscopy/colonoscopy in the previous 10 years (some had undergone both). Many of the demographic and health variables differed significantly between participants who were adherent and nonadherent to the secondary prevention behaviours (see Table 2).

Regression results

Hosmer and Lemeshow tests for each adjusted model of colorectal cancer primary prevention behaviours showed that the models were well-calibrated (p-values >0.05) across all imputed datasets. The mean area under the curve (AUC) for each adjusted model across all imputed datasets was between 0.61 (alcohol adherence) and 0.73 (nonsmoking adherence). Most Hosmer and Lemeshow tests (18 across 20 imputed datasets) were nonsignificant for the adjusted secondary prevention behaviour model.

Multivariable modelling of the colorectal cancer primary prevention behaviours

Women had higher odds than men of being nonsmokers (1.24; 95% confidence limits [CL]: 1.09, 1.40; $p < 0.001$), achieving recommended fruit and vegetable consumption levels (2.34; 95% CL: 2.21, 2.48; $p < 0.001$) and having a healthy BMI (2.49; 95% CL: 2.33, 2.66; $p < 0.001$). Conversely, women had lower odds of being adherent to alcohol (0.66; 95% CL: 0.60, 0.72; $p < 0.001$) and physical activity (0.88; 95% CL: 0.80, 0.97; $p < 0.01$) recommendations (see Table 3). Higher household income was associated with higher odds of being a nonsmoker and lower odds of BMI and alcohol intake adherence relative to those in the lowest household income category. Higher educational attainment was also associated with higher odds of nonsmoking and adherence to alcohol and fruit and vegetable consumption guidelines relative to those with an elementary school education or less. Multimorbidity was associated with lower odds of BMI adherence, and family history of colorectal cancer was associated with higher odds of being a nonsmoker (1.26; 95% CL: 1.03, 1.53; $p < 0.05$) relative to those with no such history (see Table 3).

Modelling composite scores

The composite score for women was 0.34 points higher (95% CL: 0.32, 0.37; $p < 0.001$) than for men (see Table 4). Unmarried participants had composite scores 0.08 points lower (95% CL: −0.12, −0.05; $p < 0.001$) than married participants. Composite adherence score increased with educational attainment and perceived healthiness. Those who self-reported excellent health had composite scores 0.93 points higher (95% CL: 0.77, 1.08; $p < 0.001$) than those in poor health. Similarly, multimorbidity was associated with lower composite scores relative to those with no chronic disease.

Multivariable modelling of colorectal cancer secondary prevention behaviours

Older participants had significantly higher odds of adhering to colorectal cancer

TABLE 2
Baseline characteristics of BCGP participants compared by adherence and nonadherence to each primary and secondary colorectal cancer prevention behaviour[a]

	Nonsmoking[b]			BMI[b]			Physical activity[b]			Alcohol consumption[b,c]			FVC[b,c]			Screening[d]		
	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n(%)	*p*	Ad, N (%)	Non, N (%)	*p*	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n (%)	*p*
Sex			0.57			<0.001			<0.001			<0.001			<0.001			0.28
Male	5435 (94.6)	308 (5.4)		1761 (30.7)	3982 (69.3)		5180 (90.2)	563 (9.8)		5108 (88.9)	635 (11.1)		3126 (54.4)	2617 (45.6)		2944 (63.0)	1730 (47.0)	
Female	11 847 (94.9)	643 (5.1)		6291 (50.4)	6199 (49.6)		11 028 (88.3)	1462 (11.7)		10 683 (85.5)	1807 (14.5)		9034 (72.3)	3456 (27.7)		6148 (62.0)	3761 (48.0)	
Age, years			<0.001			<0.001			0.09			<0.001			<0.01			<0.001
≥35 to <50	4737 (93.7)	320 (6.3)		2607 (51.6)	2450 (48.4)		4460 (88.2)	597 (11.8)		4525 (89.5)	532 (10.5)		3275 (64.8)	1782 (35.2)		N/A	N/A	
≥50 to <60	6000 (94.4)	357 (5.6)		2780 (43.7)	3577 (56.3)		5647 (88.8)	710 (11.2)		5476 (86.1)	881 (13.9)		4279 (67.3)	2078 32.7)		3880 (54.3)	3271 (45.7)	
≥60 to <70	6545 (96.0)	274 (4.0)		2665 (39.1)	4154 (60.9)		6101 (89.5)	718 (10.5)		5790 (84.9)	1029 (15.1)		4606 (67.5)	2213 (32.5)		5212 (70.1)	2220 (29.9)	
Marital status			<0.001			0.58			<0.01			<0.001			<0.001			<0.001
Married	13 431 (96.0)	564 (4.0)		6196 (44.3)	7799 (55.7)		12 501 (89.3)	1494 (10.7)		12 055 (86.1)	1940 (13.9)		9441 (67.5)	4554 (32.5)		6905 (63.3)	4010 (36.7)	
Unmarried	3790 (90.8)	382 (9.2)		1826 (43.8)	2346 (56.2)		3654 (87.6)	518 (12.4)		3677 (88.1)	495 (11.9)		2675 (64.1)	1497 (35.9)		2164 (59.6)	1464 (40.4)	
Missing	61 (92.4)	5 (7.6)		30 (45.5)	36 (54.5)		53 (80.3)	13 (19.7)		59 (89.4)	76 (10.6)		44 (66.7)	22 (33.3)		23 (57.5)	17 (42.5)	
Annual household income, CAD			<0.001			<0.001			<0.001			<0.001			<0.001			<0.001
<25 000	719 (85.5)	122 (14.5)		360 (42.8)	481 (57.2)		683 (81.2)	158 (18.8)		753 (89.5)	88 (10.5)		453 (53.9)	388 (46.1)		487 (57.2)	364 (42.8)	
25 000–49 999	2390 (92.5)	193 (7.5)		1043 (40.4)	1540 (59.6)		2237 (86.6)	346 (13.4)		2306 (89.3)	277 (10.7)		1667 (64.5)	916 (35.5)		1534 (62.0)	942 (38.0)	
50 000–74 999	3441 (94.9)	186 (5.1)		1519 (41.9)	2108 (58.1)		3226 (88.9)	401 (11.1)		3135 (86.4)	492 (13.6)		2362 (65.1)	1265 (34.9)		2005 (64.9)	1082 (35.1)	
75 000–150 000	6979 (96.1)	280 (3.9)		3197 (44.0)	4062 (56.0)		6495 (89.5)	764 (10.5)		6266 (86.3)	993 (13.7)		4953 (68.2)	2306 (31.8)		3271 (61.7)	2027 (38.3)	
≥150 000	2869 (96.0)	119 (4.0)		1496 (50.1)	1492 (49.9)		2740 (91.7)	248 (8.3)		2508 (83.9)	480 (16.1)		2089 (69.9)	899 (30.1)		1210 (62.3)	731 (37.7)	
Missing	884 (94.5)	51 (5.5)		437 (46.7)	498 (53.3)		827 (88.4)	108 (11.6)		823 (88.0)	112 (12.0)		636 (68.0)	299 (32.0)		585 (62.9)	345 (37.1)	

Continued on the following page

TABLE 2 (continued)
Baseline characteristics of BCGP participants compared by adherence and nonadherence to each primary and secondary colorectal cancer prevention behaviour[a]

	Nonsmoking[b]			BMI[b]			Physical activity[b]			Alcohol consumption[b,c]			FVC[b,c]			Screening[d]		
	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n(%)	*p*	Ad, N (%)	Non, N (%)	*p*	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n (%)	*p*
Education			<0.001			<0.001			<0.001			<0.01			<0.001			<0.01
≤Elementary	127 (82.5)	27 (17.5)		42 (27.3)	112 (72.7)		123 (79.9)	31 (20.1)		126 (81.8)	28 (18.2)		71 (46.1)	83 (53.9)		96 (61.9)	59 (38.1)	
High school	2921 (93.1)	217 (6.9)		1125 (35.9)	2013 (64.1)		2700 (86.0)	438 (14.0)		2690 (85.7)	448 (14.3)		1886 (60.1)	1252 (39.9)		1738 (60.2)	1149 (39.8)	
Post-high school training	6323 (93.6)	434 (6.4)		2721 (40.3)	4036 (59.7)		5951 (88.1)	806 (11.9)		5809 (86.0)	948 (14.0)		4349 (64.4)	2408 (35.6)		3561 (62.3)	2154 (37.7)	
Bachelor's	4624 (96.6)	164 (3.4)		2416 (50.5)	2372 (49.5)		4297 (89.7)	491 (10.3)		4221 (88.2)	567 (11.8)		3372 (70.4)	1416 (29.6)		2081 (62.3)	1260 (37.7)	
Postgraduate	3216 (97.0)	100 (3.0)		1712 (51.6)	1604 (48.4)		3062 (92.3)	254 (7.7)		2879 (86.8)	437 (13.2)		2432 (73.3)	884 (26.7)		1581 (65.5)	834 (34.5)	
Missing	71 (88.8)	9 (11.2)		36 (45.0)	44 (55.0)		75 (93.8)	5 (6.2)		66 (82.5)	14 (17.5)		50 (62.5)	30 (37.5)		35 (50.0)	35 (50.0)	
Ethnicity			0.13			<0.001			<0.001			<0.001			<0.001			<0.001
White	14 600 (95.0)	776 (5.0)		6676 (43.3)	8700 (56.6)		13 755 (89.5)	1621 (10.5)		13 173 (85.7)	2203 (14.3)		10 479 (68.2)	4897 (31.8)		7871 (63.2)	4578 (36.8)	
Other	2187 (94.2)	135 (5.8)		1176 (50.6)	1146 (49.4)		1971 (84.9)	351 (15.1)		2170 (93.5)	152 (6.5)		1332 (57.4)	990 (42.6)		935 (55.6)	748 (44.4)	
Missing	495 (92.5)	40 (4.2)		200 (37.4)	335 (62.6)		482 (90.1)	53 (9.9)		448 (83.7)	87 (16.3)		349 (65.2)	186 (34.8)		285 (63.3)	165 (36.7)	
General health			<0.001			<0.001			<0.001			<0.05			<0.001			0.58
Poor	103 (78.0)	29 (22.0)		36 (27.3)	96 (72.7)		73 (55.3)	59 (44.7)		120 (90.9)	12 (9.1)		62 (47.0)	70 (53.0)		73 (64.6)	40 (35.4)	
Fair	743 (86.6)	115 (13.4)		234 (27.3)	624 (72.7)		641 (74.7)	217 (25.3)		770 (89.7)	88 (10.3)		466 (54.3)	392 (45.7)		467 (63.5)	269 (36.5)	
Good	4538 (92.4)	373 (7.6)		1510 (30.7)	3401 (69.3)		4069 (82.9)	842 (17.1)		4278 (87.1)	633 (12.9)		2895 (58.9)	2016 (41.1)		2498 (61.8)	1547 (38.2)	
Very good	7826 (95.7)	351 (4.3)		3747 (45.8)	4430 (54.2)		7466 (91.3)	711 (8.7)		7050 (86.2)	1127 (13.8)		5625 (68.8)	2552 (31.2)		4033 (63.0)	2369 (37.0)	
Excellent	4007 (98.1)	79 (1.9)		2497 (61.1)	1589 (38.9)		3896 (95.3)	190 (4.7)		3512 (86.0)	574 (14.0)		3060 (74.9)	1026 (25.1)		1987 (61.7)	1231 (38.3)	
Missing	65 (94.2)	4 (5.8)		28 (40.6)	41 (59.4)		63 (91.3)	6 (8.7)		61 (88.4)	8 (11.6)		52 (75.4)	17 (24.6)		34 (49.3)	35 (50.7)	

Continued on the following page

TABLE 2 (continued)
Baseline characteristics of BCGP participants compared by adherence and nonadherence to each primary and secondary colorectal cancer prevention behaviour[a]

	Nonsmoking[b]			BMI[b]			Physical activity[b]			Alcohol consumption[b,c]			FVC[b,c]			Screening[d]		
	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n(%)	*p*	Ad, N (%)	Non, N (%)	*p*	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n (%)	*p*
Time since last routine medical exam			<0.001			<0.001			<0.05			0.22			<0.001			<0.001
<6 months	5225 (94.6)	296 (5.4)		2265 (41.0)	3256 (59.0)		4904 (88.8)	617 (11.2)		4739 (85.8)	782 (14.2)		3733 (67.6)	1788 (32.4)		3392 (71.4)	1360 (28.6)	
6 months to <1 year	5050 (95.7)	227 (4.3)		2391 (45.3)	2886 (54.7)		4755 (90.1)	522 (9.9)		4550 (86.2)	727 (13.8)		3583 (67.9)	1694 (32.1)		3011 (68.5)	1384 (31.5)	
1 to <2 years	3947 (94.9)	210 (5.1)		1904 (45.8)	2253 (54.2)		3681 (88.5)	476 (11.5)		3626 (87.2)	531 (12.8)		2781 (66.9)	1376 (33.1)		1849 (58.0)	1340 (42.0)	
2 to <3 years	1141 (94.0)	73 (6.0)		544 (44.8)	670 (55.2)		1069 (88.1)	145 (11.9)		1059 (87.2)	155 (12.8)		798 (65.7)	416 (34.3)		357 (39.4)	548 (60.6)	
≥3 years	1535 (93.0)	116 (7.0)		761 (46.1)	890 (53.9)		1445 (87.5)	206 (12.5)		1447 (87.6)	204 (12.4)		1030 (62.4)	621 (37.6)		387 (35.6)	700 (64.4)	
Never	147 (89.1)	18 (10.9)		79 (47.9)	86 (52.1)		145 (87.9)	20 (12.1)		145 (87.9)	20 (12.1)		90 (54.5)	75 (45.5)		26 (31.7)	56 (68.3)	
Missing	237 (95.6)	11 (4.4)		108 (43.5)	140 (56.5)		209 (84.3)	39 (15.7)		225 (90.7)	23 (9.3)		145 (58.5)	103 (41.5)		70 (40.5)	103 (59.5)	
Family history of CRC			<0.01			0.05			0.46			0.03			0.10			N/A
Yes	1934 (96.1)	79 (3.4)		847 (42.1)	1166 (57.9)		1800 (89.4)	213 (10.6)		1711 (85.0)	302 (15.0)		1376 (68.4)	637 (31.6)		N/A	N/A	
No	15 263 (94.6)	869 (5.4)		7157 (88.9)	8975 (55.6)		14 332 (88.8)	1800 (11.2)		14 000 (86.8)	2132 (13.2)		10 731 (66.5)	5401 (33.5)		9092 (62.3)	5491 (47.7)	
Missing	85 (96.6)	3 (3.4)		48 (54.5)	40 (45.5)		76 (86.4)	12 (13.6)		80 (90.9)	8 (9.1)		53 (60.2)	35 (39.8)		N/A	N/A	
Personal CRC-related history			<0.001			<0.001			<0.001			<0.001			<0.01			N/A
Yes	1973 (93.2)	143 (6.8)		818 (38.7)	1298 (61.3)		1835 (86.7)	281 (13.3)		1722 (83.7)	344 (16.3)		1355 (64.0)	761 (36.0)		N/A	N/A	
No	15 309 (95.0)	808 (5.0)		7234 (44.9)	8883 (55.1)		14 373 (89.2)	1744 (10.8)		14 019 (87.0)	2098 (13.0)		10 805 (67.0)	5312 (33.0)		9092 (62.3)	5491 (47.7)	

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TABLE 2 (continued)
Baseline characteristics of BCGP participants compared by adherence and nonadherence to each primary and secondary colorectal cancer prevention behaviour[a]

	Nonsmoking[b]			BMI[b]			Physical activity[b]			Alcohol consumption[b,c]			FVC[b,c]			Screening[d]		
	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n(%)	*p*	Ad, N (%)	Non, N (%)	*p*	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n (%)	*p*	Ad, n (%)	Non, n (%)	*p*
Chronic diseases			<0.001			<0.001			<0.001			<0.001			0.27			<0.001
0	6641 (95.7)	296 (4.3)		3542 (51.1)	3395 (48.9)		6294 (90.7)	643 (9.3)		6105 (88.0)	832 (12.0)		4580 (66.0)	2357 (34.0)		2907 (57.3)	2162 (42.7)	
1	5670 (95.2)	285 (4.8)		2605 (43.7)	3350 (56.3)		5347 (89.8)	608 (10.2)		5126 (86.1)	829 (13.9)		4016 (67.4)	1939 (32.6)		3066 (62.9)	1811 (37.1)	
2	3030 (94.6)	172 (5.4)		1267 (39.6)	1935 (60.4)		2818 (88.0)	384 (12.0)		2717 (84.9)	485 (15.1)		2153 (67.2)	1049 (32.8)		1808 (65.3)	961 (34.7)	
≥3	1912 (90.7)	197 (9.3)		619 (29.4)	1490 (70.6)		1725 (81.8)	384 (18.2)		1818 (86.2)	291 (13.8)		1390 (65.9)	719 (34.1)		1311 (70.2)	557 (29.8)	
Missing	29 (96.7)	1 (3.3)		19 (63.3)	11 (36.7)		24 (80.0)	6 (20.0)		25 (83.3)	5 (16.7)		21 (0.7)	9 (0.3)		N/A	N/A	

Abbreviations: Ad, adherent to prevention behaviour; BCGP, BC Generations Project; BMI, body mass index; CRC, colorectal cancer; FVC, fruit and vegetable consumption; Non, nonadherent to prevention behaviour.

[a] *p* values obtained from chi-square tests.

[b] The analysis described in first five columns of this table is limited to participants with complete data for all colorectal cancer primary prevention variables (i.e. smoking, alcohol intake, BMI, fruit and vegetable consumption and physical activity) who represented 69.9% of the total BCGP cohort with no previous diagnosis of cancer.

[c] Average daily consumption.

[d] The analysis presented in the final column was limited to those with complete data for colorectal cancer secondary prevention behaviour (i.e. screening), aged ≥50 years (based on the Canadian Task Force on Preventive Health Care recommending colorectal cancer screening only to people aged 50–74 years[6] and participation in the BCGP being limited to those aged 35–69 years) and of average risk of colorectal cancer as defined by the Canadian Task Force on Preventive Health Care. This analysis was also limited to those with complete data for colorectal cancer screening. This represented 55.9% of the total BCGP cohort with no previous diagnosis of cancer.

TABLE 3
Association between adherence to colorectal cancer primary prevention behaviours and potential predictors in the BCGP[a]

Factor	Odds ratios (95% confidence limits)				
	Nonsmoking	BMI	Physical activity	Alcohol	FVC
Sex					
Male	Ref.	Ref.	Ref.	Ref.	Ref.
Female	1.24 (1.09, 1.40)**	2.49 (2.33, 2.66)***	0.88 (0.80, 0.97)*	0.66 (0.60, 0.72)***	2.34 (2.21, 2.48)***
Age, years					
≥35 to <50	Ref.	Ref.	Ref.	Ref.	Ref.
≥50 to <60	1.40 (1.22, 1.60)***	0.86 (0.80, 0.93)***	1.23 (1.09, 1.37)***	0.78 (0.70, 0.86)***	1.17 (1.09, 1.26)***
≥60 to <70	2.16 (1.83, 2.54)***	0.79 (0.73, 0.86)***	1.29 (1.14, 1.45)***	0.71 (0.64, 0.79)***	1.25 (1.16, 1.34)***
Marital status					
Married	Ref.	Ref.	Ref.	Ref.	Ref.
Unmarried	0.52 (0.45, 0.59)***	0.90 (0.83, 0.97)**	1.02 (0.91, 1.15)	1.03 (0.93, 1.14)	0.85 (0.79, 0.91)***
Annual household income, CAD					
<25 000	Ref.	Ref.	Ref.	Ref.	Ref.
25 000–49 999	1.52 (1.25, 1.85)***	0.84 (0.71, 0.98)*	1.20 (0.99, 1.46)	0.99 (0.80, 1.22)	1.29 (1.13, 1.47)***
50 000–74 999	2.02 (1.63, 2.50)***	0.83 (0.71, 0.96)*	1.35 (1.11, 1.65)**	0.76 (0.62, 0.93)**	1.26 (1.10, 1.43)**
75 000–150 000	2.38 (1.92, 2.94)***	0.76 (0.65, 0.89)**	1.32 (1.09, 1.61)**	0.70 (0.57, 0.86)**	1.43 (1.26, 1.63)***
≥150 000	1.88 (1.44, 2.46)***	0.83 (0.71, 0.99)*	1.45 (1.15, 1.82)**	0.56 (0.45, 0.71)***	1.37 (1.19, 1.58)***
Education					
Elementary school or less	Ref.	Ref.	Ref.	Ref.	Ref.
High school	1.61 (1.11, 2.34)*	0.99 (0.71, 1.39)	1.10 (0.75, 1.62)	1.53 (1.07, 2.19)*	1.26 (0.97, 1.65)
Post-high school training	1.84 (1.28, 2.65)**	1.13 (0.81, 1.58)	1.26 (0.86, 1.85)	1.60 (1.12, 2.28)*	1.53 (1.18, 1.99)**
Bachelor's degree	3.40 (2.32, 5.00)***	1.57 (1.12, 2.19)**	1.29 (0.87, 1.90)	1.96 (1.37, 2.80)***	2.06 (1.58, 2.69)***
Postgraduate degree	3.74 (2.49, 5.61)***	1.68 (1.20, 2.19)**	1.56 (1.05, 2.32)*	1.82 (1.26, 2.61)**	2.32 (1.77, 3.03)***
Ethnicity					
White	Ref.	Ref.	Ref.	Ref.	Ref.
Other	1.07 (0.91, 1.25)	1.36 (1.25, 1.49)***	0.75 (0.67, 0.85)***	2.10 (1.82, 2.43)***	0.63 (0.59, 0.68)***
Perceived health					
Poor	Ref.	Ref.	Ref.	Ref.	Ref.
Fair	1.06 (0.72, 1.58)	0.96 (0.65, 1.42)	2.21 (1.57, 3.10)***	0.80 (0.45, 1.40)	1.07 (0.79, 1.44)
Good	1.52 (1.04, 2.23)*	1.06 (0.73, 1.53)	3.41 (2.48, 4.71)***	0.59 (0.34, 1.01)	1.36 (1.02, 1.81)*
Very good	2.50 (1.69, 3.68)***	1.88 (1.30, 2.74)**	7.00 (5.05, 9.71)***	0.54 (0.31, 0.92)*	1.92 (1.44, 2.56)***
Excellent	4.51 (2.96, 6.88)***	3.21 (2.20, 4.69)***	13.32 (9.38, 18.92)***	0.52 (0.30, 0.90)*	2.49 (1.86, 3.34)***

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TABLE 3 (continued)
Association between adherence to colorectal cancer primary prevention behaviours and potential predictors in the BCGP[a]

Factor	Odds ratios (95% confidence limits)				
	Nonsmoking	BMI	Physical activity	Alcohol	FVC
Time since last routine medical exam					
<6 months	Ref.	Ref.	Ref.	Ref.	Ref.
6 months to <1 year	1.12 (0.96, 1.30)	1.10 (1.02, 1.19)*	1.06 (0.94, 1.19)	1.08 (0.98, 1.19)	0.93 (0.87, 1.00)
1 to <2 years	0.99 (0.85, 1.16)	1.11 (1.02, 1.19)*	0.92 (0.81, 1.04)	1.09 (0.98, 1.21)	0.91 (0.85, 0.98)*
2 to <3 years	0.88 (0.70, 1.11)	1.06 (0.93, 1.20)	0.88 (0.73, 1.06)	1.11 (0.94, 1.31)	0.95 (0.84, 1.06)
≥3 years	0.75 (0.62, 0.92)**	1.17 (1.05, 1.31)**	0.82 (0.70, 0.96)	1.06 (0.91, 1.23)	0.88 (0.80, 0.98)*
Never	0.63 (0.40, 0.97)*	1.32 (0.96, 1.80)	1.04 (0.67, 1.63)	0.86 (0.58, 1.28)	0.69 (0.53, 0.90)**
Family history of colorectal cancer					
No	Ref.	Ref.	Ref.	Ref.	Ref.
Yes	1.26 (1.03, 1.53)*	0.93 (0.84, 1.02)	1.01 (0.87, 1.17)	1.01 (0.90, 1.14)	1.08 (0.99, 1.18)
Number of chronic diseases					
0	Ref.	Ref.	Ref.	Ref.	Ref.
1	0.93 (0.80, 1.07)	0.84 (0.78, 0.90)***	1.00 (0.89, 1.12)	0.88 (0.80, 0.96)**	1.10 (1.03, 1.18)**
2	0.94 (0.79, 1.11)	0.78 (0.72, 0.85)***	0.96 (0.84, 1.09)	0.78 (0.70, 0.87)***	1.15 (1.07, 1.25)***
≥3	0.78 (0.65, 0.94)**	0.57 (0.51, 0.64)***	0.80 (0.69, 0.93)**	0.87 (0.76, 1.00)	1.27 (1.15, 1.40)**

Abbreviations: BCGP, BC Generations Project; BMI, body mass index; CL, confidence limit; FVC, fruit and vegetable consumption; Ref., reference.

[a] The results on the subset of complete cases produced similar results to the analysis of the multiply imputed data (data not shown), but with marginally wider 95% confidence intervals and slightly larger standard errors.[23]

*$p < 0.05$.

**$p < 0.01$.

***$p < 0.001$.

screening guidelines than younger participants (1.84; 95% CL: 1.71, 1.98; $p < 0.001$) (see Figure 1) as did unmarried (0.89; 95% CL: 0.81, 0.98; $p < 0.01$) relative to married participants. Increasing time since last routine medical examination was also associated with lower odds. Multimorbidity was associated with higher odds of adherence to colorectal cancer screening guidelines relative to no chronic disease as was nonsmoking relative to smoking (1.36; 95% CL: 1.16, 1.61; $p < 0.001$) and adherence to fruit and vegetable consumption guidelines (1.14; 95% CL: 1.05, 1.23; $p < 0.001$) compared to being nonadherent.

Discussion

Research has shown that adherence to WCRF cancer prevention guidelines is inversely associated with cancer risk.[24] In this current study, we measured adherence to colorectal cancer prevention guidelines in a British Columbia cohort and examined sociodemographic and health-related correlates of this adherence, both to individual behaviours and combined behaviours. Participants were highly adherent to nonsmoking (94.8%), alcohol consumption (86.6%) and physical activity (88.9%) guidelines, but less likely to adhere to fruit and vegetable consumption recommendations (66.7%) or to have a healthy BMI (44.2%). The composite adherence score indicated good overall adherence by this cohort to Canadian Cancer Society/WCRF guidelines on preventing colorectal cancer.

Comparing these results with those of other studies is complicated by the WCRF guidelines being operationalized in different ways, given the absence of broadly accepted metrics. In addition, this study included nonsmoking as a colorectal cancer prevention behaviour which, while not directly included in WCRF recommendations, is mentioned in the documentation for these guidelines, and is the largest individual preventable cause of cancer.[25]

One study, by Whelan et al.,[26] from Alberta's Tomorrow Project (a regional cohort within CanPath)[14] reported a similar mean (SD) composite score (3.3 [1.2]), but operationalized seven variables, indicating lower overall adherence than in our British Columbia analysis.[26] Adherence to alcohol guidelines was similar to our results (88%), but physical activity and fruit and vegetable consumption adherence was lower, at 48% and 35–44% (depending on sex), respectively. Adherence to BMI was closer to our findings (23% for men and 40% for women).

Jung et al.[27] reported lower BMI adherence levels in an older cohort, although

TABLE 4
Linear regression associations between the adherence composite score and colorectal cancer primary prevention behaviours and potential predictors in the BCGP

Factor	β coefficient (95% CL)	*p* value
Sex		
Male	Ref.	
Female	0.34 (0.32, 0.37)	<0.001
Age		
≥35 to <50	Ref.	
≥50 to <60	0.04 (−0.03, 0.04)	0.83
≥60 to <70	0.002 (−0.03, 0.04)	0.88
Marital status		
Married	Ref.	
Unmarried	−0.08 (−0.12, −0.05)	<0.001
Household income, CAD		
<25 000	Ref.	
25 000–49 999	0.11 (0.04, 0.18)	<0.01
50 000–74 999	0.09 (0.03, 0.16)	<0.01
75 000–150 000	0.09 (0.03, 0.16)	<0.01
≥150 000	0.07 (−0.04, 0.14)	0.06
Education		
Elementary school or less	Ref.	–
High school	0.21 (0.07, 0.36)	<0.01
Post-high school training	0.31 (0.17, 0.45)	<0.001
Bachelor's degree	0.49 (0.34, 0.63)	<0.001
Postgraduate degree	0.54 (0.49, 0.69)	<0.001
Ethnicity		
White	Ref.	–
Other	0.02 (−0.02, 0.06)	0.30
Perceived health		
Poor	Ref.	
Fair	0.25 (0.09, 0.41)	<0.01
Good	0.40 (0.24, 0.55)	<0.001
Very good	0.69 (0.53, 0.84)	<0.001
Excellent	0.93 (0.77, 1.08)	<0.001
Time since last routine medical exam		
<6 months	Ref.	
6 months to <1 year	0.02 (−0.01, 0.06)	0.20
1 to <2 years	0.01 (−0.04, 0.03)	0.74
2 to <3 years	−0.03 (−0.09, 0.03)	0.29
3 or more years	−0.04 (−0.09, 0.01)	0.08
Never	−0.08 (−0.21, 0.06)	0.27
Family history of colorectal cancer		
No	Ref.	
Yes	−0.01 (−0.03, 0.05)	0.66
Chronic diseases		
0	Ref.	
1	−0.04 (−0.07, −0.01)	<0.05
2	−0.05 (−0.09, −0.01)	<0.05
≥3	−0.13 (−0.18, −0.08)	<0.001

Abbreviations: BCGP, BC Generations Project; CL, confidence limit; Ref., reference.

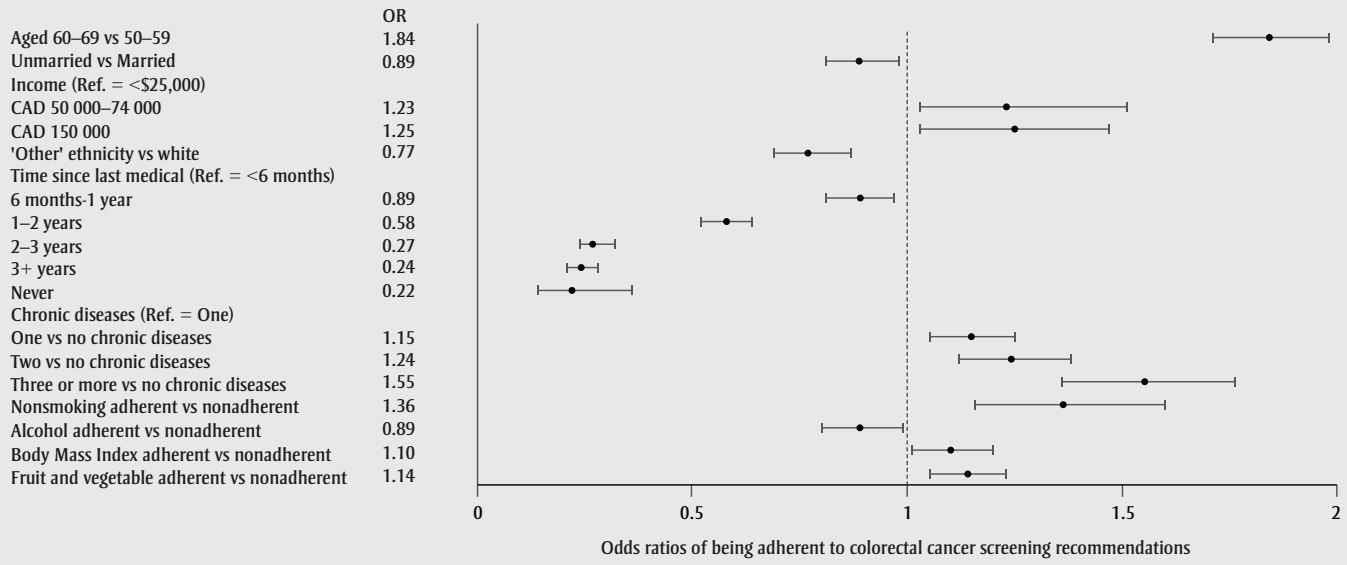
they operationalized adherence as having a normal BMI throughout adulthood. At 90.8% for men and 94.2% for women, alcohol adherence was similar to our findings. In contrast, they reported lower physical activity adherence (26.2% for men and 18.4% for women), which may be because of the higher mean age of the study participants (74.5 years) than in our cohort.[27] They also reported lower overall mean (SD) composite score relative to the seven guidelines they operationalized (men: 3.24 [1.10]; women: 3.17 [1.10]).[27]

In keeping with the literature, greater perceived and actual health in our analysis were also strongly associated with higher composite score. It was also those with the lowest perceived health who were least likely to be adherent to individual colorectal cancer primary prevention behaviours. Individual behaviour adherence varied by sex, with women significantly more adherent to nonsmoking, fruit and vegetable consumption and BMI guidelines, but significantly less adherent to alcohol and physical activity recommendations. Research generally finds that women consume less alcohol than men,[28] but these results suggest women may be drinking more relative to their "safe" levels.

Finally, family history of colorectal cancer was associated with higher odds of being a nonsmoker. Given the increased risk for those with a family history of the disease[29] and for smokers[30], perhaps participants who are at an increased risk are taking action to reduce their risk in controllable domains.

The relative importance of individual components is important to recognize in consideration of the composite score. For example, studies examining prevention guideline adherence have consistently reported nonsmoking, followed by BMI and diet-related factors, to be a stronger predictor of mortality outcome than any other lifestyle factor.[24] The varying impact of each guideline on risk suggests it may be appropriate to weight each and derive a composite score attuned to the specific risk for each lifestyle factor. Such a task would be complex and further complicated by considering specific cancer sites, for example, appropriate weighting of guidelines might be subtly, but importantly, different for CRC relative to lung cancer.

FIGURE 1
Odds risk for colorectal cancer screening adherence factors in the BCGP



Abbreviations: BCGP, BC Generations Project; BMI, body mass index; OR, odds ratio; Ref., reference

Note: Each small square is aligned with the point on the x-axis that represents the odds risk of adherence to colorectal cancer screening associated with each factor listed in the y-axis. The horizontal line through each square represents the 95% confidence interval. Only statistically significant variables are shown.

Adherence to colorectal cancer screening in this cohort (62.4%) was much higher than the most recently available Canada-wide administrative data (23%).[31] This may be, in part, because these Canada-wide data were from 2012, when many provincial colorectal cancer screening programs were in their infancy or non-existent. In British Columbia, such a program was not established until 2013.

The high colorectal cancer screening rates reported here may also be because we combined flexible sigmoidoscopy and colonoscopy assessments. Indeed, the 2012 CCHS found similar levels of screening adherence (55.2%) using the same definition of screening adherence (i.e. FOBT and/or either flexible sigmoidoscopy or colonoscopy).[11] This is a limitation, as colonoscopy is not routinely recommended for screening in British Columbia, and some of the participants who were defined as adherent because they had had a colonoscopy had done so for diagnostic reasons. However, the proportion of participants adherent to FOBT alone was still high (43.4%). Limiting the screening dataset to participants at average risk of colorectal cancer also improves the accuracy of this measure: only those participants who met the CTFPHC guidelines were included.

The assessment of predictors of colorectal cancer screening adherence in this cohort identified some potentially important factors in guiding future colorectal cancer screening interventions. Older participants were more likely to adhere to screening guidelines. This has also been reported by Singh et al.[11] and Wong et al.,[32] and suggests participants may be delaying screening. Alternatively, older participants may be more likely to have undergone flexible sigmoidoscopy or colonoscopy for non-colorectal cancer screening reasons. In addition, contact with the health care system may be an important screening determinant; participants had lower odds of being adherent the longer it had been since their last routine medical examination. Relatedly, those with chronic conditions were more likely to be adherent, perhaps reflecting their more regular contact with health care professionals.

Strengths and limitations

Strengths of this study include the large sample size and the availability of detailed information on both colorectal cancer primary and secondary prevention behaviours. However, the available data did not provide all the information required for the full operationalization of all WCRF cancer prevention recommendations. This reduces the validity of the current scoring system. In addition, response bias is possible in the available data given the self-report nature of most measures, that is, healthy behaviours may be overreported and unhealthy behaviours underreported. The cross-sectional nature of the data also disallows assessment of the impact of adherence on cancer incidence, although because the BCGP is an ongoing longitudinal cohort, these outcomes could be assessed in the future.

The high levels of perceived good health support a volunteer effect in this study. For example, participants in this study had smoking levels almost one-third of those reported in a recent national survey (5.2% versus 13%).[33] Part of this difference is likely because participants were residents of British Columbia; in the same survey British Columbians had the joint lowest level of smoking prevalence among adults in Canada (10%). The remainder may be attributed to participants in the BCGP being more likely to be adherent to health behaviour recommendations, which means the results reported here must be interpreted with caution. In terms of health status, a recent cohort profile of BCGP found higher proportions of some chronic conditions compared to CCHS participants of the same age.[13] Differences between BCGP participants and the general British Columbia population (35–69 years) included participants being more likely to be highly educated, female and Canadian or British born.[13] The trends in our analytic sample were the same. These limitations, in addition to those to do with healthy volunteer effect, reduce the

generalizability of our results, in particular to underrepresented groups such as immigrants and those living at lower socioeconomic status.

Conclusion

This study found high levels of adherence to some colorectal cancer prevention behaviours. While this may be partially explained by a healthy volunteer effect, given the contrast in results to those from other similar cohorts, it is likely more reflective of the general healthy lifestyle of British Columbia residents. Research has consistently found that British Columbia has the lowest rates of some risky health behaviours and chronic diseases,[33] and the highest rates of health-protective behaviours such as physical activity. This study supports these findings in the domain of colorectal cancer prevention and highlights the need for further research to understand British Columbia's successes to enable their translation to other Canadian provinces.

The results also suggest a clustering of poorer adherence to colorectal cancer primary and secondary prevention behaviours with each other and with other risk factors. For example, indicators of lower socioeconomic status such as low household income and educational attainment were associated with increased smoking and lower colorectal cancer screening adherence. Similarly, lower educational attainment was associated with lower composite score. To address this finding, policy could be used to make free weight-loss support and cheaper healthy food choices available to groups living at lower socioeconomic status. Research could help ensure any such policy was tailored to the needs and preferences of target groups.

Finally, adherence to colorectal cancer screening guidelines was high relative to Canadian screening targets, but almost a third of participants were not being screened as recommended, despite this sample likely being more health conscious than the general population. Further research should build on the analysis presented here to identify more specific targetable populations for prevention interventions. Future work in this cohort can also examine the impact of adherence to cancer prevention guidelines on colorectal cancer incidence and mortality as well as other disease outcomes.

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Conflicts of interest

Over the past 2 years, MEK has received consulting fees from Biogen Inc. for projects unrelated to this research and manuscript.

The rest of the authors declare that they have no conflicts of interest.

Author contributions and statement

MSM – Conceived and designed the study, conducted the analysis, compiled the results, wrote the manuscript.

CG – Provided critical feedback on the conception and design of the study, contributed to the final version of the manuscript.

MEK – Provided critical feedback on the design of the methods and analysis, contributed to the final version of the manuscript.

JT – Provided critical feedback on the conception of the study, contributed to the final version of the manuscript.

TD – Provided critical feedback on the conception and design of the study, facilitated acquisition of the data, contributed to the final version of the manuscript.

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