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Original quantitative research

A cross-sectional study of pain status and psychological distress among individuals living with chronic pain: the Chronic Pain & COVID-19 Pan-Canadian Study

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Abstract

Background: The COVID-19 pandemic has had a disproportionate impact on vulnerable populations, including individuals with chronic pain. We examined associations between geographical variations in COVID-19 infection rates, stress and pain severity, and investigated factors associated with changes in pain status and psychological distress among individuals living with chronic pain during the pandemic.

Methods: This investigation is part of a larger initiative, the Chronic Pain & COVID-19 Pan-Canadian Study, which adopted a cross-sectional observational design. A total of 3159 individuals living with chronic pain completed a quantitative survey between 16 April and 31 May 2020.

Results: Two-thirds (68.1%) of participants were between 40 and 69 years old, and 83.5% were women. Two-thirds (68.9%) of individuals reported worsened pain since pandemic onset. Higher levels of perceived pandemic-related risks (adjusted odds ratio: 1.27; 95% confidence interval: 1.03–1.56) and stress (1.21; 1.05–1.41), changes in pharmacological (3.17; 2.49–4.05) and physical/psychological (2.04; 1.62–2.58) pain treatments and being employed at the beginning of the pandemic (1.42; 1.09–1.86) were associated with increased likelihood of reporting worsened pain. Job loss (34.9% of individuals were employed pre-pandemic) was associated with lower likelihood (0.67; 0.48–0.94) of reporting worsened pain. Almost half (43.2%) of individuals reported moderate/severe levels of psychological distress. Negative emotions toward the pandemic (2.14; 1.78–2.57) and overall stress (1.43; 1.36–1.50) were associated with moderate/severe psychological distress.

Conclusion: Study results identified psychosocial factors to consider in addition to biomedical factors in monitoring patients' status and facilitating treatment access for chronic pain patients during a pandemic.

Keywords: *COVID-19, pain, psychological distress, pandemic*

Highlights

- Two-thirds of individuals who completed an online survey reported worsened pain since the beginning of the COVID-19 pandemic.
- Almost half of respondents experienced moderate to severe psychological distress.
- Changes to pain treatments during the pandemic were significantly associated with worsened pain.
- Geographical aspects, such as rural vs. urban living or living in a province with higher infection rates were not associated with pain status or psychological distress.
- In future waves of the pandemic, consideration must be given to continue offering adequate pharmacological and physical/psychological pain treatments.

Introduction

Chronic pain is defined as a pain that has been present for more than 3 months, that has persisted for longer than the normal tissue-healing time or that is associated with a chronic condition.[1,2] Worldwide, approximately 20% of the adult population

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lives with chronic pain.[3,4] Inadequate chronic pain management costs between $38.3 billion and $40.4 billion in annual direct and indirect health care costs in Canada.[5]

Chronic pain can have a wide range of repercussions on a person's life and their health-related quality of life and mental health comorbidities.[6] These impacts on physical and mental health and well-being may be heightened during times of high stress. One-quarter of individuals in the general population report experiencing anxiety or depressive symptoms since the beginning of the COVID-19 pandemic.[7] However, there is a paucity of empirical data on the physical and mental health effects of the COVID-19 pandemic on vulnerable populations such as individuals living with chronic pain. Describing and identifying factors associated with poor physical and mental health statuses can inform public health decisions in future waves of the pandemic.

Based on expert opinion, individuals with chronic pain are likely to experience an exacerbation of their health condition during and after the COVID-19 pandemic.[8] This crisis and the associated psychological stressors may also precipitate a new onset of chronic pain.[8] One out of two individuals receiving tertiary chronic pain treatment in Canada live below the poverty line,[9] and the pandemic has disproportionally affected populations with low socioeconomic status. Furthermore, access to proper pain assessment, treatment and management has been challenging in Canada for a long time—particularly in rural and remote regions[10]—and the large-scale shut down of pain clinics, allied health professionals' offices and exercise facilities during the pandemic has worsened pain management access.

The goal of this cross-sectional study was to document the physical and mental health status and socioeconomic status of Canadians living with chronic pain during the COVID-19 pandemic. The specific objectives were to (1) examine the association between geographical variations in COVID-19 infection rate, stress appraisal and pain severity; and (2) investigate the biopsychosocial factors associated with (a) changes in pain status during the COVID-19 pandemic, and (b) psychological distress among individuals living with chronic pain.

We hypothesized that (1) high provincial infection rates of COVID-19 would be associated with higher levels of stress appraisal and pain severity; and (2) the degree of geographical infection rates of COVID-19 and levels of perceived global and pandemic-specific stress would be associated with pain deterioration and psychological distress.

Methods

Design

The present study is part of a larger initiative, the Chronic Pain & COVID-19 Pan-Canadian Study, which used a cross-sectional mixed-method design to answer various pandemic-related research questions.[11] Quantitative survey data are summarized in the present article.

As shown by the shaded area in Figure 1, the study started at an early stage of the pandemic when the number of cumulative cases was growing exponentially in some provinces and the peak number of COVID-19 cases had not yet been reached.

Participants

Eligible participants were adults (≥18 years old) living in Canada, fluent in French and/or English, who had pain for more than 3 months and access to the Internet.

Recruitment

The study used a non-probabilistic sampling approach. Study advertisements that contained a web-based hyperlink to a consent form and questionnaire in French and English were published through patient associations, pain organizations, research networks and social media across Canada.

Procedures

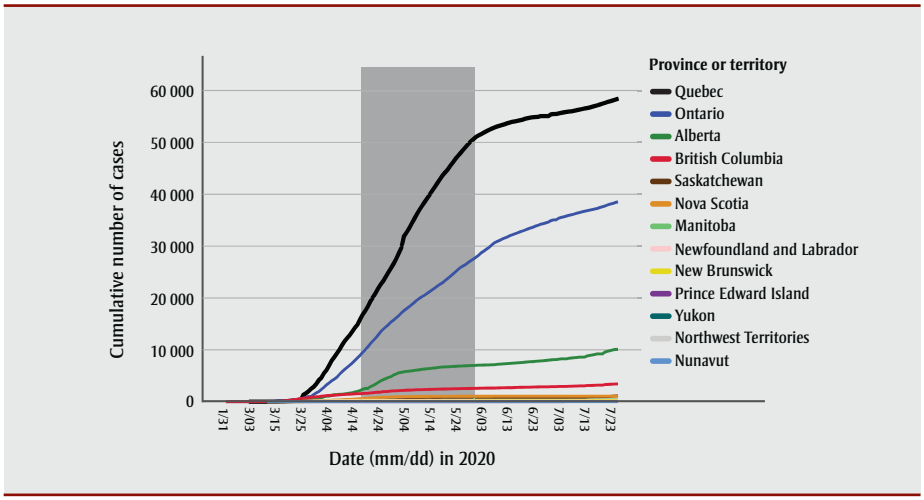
The study was approved by the research ethics board of the Centre hospitalier de l'Université de Montréal. The survey ran from 16 April to 31 May, 2020, that is, roughly one month after the beginning of public health restrictions in Canada and before these restrictions were lifted. Interested participants answered screening questions regarding their eligibility on the study's landing page and provided consent electronically. They were then automatically directed to the online study's questionnaire. Participants were eligible to win one of ten $100 prepaid Visa gift cards. Only one completed questionnaire per IP address was allowed. The full survey was pre-tested by five people with chronic pain and different education levels.

Measures

Main outcomes

Pain status change was assessed using the Patient Global Impression of Change scale,

FIGURE 1
Cumulative number of cases across provinces and territories, Canada



Source for number of COVID-19 cases: Berry et al.[12]

Note: The shaded area shows the time during which the survey was open. As of 23 March 2020, Quebec lifted the need for a second confirmatory test from a provincial lab for a case to be counted as positive. On 3 May 2020, 1317 positive cases were added to the cumulative number of cases that were missed between 2 April and 30 April 2020. On 1 April, the data source for Ontario changed from the Ministry of Health and Long Term Care to individual public health units; this led to an adjustment for positive cases that were not previously captured.

a 7-point Likert scale (from 1 for considerably worsened to 7 for considerably improved). This scale has high test–retest reliability (intraclass correlation coefficient of 0.80–0.92) and construct validity (moderate correlation with other measures of change [r = 0.53]).[13] Psychological distress was measured using a validated screening measure of depressive and anxious symptoms, the Patient Health Questionnaire-4 (PHQ-4).[14] The PHQ-4 has good convergent validity (r = 0.36–0.80 with subscales of a global measure of functioning), internal consistency (α = 0.78–0.82) and item intercorrelation (r = 0.60).[14,15]

Pain characteristics

We assessed changes (yes/no/not applicable) in pharmacological and physical/psychological treatments since the beginning of the COVID-19 pandemic and initiation of public health safety measures (mid-March 2020 in Canada). The Numerical Rating Scale (NRS) for Pain Intensity[16,17] was used to measure average and worst pain intensity and pain unpleasantness over the past 7 days. The Brief Pain Inventory (BPI)[18] measured pain interference on various aspects of daily living. The BPI is a reliable (α > 0.70) scale that has demonstrated good convergent (r = 0.57–0.81 with generic pain measures) validity and sensitivity to change.[19,20] The EQ-5D-5L[21] assessed health-related quality of life and has been shown to have adequate construct validity and responsiveness among individuals with chronic pain.[22]

Impact of the COVID-19 pandemic

A group of pain researchers, clinicians and patient representatives developed a questionnaire based on Lazarus and Folkman's transactional stress model[23] to measure (a) stressors and (b) primary appraisal. The following scores were computed from this questionnaire:

- emotional reactions toward the COVID-19 pandemic;
- stress (human and material);
- appraisal of the COVID-19 pandemic experience; and
- restrictions (work-related, health, social).

For scores on emotional reactions toward the COVID-19 pandemic, participants were asked to report the extent to which they experienced different emotions (sadness, worries, solitude, anger, powerlessness, anxiety, surprise, relief and hope) when they thought or heard about the COVID-19 pandemic on a scale from 0 (not at all) to 10 (enormously). A data reduction approach was used for further analyses: after removing skewed variables (surprise and hope) and the only positive emotion left (relief), parallel factor analysis revealed a one-factor solution. Regression analysis was carried out to generate a unique factor score for each participant.

For scores on stress (human and material), participants were asked to rate the extent to which they found several pandemic-associated factors stressful on a scale from 0 (not at all) to 10 (extremely). A similar data reduction strategy was used for these items. Factor 1, called material stress, included stress related to finances, food and essential items. Factor 2, called human stress, included stress associated with the pandemic and virus, and public health safety measures.

We used the Perceived Stress Scale-4 (PSS-4)[24] to measure the extent to which individuals found their life unpredictable, uncontrollable and overloaded over the past month. The PSS-4 has excellent internal consistency (α = 0.81) and adequate convergent validity (r = 0.66–0.73) with measures of depression and anxiety.[24]

Appraisal of the COVID-19 pandemic experience was measured in terms of (1) individuals' perceived susceptibility (accessibility of screening tests for COVID-19; perceived risk of being infected); (2) perceived severity (having access to necessary medical help should individuals get infected and their perceived change of recovery from COVID-19); (3) perceived benefits (agreement levels with confinement measures and the extent to which, despite the confinements, they can experience an active social life); and (4) perceived risks (decreased social activities and increased dependence toward others).

To assess restrictions (work-related, health, social), individuals were asked to identify which of the public health measures set in place were directly affecting them. For each subcategory (work, health, social), a sum of the number of restrictions endorsed was computed.

Data analysis

We used descriptive statistics to examine pain, geographical variations in COVID-19 infection rates, public health restriction measures and characteristics of psychological well-being.

To examine the effect of geographical variations in COVID-19 infection rate as a function of number of provincial cases, urban/rural living and their interaction with stress (Model 1: human and material-related stress, PSS-4) and pain (Model 2: pain interference, worst and average pain intensity, quality of life), we used multivariate analysis of variance.

To identify variables associated with pain deterioration (Model 3) and psychological distress (Model 4), we used multivariate logistic regression analyses. The dependent variable in Model 3 was pain deterioration (somewhat, a lot or considerably worsened vs. remained unchanged, somewhat, a lot or considerably improved). In Model 4, the dependent variable was psychological distress (PHQ-4 scores 6–12 [moderate/severe psychological distress] vs. 0–5 [no/mild psychological distress]). All variables of theoretical/clinical interest were entered in the model; the full list can be found in Table 2.

We ascertained multicollinearity using variance inflation factors (VIF) and correlation coefficients. Analyses were carried out in SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) and SPSS version 26.9 for Windows (IBM, Chicago, IL, USA).

Sample size estimation

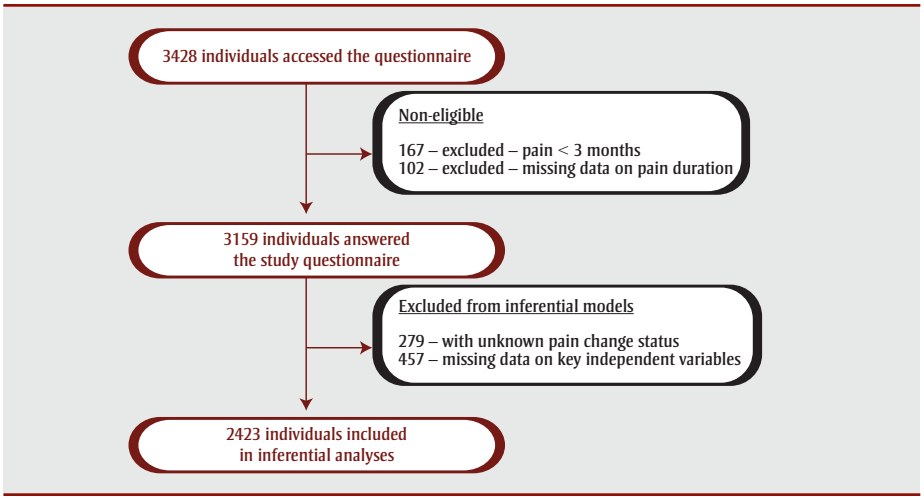
Guidelines for multivariate logistic regression analysis from large observational studies[25] recommend a sample size greater than 500 to ensure accuracy of coefficient. A sample size of 1700 participants allows for the inclusion of all explanatory factors considered in this study.

Results

Study participants

A total of 3159 eligible participants completed the study questionnaire in part or entirely (see Figure 2). Table 1 shows participants' sociodemographic, COVID-19 and pain characteristics. Participants were predominantly women (83.5%) and White (88.3%); two-thirds (68.1%) were between 40 and 69 years old. At a mean (standard deviation [SD]) of 6.13 (1.84) out of 10, participants' average pain intensity in the past 7 days was moderate, and 46.9% had had pain for more than 10 years.

FIGURE 2
Study flow chart



Many participants reported that their pain had worsened since the beginning of the COVID-19 pandemic (68.9%). Less than 1% had a confirmed diagnosis of COVID-19. A majority (73.4%) were living in provinces with higher infection rates (>150 cases per 100 000 population). Mean (SD) levels of stress (on a 0–10 scale) associated with the pandemic itself (6.9 [2.4]) and with the lockdown (5.9 [2.7]) were however moderate. Levels of psychological distress were moderate to severe in close to half the participants (n = 1153; 43.2%). Among those who were working at the beginning of the pandemic, over one-quarter (28.3%; 276/976 employed individuals) had lost their jobs.

Associations between geographical variations in COVID-19 infection rates, stress appraisal and pain

Results showed that provincial infection rates (Pillai's trace = 0.004; $F(6; 5168) = 1.87$; $p = 0.082$), urban vs. rural settings (Pillai's trace = 0.001; $F(3; 2583) = 0.48$; $p = 0.695$) or their interaction (Pillai's trace = 0.002; $F(6; 5168) = 0.74$; $p = 0.621$) were not associated with perceived stress (PSS-4, human and material stress associated with the pandemic) (Model 1). Provincial infection rates (Pillai's trace = 0.024; $F(6;5148) = 10.54$; $p < 0.001$), but neither urban/rural living conditions (Pillai's trace = 0.001; $F(3; 2573) = 1.09$; $p = 0.352$) nor their interaction (Pillai's trace = 0.003; $F(6; 5148) = 1.15$; $p = 0.332$), were associated with pain interference (but not with average or worst pain intensity or quality of life) such that individuals from provinces with between 50 and 150 cases per 100 000 reported mean (SD) higher levels of pain interference (47.5 [12.9]) compared to those from provinces with more than 150 cases per 100 000 (42.1 [14.3]) ($F(5;2593) = 15.4$; $p < 0.01$) (Model 2).

Variables associated with pain status change and psychological distress

There were no clinically significant differences (>20% difference on total scores between the groups[26] or in proportions across groups for categorical variables) between those who were included (n = 2423) and those who were excluded (n = 736) due to missing data, except for the number of public health restrictions. Compared to those retained in the model, individuals who were excluded were more likely to report no health restrictions (19.3% vs. 69.5%), no work restrictions (54.0% vs. 82.9%) and no social restrictions (37.9% vs. 73.4%). All individuals who reported being infected with COVID-19 (n = 24) were excluded from the regression analyses because of missing data; however, this represented only 0.8% of participants.

Due to high correlations between pain interference (BPI score) and the two pain intensity measures (average pain: $r = 0.631$; worst pain: $r = 0.564$), only the BPI score was included in the model.

Detailed results of the pain status change (Model 3) are shown in Table 2. Descriptive statistics on relevant variables as a function of pain status change are shown in Table 1. Older adults (adjusted odds ratio [aOR]: 0.49; 95% confidence interval [CI]: 0.32–0.76) and those who had lost their employment since the beginning of the pandemic (0.67; 0.48–0.94) were less likely to report worsened pain than younger adults or those still employed or not in the workforce.

Individuals who worked were more likely to report worsened pain than those who were not employed and not on disability (1.42; 1.09–1.86). Higher levels of perceived risks (but not susceptibility, severity or benefits) associated with COVID-19 (1.27; 1.03–1.56) and higher levels of stress associated with individuals' health and safety (human stress composite score) (1.21; 1.05–1.41) were associated with greater likelihood of reporting worsened pain. Longer pain duration (3–10 years: 1.69; 1.24–2.29; >10 years: 1.40; 1.03–1.90) and changes in pharmacological treatments (3.17; 2.49–4.05) and physical/psychological treatments (2.04; 1.62–2.58) were also associated with greater likelihood of reporting worsened pain.

Based on the study analyses, one cannot rule out that some individuals may have reported improved pain status as a result of treatment change; however, only 5% of the overall sample reported this pain status.

Detailed results of psychological distress (Model 4) are shown in Table 2. Descriptive statistics on relevant variables as a function of psychological distress are shown in Table 1. Results revealed that older adults (40–69 years old: aOR = 0.75; 95% CI: 0.57–0.98; ≥70 years old: 0.54; 0.32–0.92) were less likely to report moderate/severe psychological distress than younger adults.

Higher intensity of negative emotions associated with the pandemic (aOR = 2.14; 95% CI: 1.78–2.57), higher levels of stress associated with individuals' health and social interactions (human stress: 1.39; 1.17–1.66) and higher perceived global stress (1.43; 1.36–1.50) were associated with greater likelihood of reporting moderate/severe psychological distress.

Discussion

To our knowledge, this study is one of the first to document the effects of the COVID-19 pandemic in a large sample of individuals with chronic pain who participated in an online survey. The COVID-19 pandemic had detrimental effects on many individuals in terms of pain deterioration (70% of individuals) and psychological distress (moderate/severe distress in close to half

TABLE 1
Participants' characteristics for the overall sample and according to pain status and psychological distress for those included in the inferential analyses

Characteristics	Total sample (N = 3159)	Pain status (n = 2423)		Psychological distress (n = 2423)	
		Worsened (n = 1697)	Unchanged or improved (n = 726)	No/mild psychological distress (n = 1365)	Moderate/severe psychological distress (n = 1058)
Sociodemographic characteristics					
Age in years, n (%)					
18–39	646 (24.2)	434 (25.6)	166 (23.0)	297 (21.8)	303 (28.7)
40–69	1814 (68.1)	1181 (69.6)	472 (64.9)	945 (69.2)	708 (66.9)
≥70	205 (7.7)	82 (4.8)	88 (12.1)	123 (9.0)	47 (4.4)
Missing	494	–	–	–	–
Sex, n (%)					
Female	2225 (83.5)	1466 (86.4)	568 (78.2)	1115 (81.7)	919 (86.9)
Male	429 (16.1)	231 (13.6)	158 (21.8)	250 (18.3)	139 (13.1)
Undetermined	11 (0.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Missing	494	–	–	–	–
Ethnicity, n (%)					
White	2350 (88.2)	1502 (88.5)	648 (89.3)	1228 (90.0)	921 (87.0)
Other	315 (11.8)	195 (11.5)	78 (10.7)	137 (10.0)	137 (13.0)
Missing	494	–	–	–	–
Living condition, n (%)					
Alone	560 (21.0)	348 (20.5)	159 (21.9)	283 (20.7)	224 (21.2)
Other	2105 (79.0)	1349 (79.5)	567 (78.1)	1082 (79.3)	834 (78.8)
Missing	494	–	–	–	–
Civil status, n (%)					
Married or common law	1555 (58.6)	1005 (59.2)	417 (57.4)	842 (61.7)	580 (54.8)
Other	1099 (41.4)	692 (40.8)	309 (42.6)	523 (38.3)	478 (45.2)
Missing	505	–	–	–	–
Education, n (%)					
Less than university	1444 (54.8)	939 (55.4)	385 (53.0)	678 (49.7)	646 (61.1)
University	1193 (45.2)	758 (44.6)	341 (47.0)	687 (50.3)	412 (38.9)
Missing	522	–	–	–	–
Living area, n (%)					
Rural	359 (11.4)	227 (13.4)	104 (14.3)	183 (13.4)	148 (14.0)
Urban	2800 (88.6)	1470 (86.6)	622 (85.7)	1182 (86.6)	910 (86.0)
Work status, n (%)					
Working part-time or full-time	976 (34.9)	610 (40.0)	247 (34.2)	518 (38.0)	339 (32.1)
Temporary or permanent invalidity	899 (32.2)	600 (35.5)	189 (26.0)	369 (27.1)	420 (39.6)
Other	918 (32.9)	487 (24.5)	290 (39.8)	478 (34.9)	299 (28.3)
Missing	366	–	–	–	–
Work status change, n (%)					
Loss of employment	276 (10.0)	148 (8.7)	87 (12.0)	127 (9.2)	108 (10.2)
No loss of employment	2484 (90.0)	1549 (91.3)	639 (88.0)	1238 (90.8)	950 (89.8)
Missing	399	–	–	–	–

Continued on the following page

TABLE 1 (continued)
Participants' characteristics for the overall sample and according to pain status and psychological distress for those included in the inferential analyses

Characteristics	Total sample (N = 3159)	Pain status (n = 2423)		Psychological distress (n = 2423)	
		Worsened (n = 1697)	Unchanged or improved (n = 726)	No/mild psychological distress (n = 1365)	Moderate/severe psychological distress (n = 1058)
COVID-19 pandemic-related characteristics					
Geographical variations in COVID-19 infection rates (per 100 000), n (%)					
>150	1923 (73.4)	1214 (71.5)	564 (77.7)	1025 (75.0)	753 (71.2)
50–150	641 (24.5)	443 (26.2)	147 (20.3)	312 (22.9)	278 (26.3)
<50	57 (2.1)	40 (2.3)	15 (2.0)	28 (2.1)	27 (2.5)
Missing	538	–	–	–	–
COVID-19 infection, n (%)					
Yes, with complications requiring care	8 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Yes, without complications	16 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Waiting for test result	15 (0.5)	12 (0.7)	1 (0.1)	8 (0.6)	5 (0.5)
Untested but with symptoms	77 (2.8)	56 (3.3)	12 (1.7)	32 (2.3)	36 (3.4)
Not infected	2671 (95.8)	1629 (96.0)	713 (98.2)	1325 (97.1)	1017 (96.1)
Missing	372	–	–	–	–
Work-related restrictions, mean score (SD)	0.57 (0.70)	0.58 (0.70)	0.55 (0.69)	0.58 (0.71)	0.56 (0.68)
Health-related restrictions, mean score (SD)	1.22 (0.76)	1.30 (0.75)	1.04 (0.77)	1.11 (0.75)	1.36 (0.76)
Social-related restrictions, mean score (SD)	0.87 (0.83)	0.89 (0.85)	0.80 (0.79)	0.76 (0.77)	1.00 (0.88)
COVID-19 perceived susceptibility, n (%)					
0–4	2296 (84.6)	1409 (83.0)	634 (87.3)	1219 (89.4)	824 (77.9)
>4	419 (15.4)	288 (17.0)	92 (12.7)	146 (10.6)	234 (22.1)
Missing	444	–	–	–	–
COVID-19 perceived severity, n (%)					
0–4	1636 (60.2)	1006 (59.3)	431 (59.4)	803 (58.8)	634 (59.8)
>4	1081 (39.8)	691 (40.7)	295 (40.6)	562 (41.2)	424 (40.2)
Missing	442	–	–	–	–
COVID-19 perceived benefits, n (%)					
0–4	747 (27.6)	479 (28.2)	171 (23.6)	287 (20.9)	363 (34.3)
>4	1963 (72.4)	1218 (71.8)	555 (76.4)	1078 (79.1)	695 (65.7)
Missing	449	–	–	–	–
COVID-19 perceived risks, n (%)					
0–4	1460 (54.0)	861 (50.7)	453 (62.4)	827 (60.7)	487 (45.9)
>4	1245 (46.0)	836 (49.3)	273 (37.6)	538 (39.3)	571 (54.1)
Missing	454	–	–	–	–
Stress associated with the pandemic, mean score (SD)	6.88 (2.40)	7.17 (2.30)	6.18 (2.48)	6.01 (2.34)	7.99 (1.98)
Stress associated with the public health restrictions, mean score (SD)	5.88 (2.70)	6.21 (2.62)	5.15 (2.70)	5.14 (2.58)	6.85 (2.51)
Psychological characteristics					
PHQ-4, n (%)					
No/mild psychological distress	1513 (56.8)	850 (50.1)	515 (71.0)	–	–
Moderate/severe psychological distress	1153 (43.2)	847 (49.9)	211 (29.0)	–	–
Missing	493	–	–	–	–
PSS-4, mean score (SD)	7.84 (3.24)	8.25 (3.18)	6.84 (3.15)	6.28 (2.74)	9.84 (2.68)

Continued on the following page

TABLE 1 (continued)
Participants' characteristics for the overall sample and according to pain status and psychological distress for those included in the inferential analyses

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		Worsened (n = 1697)	Unchanged or improved (n = 726)	No/mild psychological distress (n = 1365)	Moderate/severe psychological distress (n = 1058)
Pain characteristics					
Pain location, n (%)					
Generalized pain	359 (11.8)	210 (12.4)	74 (10.2)	157 (11.5)	127 (12.1)
Head	82 (2.7)	31 (1.8)	23 (3.2)	34 (2.5)	20 (1.9)
Upper limb and upper body	242 (7.9)	124 (7.4)	62 (8.4)	103 (7.5)	83 (7.9)
Lower limb and lower body	2379 (77.2)	1322 (77.8)	563 (77.6)	1064 (78.0)	821 (77.5)
Multisite	13 (0.4)	5 (0.3)	2 (0.3)	6 (0.4)	1 (0.1)
Unknown/missing	84	5 (0.3)	2 (0.3)	1 (0.1)	6 (0.5)
Pain origin, n (%)					
Accident	750 (25.1)	441 (26.9)	160 (22.4)	324 (24.0)	287 (27.4)
Disease	757 (25.4)	419 (25.0)	203 (28.4)	374 (27.9)	248 (23.7)
Movement/trauma	334 (11.2)	175 (10.4)	88 (12.3)	150 (11.2)	113 (10.8)
No precise event	763 (25.6)	422 (25.1)	182 (25.5)	343 (25.5)	261 (24.9)
Other	380 (12.7)	213 (12.6)	81 (11.4)	154 (11.4)	140 (13.2)
Missing	175	27	12	20	9
BPI, mean score (SD)	43.39 (14.24)	45.23 (13.33)	39.06 (15.32)	38.83 (13.74)	49.26 (12.65)
Average pain intensity, mean score (SD)	6.13 (1.84)	6.36 (1.68)	5.64 (2.00)	5.76 (1.81)	6.63 (1.69)
Worst pain intensity, mean score (SD)	7.65 (1.77)	7.91 (1.51)	7.18 (2.03)	7.38 (1.81)	8.09 (1.51)
Global quality of life, mean score (SD)	55.66 (20.03)	54.17 (19.78)	58.80 (19.65)	59.68 (19.04)	50.80 (19.73)
Pain duration, n (%)					
≤2 years	390 (12.7)	180 (10.5)	111 (15.3)	166 (12.2)	125 (11.8)
3–10 years	1248 (40.4)	718 (42.4)	260 (35.8)	517 (37.8)	461 (43.6)
>10 years	1444 (46.9)	799 (47.1)	355 (48.9)	682 (50.0)	472 (44.6)
Missing	77	–	–	–	–
Changes in pain status, n (%)					
Considerably worsened	418 (14.5)	–	–	126 (9.2)	232 (22.0)
Worsened a lot	577 (20.0)	–	–	220 (16.2)	275 (26.0)
Somewhat worsened	990 (34.5)	–	–	504 (36.9)	340 (32.1)
Remained unchanged	750 (26.0)	–	–	431 (31.5)	183 (17.3)
Improved (somewhat, a lot, considerably)	145 (5.0)	–	–	84 (6.2)	28 (2.6)
Missing	279	–	–	–	–
Changes to pharmacological treatments, n (%)					
Yes	970 (33.9)	707 (41.7)	113 (15.6)	392 (28.7)	428 (40.5)
No	1563 (54.6)	803 (47.3)	512 (70.5)	792 (58.0)	523 (49.4)
Not applicable	331 (11.5)	187 (11.0)	101 (13.9)	181 (13.3)	107 (10.1)
Missing	315	–	–	–	–
Changes to physical/psychological treatments, n (%)					
Yes	1685 (59.5)	1140 (67.2)	334 (46.0)	821 (60.3)	653 (61.7)
No	786 (27.7)	369 (21.7)	272 (37.5)	379 (27.7)	262 (24.8)
Not applicable	362 (12.8)	188 (11.1)	120 (16.5)	165 (12.0)	143 (13.5)
Missing	326	–	–	–	–

Abbreviations: BPI, Brief Pain Inventory; PHQ-4, Patient Health Questionnaire–4; PSS-4, Perceived Stress Scale–4.
Note: Percentages are calculated based on completed data (and exclude missing data), as such the denominator can vary from one variable to another.

TABLE 2
Associations between characteristics of patients and worsened pain or psychological distress

Variables	Model 3 Worsened pain		Model 4 Moderate-severe psychological distress	
	Adjusted OR (95% CI)	*p*-value	Adjusted OR (95% CI)	*p*-value
Time of questionnaire completion				
Weeks 1–3 (complete confinement)	Ref.	–	Ref.	–
Weeks 4–5 (initial lifting of restrictions)	0.90 (0.71–1.13)	0.361	1.03 (0.79–1.33)	0.837
Weeks 6–8 (additional lifting of restrictions)	1.01 (0.78–1.31)	0.961	0.96 (0.72–1.27)	0.767
Age, years				
18–39	Ref.	–	Ref.	–
40–69	0.92 (0.71–1.18)	0.487	0.75 (0.57–0.98)	0.034
≥70	0.49 (0.32–0.76)	**0.002**	0.54 (0.32–0.92)	0.024
Sex				
Male	Ref.		Ref.	
Female	1.19 (0.92–1.55)	0.182	1.10 (0.80–1.50)	0.560
Civil status				
Other	Ref.	–	Ref.	–
Married / common law	1.07 (0.83–1.37)	0.626	0.94 (0.71–1.24)	0.659
Living condition				
Alone	Ref.	–	Ref.	–
Other	0.96 (0.71–1.31)	0.801	1.06 (0.75–1.48)	0.757
Education				
Less than university	Ref.	–	Ref.	–
University	0.96 (0.78–1.19)	0.721	0.85 (0.68–1.07)	0.166
Location				
Rural	Ref.	–	Ref.	–
Urban	1.20 (0.91–1.59)	0.205	1.06 (0.77–1.46)	0.711
Work status				
Other	Ref.	–	Ref.	–
Full-time or part-time	1.42 (1.09–1.86)	**0.011**	1.12 (0.83–1.52)	0.458
Permanent / temporary disability	1.23 (0.94–1.60)	0.132	1.16 (0.86–1.55)	0.327
Work status change				
No loss of employment	Ref.	–	Ref.	–
Loss of employment	0.67 (0.48–0.94)	**0.019**	1.09 (0.74–1.61)	0.663
Geographical variations in COVID-19 infection rates (per 100 000)				
0 to <50	Ref.	–	Ref.	–
50–150	1.05 (0.53–2.08)	0.887	0.79 (0.37–1.70)	0.547
>150	1.00 (0.52–1.93)	0.991	0.83 (0.39–1.76)	0.632
COVID-19 perceived susceptibility				
0–4	Ref.	–	Ref.	–
>4	0.98 (0.73–1.31)	0.886	1.17 (0.86–1.60)	0.309
COVID-19 perceived severity				
0–4	Ref.	–	Ref.	–
>4	0.92 (0.76–1.13)	0.437	0.92 (0.74–1.15)	0.475
COVID-19 perceived benefits				
0–4	Ref.	–	Ref.	–
>4	1.00 (0.79–1.26)	0.997	1.03 (0.80–1.32)	0.844

Continued on the following page

TABLE 2 (continued)
Associations between characteristics of patients and worsened pain or psychological distress

Variables	Model 3 Worsened pain		Model 4 Moderate-severe psychological distress	
	Adjusted OR (95% CI)	*p*-value	Adjusted OR (95% CI)	*p*-value
COVID-19 perceived risks				
0–4	Ref.	–	Ref.	–
>4	1.27 (1.03–1.56)	**0.022**	0.91 (0.73–1.13)	0.381
Work-related restrictions	0.99 (0.83–1.17)	0.856	1.06 (0.88–1.27)	0.547
Health-related restrictions	1.10 (0.96–1.27)	0.174	1.08 (0.92–1.25)	0.349
Social-related restrictions	0.98 (0.86–1.12)	0.786	1.08 (0.94–1.24)	0.275
COVID-19 emotional reactions[a]	1.17 (0.99–1.38)	0.059	2.14 (1.78–2.57)	**<0.001**
Stress (material needs)[a]	0.93 (0.82–1.05)	0.224	1.08 (0.95–1.22)	0.268
Stress (virus threat, social interactions)[a]	1.21 (1.05–1.41)	**0.011**	1.39 (1.17–1.66)	**<0.001**
PSS-4 – Perceived stress	1.04 (1.00–1.08)	0.046	1.43 (1.36–1.50)	**<0.001**
PHQ-4				
No/mild distress	Ref.	–	–	–
Moderate/severe distress	1.18 (0.92–1.52)	0.188	–	–
BPI – Pain interference	1.02 (1.01–1.03)	**<0.001**	1.02 (1.01–1.03)	**<0.001**
Pain duration, years				
0–2	Ref.	–	Ref.	–
3–10	1.69 (1.24–2.29)	**0.001**	1.00 (0.71–1.42)	0.984
>10	1.40 (1.03–1.90)	**0.033**	0.83 (0.59–1.18)	0.308
Pain status change				
Unchanged or improved	–	–	Ref.	–
Worsened	–	–	1.14 (0.88–1.47)	0.316
Changes to pharmacological treatments				
No	Ref.	–	Ref.	–
Yes	3.17 (2.49–4.05)	**<0.001**	1.27 (1.00–1.62)	0.054
Changes to physical/psychological treatments				
No	Ref.	–	Ref.	–
Yes	2.04 (1.62–2.58)	**<0.001**	1.04 (0.79–1.37)	0.783

Abbreviations: BPI, Brief Pain Inventory; CI, confidence interval; OR, odds ratio; PHQ-4, Patient Health Questionnaire-4; PSS-4, Perceived Stress Scale-4; Ref., reference.
Note: Statistically significant p-values are bolded.
[a] Regression scores derived from exploratory factor analysis.

of individuals). This is important, knowing that chronic pain is very unlikely to remit on its own and 33% of individuals on a pain clinic waitlist report suicidal ideation.[27]

These statistics are consistent with those of people with other chronic diseases that show higher rates of stress, depression and anxiety than the general population during the pandemic.[28] Two important reasons for this were identified and concerned higher deaths rates following infection with the coronavirus among medically compromised populations and inaccessibility of medical services and treatments.[28] Changes in pharmacological and physical/psychological pain treatments since the onset of the pandemic had the strongest associations with pain deterioration in the present study. The rapid shift toward virtual care or alternative accessible health care and other support options is of utmost importance in such circumstances.[29]

Pain status change associated with factors other than geography

Regional variations in COVID-19 infection rates, living in urban centres where transmission is more likely than in rural settings and experiencing higher numbers of public health safety measures were not associated with pain status or psychological distress. Prevalence of chronic pain is typically higher among rural or remote Canadian dwellers than urban dwellers,[30] but this does not mean that those individuals are also at higher risk of chronic pain deterioration. In Asian and European studies, geographical severity of the coronavirus outbreak has been positively associated with general psychological distress,[28] but has not been examined in relation to pain status.

Stress appraisal and management—a crucial element

Perceived stress was associated with both pain deterioration and psychological distress. Earlier studies on the COVID-19 pandemic have shown that sources of stress are numerous and include, for example,

fear of COVID-19 infection, socioeconomic worries and traumatic stress responses.[31,32]

In this study, stress appraisal had stronger associations with pain status and psychological distress than degree of geographical variations in COVID-19 infection. This is a clinically important finding, since minimizing the absolute number of stressors may be difficult during a pandemic; alternatively, helping individuals manage and appraise stress more optimally is achievable.[33]

Counterintuitively, having lost one's job during the pandemic was associated with lower likelihood of reporting worsened pain; however, being in the workforce at the beginning of the pandemic was associated with an increased likelihood of reporting worsened pain. While the type of employment was not measured in this study, working during the pandemic may push the boundaries of a person's physical capacity if environmental demands (e.g. caring for children at home, adjusting to remote working) increase. Losing one's job, if widely available national emergency financial programs can be made use of, may decrease an individual's level of physical activity or allow for greater engagement in pain self-management.

Deteriorated pain and psychological distress were less prevalent with older age. This is consistent with a systematic review that showed younger adults were at increased risk of psychological distress during the pandemic, likely because of the financial and professional stress associated with lockdowns in addition to increased responsibilities such as childcare.[28]

Magnitude of psychological distress

Psychological distress in this sample (43%) was double that of the general population during the COVID-19 pandemic.[8] Our findings showed that those who felt particularly vulnerable to the COVID-19 pandemic or expressed concerns about the health of others were more likely to report psychological distress. The COVID-19 pandemic puts individuals in an unpredictable situation over which they have little control, a perfect recipe for increased stress.[33] In contrast to pain status change, changes in pharmacological or physical/psychological treatments for pain did not increase the odds of reporting moderate to severe psychological distress. Some of those treatment changes may have been initiated by individuals with chronic pain to limit their risk of COVID-19 infection (e.g. by avoiding hospitals), which in turn may have led to a reduced perceived threat. For others, unwanted changes to their treatments may have led to a worsening of their psychological distress.

Strengths and limitations

The cross-sectional design of this study precluded the ability to make causal inferences. The self-selection of participants in the study through a convenience sampling strategy that included patient organizations limited generalizability of our findings to all individuals with chronic pain. However, compared to other large random surveys, our study sample was of a similar age (mean age: 49.7 compared to 46.6–48.4)[2,34,35] and had a similar percentage of workers (34.9% compared to 38–44%)[2,34]; pain duration (46.9% with pain duration >10 years compared to 46–46.7%)[2,36]; and pain intensity (mean 0–10 pain score: 6.1 vs. 6.3–6.9)[34,37] compared to other large random surveys.

Female participants were overrepresented in this study compared to other studies.[2,34,35,37] It is possible that such representation was in part due to the recruitment strategies that relied primarily on social media.[38,39] Nonetheless, we were able to recruit a nonnegligible number of male participants (n = 429), allowing us to consider this variable in the multivariate models.

The exclusion of individuals with missing data likely resulted in a sample that was less affected by the pandemic than those included. Moreover, patient self-report data may have been subject to recall bias and/or misclassification. These characteristics, however, allow to focus on the individuals' perspectives and to document their lived experience, something very difficult to achieve in large epidemiological studies using medico-administrative databases.

Implications and recommendations

Given the cross-sectional nature and convenience sampling procedure used in this study, it will be important to validate study findings in other samples of individuals living with chronic pain. Study results showed deteriorated pain and psychological status during the COVID-19 pandemic in a population that already faced multiple types of physical, socioeconomic and mental health challenges. The pandemic has exacerbated all of these challenges.[40,41] Given the trajectory of chronic pain, it is likely that many individuals will not return to their pre-pandemic pain state once it is over, and rates of chronic pain may increase over time.[5] As suggested in the latest report of the Canadian Pain Task Force, tangible system responses to the COVID-19 pandemic should be implemented to improve the conditions of individuals living with chronic pain.[5] These include the identification of pain as a health care priority, supporting epidemiological research on pain (including post viral pain), facilitating the implementation of virtual stepped care for pain and mental health, facilitating access to self-management tools and creating centralized and interdisciplinary assessment, intake and care.[5]

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Dissemination

Study results have been presented at two conferences—Canadian Psychological Association and Centre de recherche du Centre hospitalier de l'Université de Montréal (CHUM). Two public webinars also took place to disseminate study results to the general public. In addition, we plan to further disseminate study results to participants and the general public through infographics, and press releases through partnering organizations.

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Conflict of interest

All authors declare no support from commercial entities for the submitted work. MH, GM and KS are employees of Pain BC, a charitable non-profit organization working to enhance the well-being of people living with pain; this organization receives funding from the British Columbia Ministry of Health. GM received funding from the Michael Smith Foundation for Health Research through InSearch Research Group for work unrelated to this submission.

Authors' contributions and statement

MGP – conceptualization, data curation, formal analysis, investigation, methodology, writing – original draft and review and editing; AL – conceptualization, data curation, funding acquisition, methodology, writing – review and editing; LD – conceptualization, data curation, funding acquisition, methodology, writing – review and editing; MH – conceptualization, data curation, funding acquisition, methodology, writing – review and editing; GM – conceptualization, data curation, funding acquisition, methodology, writing – review and editing; KS – conceptualization, data curation, funding acquisition, methodology, writing – review and editing; JMT – conceptualization, data curation, funding acquisition, methodology, writing – review and editing; MD – formal analysis, writing-review and editing; AJM – conceptualization, data curation, methodology, project administration, writing – review and editing; NS – methodology, analysis, writing-review and editing; MC – conceptualization, data curation, funding acquisition, methodology, writing – review and editing.

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Original quantitative research

Substance use classes and symptoms of anxiety and depression among Canadian secondary school students

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This article has been peer reviewed.

Abstract

Introduction: Few studies have assessed patterns of substance use among Canadian adolescents. This cross-sectional study examined substance use classes among Canadian secondary school students and associations with anxiety and depression.

Methods: This study used data from Year 6 (2017/18) of the COMPASS study. Students (n = 51 767) reported their substance use (alcohol, cannabis, cigarette and e-cigarette use) and anxiety and depression symptoms. We employed latent class analysis to identify substance use classes and multinomial logistic regression to examine how anxiety and depression were associated with class membership.

Results: Overall, 40% of students indicated having anxiety and/or depression (50% in females; 29% in males) and 60% of students reported substance use (60% in females; 61% in males). We identified three substance use classes: *poly-use*, *dual use*, and *non-use*. Females with both anxiety and depression had the highest odds of being in the poly-use class compared to the non-use class (odds ratio [OR] = 4.09; 95% confidence interval [CI]: 3.59–4.65) followed by females with depression only (OR = 2.65; 95% CI: 2.31–3.04) and males with both anxiety and depression (OR = 2.48; 95% CI: 2.19–2.80). Symptomatology was also associated with belonging to the dual use class except among males with anxiety only (OR = 1.13; 95% CI: 0.94–1.37).

Conclusion: Canadian secondary school students are engaging in dual and poly-substance use, and anxiety and depression were associated with such use. Females had a higher prevalence of anxiety and depression and should be a priority population for mental health programming.

Keywords: *anxiety, depression, alcohol drinking, cannabis smoking, cigarette smoking, vaping, latent class analyses, adolescent*

Highlights

- 40% of students indicated anxiety and/or depression and 60% of students reported substance use.
- Females had a higher prevalence of anxiety and/or depression (50% vs. 29%).
- Overall, anxiety and/or depression were associated with dual use and poly-substance use.
- Females with both anxiety and depression had the highest odds of being in the poly-substance use class.

Introduction

In 2017, 57% of Canadians aged 15 to 19 years reported alcohol use, 19% reported cannabis use, 8% reported cigarette smoking and 23% reported trying e-cigarettes.[1] Such use is associated with adverse mental, physical and academic outcomes.[2,3] Notably, recent evidence shows an estimated 23% of Canadian students in Grades 9 to 12 use more than one substance, also known as poly-substance use or poly-use.[4]

While the prevalence of substance non-use has remained steady among high school students over the past five years, poly-use is increasing among adolescents, likely due to the emergence of e-cigarettes.[5] A recent systematic review identified strong evidence for the presence of subgroups of adolescent substance use, with common clusters being low use, single- or dual-substance use, moderate general multi-use and high multi-use.[6] Unfortunately, there is limited research examining patterns of substance use among Canadian adolescents and how e-cigarette use fits in.[6-9] This is concerning, as poly-use is associated with higher risks of negative social and health consequences.[10,11]

Age has been consistently identified as a risk factor for poly-substance use.[6,12] The relationship between sex and poly-substance use is more nuanced. Most studies found males more likely to be in higher use categories,[4,5,9,13-18] but others have found no difference[19-22] or increased risk for females in certain poly-use classes,[23,24] or different latent classes.[25] Other individual-level factors associated with poly-substance use include lower socioeconomic status, early-onset substance use, low social connectedness and parental and peer substance use.[6,12,16,24,26-34]

Substance use has also been associated with adolescent anxiety and depression.[35,36] This is a common problem among adolescents: one-third of Ontario high school students report moderate-to-severe symptoms

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of anxiety and/or depression.[37] Generally, those who report poly-use have higher instances of poor mental health, including anxiety and depression.[11,38-40] However, one study identified protective effects of internalizing problems (which is a measure capturing anxiety, depression and somatic symptoms) on poly-use class membership among adolescents.[24]

Most of the work examining poly-use and poor mental health among adolescents has focussed on depression. However, there is a high prevalence of comorbidity, with an estimated 25% to 50% of youth with depression also meeting the criteria for an anxiety disorder.[41] These youth have a higher risk of longer duration of symptoms, greater impairment, recurrence and greater utilization of mental health services.[41] Therefore, it is important to consider both depression and anxiety simultaneously in analyses.

In the context of the limitations in the current knowledge base, our objectives were to determine the substance use classes among Canadian secondary school students and examine their cross-sectional associations with anxiety and depression symptoms.

Methods

Design

The COMPASS study is a prospective cohort study in Canada that annually collects data from students in Grades 9 to 12 in British Columbia, Alberta and Ontario, and Secondary I to V in Quebec (the equivalent of Grades 7 to 11). Students in Grades 7 and 8 equivalent or with no assigned grade were categorized as "other." To examine cross-sectional patterns of substance use, this study used student questionnaire data from Year 6 (Y6: 2017/18) of the COMPASS study from 122 schools in British Columbia (n = 16), Alberta (n = 8), Ontario (n = 61), and Quebec (n = 37). Schools were purposively sampled based on permitted use of passive consent protocols.[42] A full description of the COMPASS study can be found online (https://uwaterloo.ca/compass-system/) or in print.[43]

Participants

A total of 66434 students participated in Y6 of the COMPASS study. Student response rate was 81.8% and the primary reason for non-response was being absent at the time of data collection. Among respondents, 51767 had complete data (complete information for covariates and at least one substance use measure) and were included in the final sample. There were no significant differences in chi-square tests comparing those included and excluded based on missing outcome data (data available upon request).

Measures

Substance use

Students were asked to report *alcohol use* ("In the last 12 months, how often did you have a drink of alcohol that was more than just a sip?"); *cannabis use* ("In the last 12 months, how often did you use marijuana or cannabis? [a joint, pot, weed, hash]"); *cigarette use* ("Have you ever tried cigarette smoking, even just a few puffs?" and "On how many of the last 30 days did you smoke one or more cigarettes?"); and *e-cigarette use* ("Have you ever tried an electronic cigarette, also known as an e-cigarette?" and "On how many of the last 30 days did you use an e-cigarette?"). It should be noted that these measures are not equivalent to problematic substance use and should not be interpreted as such.

Anxiety

The *Generalized Anxiety Disorder 7* (GAD-7) scale[44] was used to assess generalized *anxiety symptoms*. The GAD-7 reports on self-perceived feelings of worry, fear and irritability over a two-week period. Students were asked how often they were bothered by each symptom with the following response options: "Not at all," "Several days," "Over half the days" or "Nearly every day." The GAD-7 has been found to be reliable among adolescents (α = 0.91)[45] and in the current study had an alpha coefficient of 0.91 for females and 0.90 for males. When screening for anxiety disorders, a score of 10 is used as a recommended cut point for further evaluation and was used to categorize students as having clinically relevant anxiety symptomatology (herein "anxiety").[44]

Depression

The *Center for Epidemiological Studies Depression Scale* (CES-D-10)[46,47] was used to assess *depression symptoms*. Items assess characteristics of clinical depression, including negative affect, anhedonia and somatic symptoms, such as "I felt everything I did was an effort," or "I could not get 'going.'" Students were asked how often they experienced each symptom within the last 7 days, with the following response options: "None or less than 1 day," "1–2 days," "3–4 days," or "5–7 days." The CES-D-10 has been found to be reliable among adolescents (α = 0.85)[46] and in the current study had an alpha coefficient of 0.74 for females and 0.78 for males. A score of 10 or higher is indicative of clinically relevant depression symptomatology (herein "depression").[46]

Covariates

Poly-substance use is associated with other risky behaviour[11,48-51] as well as family and friend support.[4] *Truancy* was used as a measure of student risky behaviour. Students were asked, "In the last 4 weeks, how many classes did you skip when you were not supposed to?" Students who reported any number of classes skipped were categorized as truant. To ascertain whether students felt they had *family* or *friend support*, they were asked how much they agreed with the statement "I can talk about my problems with my family/friends." Students who selected "Agree" or "Strongly agree" were categorized as having family or friend support.

Consistent with other adolescent health research,[52] *sex* (male, female), *grade* (9, 10, 11, 12, other), *ethnicity* (White, non-White), and *weekly spending money* (zero, $1–$20, $21–$100, $100+, don't know), were included as demographic covariates.

Analysis

Descriptive statistics were calculated for the entire sample. Chi-square statistics and Cramer's V were used to compare descriptive statistics by sex for categorical variables. Cramer's V is a measure of effect size from 0 to 1 where values greater than 0.1 indicate an effect.[53]

To create substance use classes and examine their associations with anxiety and depression, latent class analysis (LCA)[54] was implemented using Mplus version 8.2 (Muthen & Muthen, Los Angeles, CA, USA). LCA is a measurement model that uses categorical variables to identify homogenous latent classes within the data that are mutually exclusive and exhaustive.[54] First, a series of LCA models were fit to determine the number of classes to best fit the data. Categorical indicators of alcohol use, cannabis use, cigarette use and e-cigarette use were used as latent class indicators.

Using multiple group LCA, we evaluated whether there were statistically significant differences in class membership by sex ($p < 0.05$). Sex was first used as a grouping variable to explore differences among male and female students. Chi-square tests for measurement invariance compared models in which classes were fixed and then allowed to vary by sex. Tests indicated significant differences in classes between males and females. Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values indicated better model fit when classes were allowed to vary by sex. Therefore, separate classes were created for male and female students and the following steps were carried out separately for males and females.

To establish the best-fitting LCA solution, we started with a one-class solution and added classes until good fit was no longer obtained. We used log-likelihood, AIC, BIC and the Lo-Mendell-Rubin adjusted likelihood ratio test (LMRT) as indicators of model fit. Lower log-likelihood, AIC and BIC values indicate better model fit.[55] The LMRT tests whether a model with k classes fits better than a model with $k-1$ classes; a significant result indicates that it does.[56] These model selection criteria, combined with model interpretability, were used to place participants into the appropriate latent classes. While entropy was not used for model selection, it is reported as an indicator of classification from zero to one, with larger values indicating better latent class separation.[54,57]

After identifying substance use classes using LCA, we conducted multinomial logistic regression to examine how anxiety and depression were associated with likelihood of membership in each class using the R3STEP command in Mplus.[58] Covariates included in the model were sex, grade, ethnicity, weekly spending money, family support, friend support and truancy. The TYPE = COMPLEX and CLUSTER commands in MPlus were used to account for the nesting of students within schools.

Results

Descriptive statistics

About half of the sample was female, and over two-thirds identified as White (Table 1). In 2017/18, 40% of students reported no substance use, 22% reported the use of one substance (i.e. past-year use of alcohol or cannabis or ever use of cigarettes or e-cigarettes) and 38% reported the use of two or more substances. Just over half of students reported having used alcohol in the past year (52%), whereas most had not used cannabis in the past year (77%). Overall, 23% of students reported trying cigarettes and 37% reported trying e-cigarettes. Most students reported having family (59%) and friend (76%) support and no truancy in the past four weeks (67%). Overall, 40% of students indicated having anxiety and/or depression. Chi-square tests indicated significant differences by sex for all variables except grade, while Cramer's V only indicated an effect for e-cigarette use (ever use: female 32%; male 41%) and anxiety and depression (anxiety and/or depression: female 50%; male 29%).

Substance use classes

A three-class model was selected as the best fitting model, as it had lower values for the model selection criteria and a more appropriate interpretation than its smaller and larger counterparts (Table 2).

The three classes identified in this study were named *poly-use class*, *dual use class* and *non-use class* (Table 3; Figure 1). The high-use class, *poly-use*, made up 11% of the female sample and 15% of the male sample. This class had the highest probability of all forms of substance use. Female students in this class were most likely to use alcohol one to three times per month and cannabis once per week or more often, to have tried cigarettes and to have used e-cigarettes on six or more days in the past month. Male students in this class were most likely to use alcohol and cannabis once per week or more, to have used cigarettes one to five days in the past month and to have used e-cigarettes six or more days in the past month. The *dual use class* made up 26% of the female sample and 26% of the male sample. This class had a relatively high probability of alcohol and e-cigarette use, and a lower probability of cannabis and cigarette use. Finally, the *non-use class* represented the students reporting no or low use. This class made up 62% of the female sample and 59% of the male sample. Students in this class were most likely to report no past-year alcohol or cannabis use and never having tried cigarettes or e-cigarettes.

Mental illness and substance use classes

Anxiety and depression were first explored descriptively by substance use class (Figure 2). Among females, those with only anxiety had 1.48 (95% confidence interval [CI]: 1.20–1.83) higher odds of being in the poly-use class and had 1.33 (1.16–1.51) higher odds of being in the dual use class than in the non-use class (Table 4). Those with only depression had 2.65 (2.31–3.04) higher odds of being in the poly-use class and 1.48 (1.34–1.64) higher odds of being in the dual use class compared to the non-use class. Finally, those with both anxiety and depression had 4.09 (3.59–4.65) higher odds of being in the poly-use class and 1.81 (1.65–1.99) higher odds of being in the dual use class than in the non-use class.

Among males, those with only anxiety had 1.41 (1.14–1.73) higher odds of being in the poly-use class compared to the non-use class. Differences between the dual use and non-use class were not statistically significant. Those with only depression had 1.69 (1.52–1.87) higher odds of being in the poly-use class and 1.21 (1.10–1.34) higher odds of being in the dual use class compared to the non-use class. Finally, those with both anxiety and depression had 2.48 (2.19–2.80) higher odds of being in the poly-use class and 1.18 (1.05-1.32) higher odds of being in the dual use class.

Discussion

This study examined a sample of Canadian adolescents from Alberta, British Columbia, Ontario and Quebec schools. We identified that three in five adolescents used one or more substances and two in five students experienced clinically relevant psychiatric symptomatology. Co-occurrence of anxiety and depression was high, especially among female students; few students identified as having anxiety alone. The high prevalence of substance use and symptoms of anxiety or depression in this population during an important developmental period is a cause for concern.

Despite statistical tests indicating that classes differed by sex, similar classes were identified for female and male students. Results from the latent class analysis indicated three different patterns of substance use: poly-substance use, dual substance use and non-use. While similar classes were identified for female and male students, a higher proportion of male students were in the poly-substance use class and male students were more likely to use substances at a higher

TABLE 1
Descriptive characteristics of the Year 6 (2017/18) COMPASS sample, by sex (British Columbia, Alberta, Ontario and Quebec, Canada)

Variable	Total sample (n = 51 767)		Female (n = 26 308)		Male (n = 25 459)		Chi-square / *t* test *p*-value	Cramer's V
	n	%	n	%	n	%		
Grade								
9	12 197	23.6	6 212	23.6	5 985	23.5	0.91	0.00
10	12 767	24.7	6 493	24.7	6 274	24.6		
11	12 406	24.0	6 328	24.0	6 078	23.9		
12	8 168	15.8	4 111	15.6	4 057	15.9		
Other[a]	6 229	12.0	3 164	12.0	3 065	12.0		
Ethnicity								
White	34 890	67.4	17 859	67.9	17 031	66.9	0.02	0.01
Non-White	16 877	32.6	8 449	32.1	8 428	33.1		
Weekly spending money								
Zero	8 318	16.1	3 777	14.4	4 541	17.8	< 0.01	0.08
$1–$20	13 029	25.2	6 750	25.7	6 279	24.7		
$21–$100	12 433	24.0	6 755	25.7	5 678	22.3		
$100+	9 819	19.0	4 545	17.3	5 274	20.7		
Don't know	8 168	15.8	4 481	17.0	3 687	14.5		
Past-year alcohol use								
None	24 537	47.6	12 184	46.5	12 353	48.7	< 0.01	0.08
< 1 x /month	10 532	20.4	5 939	22.7	4 593	18.1		
1–3 x /month	11 930	23.1	6 256	23.9	5 674	22.4		
≥ 1 x /week	4 568	8.9	1 838	7.0	2 730	10.8		
Missing	200							
Past-year cannabis use								
None	39 808	77.1	20 459	77.9	19 349	76.2	< 0.01	0.06
< 1 x /month	4 959	9.6	2 724	10.4	2 235	8.8		
1–3 x /month	3 088	6.0	1 556	5.9	1 532	6.0		
≥ 1 x /week	3 790	7.3	1 515	5.8	2 275	9.0		
Missing	122							
Cigarette use								
None	39 820	77.0	20 456	77.8	19 364	76.1	< 0.01	0.04
Ever use	7 049	13.6	3 609	13.7	3 440	13.5		
1–5 days (in past month)	2 790	5.4	1 358	5.2	1 432	5.6		
6+ days (in past month)	2 067	4.0	869	3.3	1 198	4.7		
Missing	41							
E-cigarette use								
None	32 616	63.4	17 733	67.7	14 883	58.9	< 0.01	0.13
Ever use	7 522	14.6	3 741	14.3	3 781	15.0		
1–5 days (in past month)	6 844	13.3	3 278	12.5	3 566	14.1		
6+ days (in past month)	4 494	8.7	1 447	5.5	3 047	12.1		
Missing	291							
Family support								
No	21 245	41.0	11 632	44.2	9 613	37.8	< 0.01	0.07
Yes	30 522	59.0	14 676	55.8	15 846	62.2		

Continued on the following page

TABLE 1 (continued)
Descriptive characteristics of the Year 6 (2017/18) COMPASS sample (n = 51 767), by sex (British Columbia, Alberta, Ontario and Quebec, Canada)

Variable	Total sample (n = 51 767)		Female (n = 26 308)		Male (n = 25 459)		Chi-square / *t* test *p*-value	Cramer's V
	n	%	n	%	n	%		
Friend support								
No	12 684	24.5	6 012	22.9	6 672	26.2	< 0.01	−0.04
Yes	39 083	75.5	20 296	77.2	18 787	73.8		
Truancy								
No	34 648	66.9	17 212	65.4	17 436	68.5	< 0.01	−0.03
Yes	17 119	33.1	9 096	34.6	8 023	31.5		
Anxiety and depression symptoms								
None	31 335	60.5	13 224	50.3	18 111	71.1	< 0.01	0.24
Anxiety only	2 209	4.3	1 450	5.5	759	3.0		
Depression only	7 764	15.0	4 206	16.0	3 558	14.0		
Both	10 459	20.2	7 428	28.2	3 031	11.9		

Notes: Anxiety symptoms were assessed using the GAD-7 scale; depression symptoms were assessed using the CES-D-10. A score of ≥ 10 was used as the cut-off to indicate anxiety and depression. Family/friend support refers to students agreeing with the statement "I can talk about my problems with my family/friends."

[a] Primarily Grades 7 and 8 equivalents.

frequency. This result supports research that has found males more likely to belong to higher-use categories,[4,5,9,13-18] although others have found no difference[19-22] or increased risk for females in certain poly-use classes (e.g. nonmedical use of prescription medication, not measured in this study).[23,24] It should be noted that measures of substance use did not differentiate between simultaneous use (i.e. "true" co-use) and concurrent use (i.e. sequential use); therefore, students in the poly-substance use class did not necessarily use substances simultaneously.

These results are consistent with a recent systematic review that identified typical patterns of substance use among adolescents: a low-use or no-use class comprising the most adolescents, a predominantly alcohol-use class, and finally high multi-use groups.[6] Our study findings differed from that review in two main ways. First, we identified only one multi-use group, while other studies have identified a moderate and a high multi-use group;[14,24,59-62] although many of these surveys included additional illicit substances (i.e. ecstasy, amphetamines, cocaine[14,24,59]), which were not examined in this study.

Second, rather than a predominantly alcohol-use class, we identified a dual use class that also included trying e-cigarettes. This is similar to a USA study that identified an alcohol and e-cigarette use class.[9] These findings highlight that adolescent prevention and treatment strategies should consider substance use patterns, including dual and poly-substance use.

The current study highlights the importance of including e-cigarette use or vaping when examining patterns of adolescent substance use. It is often included with cigarettes as a tobacco product; however, trends in use are diverging.[63] For example, in 2017/18, 13% of adolescents reported exclusive e-cigarette use while only 3% reported cigarette use and 5% reported dual use, although e-cigarette use has been found to predict future dual use.[64] While previous studies have identified an "alcohol only" class,[25,61,65] that was not the

TABLE 2
Model fit indices for 1 through 7 latent class models of substance use in Year 6 (2017/18) of the COMPASS study, by sex

Number of classes	Log-likelihood	FP	AIC	BIC	LMRT *p*-value	Entropy
Female						
1	−96 491.1	12	193 006.2	193 066.2	—	1.00
2	−84 113.0	25	168 276.0	168 400.9	0.00	0.82
3	**−82 633.7**	**38**	**165 343.4**	**165 533.4**	**0.00**	**0.76**
4	−82 435.3	51	164 972.6	165 227.6	0.02	0.78
5	−82 247.2	64	164 622.4	164 942.3	0.77	0.74
6	−82 191.3	77	164 536.7	164 921.6	0.78	0.69
7	−82 157.8	90	164 495.5	164 945.5	0.79	0.72
Male						
1	−100 222.3	12	200 468.7	200 528.3	—	1.00
2	−86 759.7	25	173 569.5	173 693.6	0.00	0.84
3	**−85 059.5**	**38**	**170 195.0**	**170 383.7**	**0.00**	**0.76**
4	−84 853.8	51	169 810.0	170 062.9	0.06	0.73
5	−84 744.9	64	169 617.7	169 935.6	0.26	0.74
6	−84 706.9	77	169 567.8	169 950.2	0.66	0.74
7	Did not converge					

Abbreviations: AIC, Akaike information criterion; BIC, Bayesian information criterion; FP, free parameters; LMRT, Lo-Mendell-Rubin Test.

Notes: Bold typeface signifies class model selected. "—" signifies no value.

TABLE 3
Conditional item-response probabilities and the prevalence of substance use behaviours in Year 6 (2017/18) of the COMPASS study, by sex

Variable	Female			Male		
	Class 1 Poly-use	Class 2 Dual use	Class 3 Non-use	Class 1 Poly-use	Class 2 Dual use	Class 3 Non-use
Latent class prevalence	11.4%	26.2%	62.4%	14.7%	26.0%	59.3%
Past-year alcohol use						
None	0.04	0.10	0.73	0.05	0.15	0.76
< 1 x /month	0.11	0.35	0.19	0.09	0.32	0.14
1–3 x /month	0.49	0.47	0.08	0.40	0.43	0.08
≥ 1 x /week	0.36	0.08	0.01	0.47	0.10	0.02
Past-year cannabis use						
None	0.11	0.63	1.00	0.13	0.63	0.99
< 1 x /month	0.21	0.27	0.00	0.17	0.22	0.01
1–3 x /month	0.28	0.09	0.00	0.22	0.10	0.00
≥ 1 x /week	0.41	0.02	0.00	0.49	0.05	0.00
Cigarette use						
None	0.12	0.64	0.98	0.12	0.66	0.98
Ever use	0.33	0.31	0.02	0.29	0.29	0.02
Past month, 1–5 days	0.30	0.05	0.00	0.30	0.04	0.00
Past month, 6+ days	0.25	0.01	0.00	0.30	0.01	0.00
E-cigarette use						
None	0.15	0.35	0.95	0.06	0.23	0.90
Ever use	0.17	0.34	0.04	0.09	0.34	0.07
Past month, 1–5 days	0.33	0.27	0.01	0.27	0.32	0.02
Past month, 6+ days	0.35	0.04	0.00	0.58	0.11	0.00

case in this study. Our dual use class comprised a quarter of the students, and the presence of this class indicates that students who were previously only experimenting with alcohol a few times per month may now also be experimenting with e-cigarettes. In the poly-substance use class, e-cigarette use was more frequent than in the dual use class. Due to the negative effects of nicotine on the developing brain[66] and the largely unknown long-term effects of e-cigarette use on lung health,[67] the prevalence of this dual use class is concerning and should be considered in future work examining adolescent substance use. It is important for surveillance work to be able to monitor the use of new substances that emerge in the marketplace and how new products and changes to regulations may impact substance use profiles among adolescents.

The descriptive statistics showed a gradient in anxiety or depression symptom prevalence across classes (Figure 2). Those in the poly-use class had the highest prevalence of anxiety and depression, followed by the dual use class and the non-use class. While other studies have also identified this gradient, it has not been previously examined by sex.[11,38] Notably, prevalence of anxiety and depression in the lowest-risk group (i.e. non-use) among females (23%) was similar to prevalence in the highest-risk group (i.e. poly-substance use) among males (20%). Based on these

FIGURE 1
Substance use item probabilities for three-class latent class model in Year 6 (2017/18) of the COMPASS study, by sex

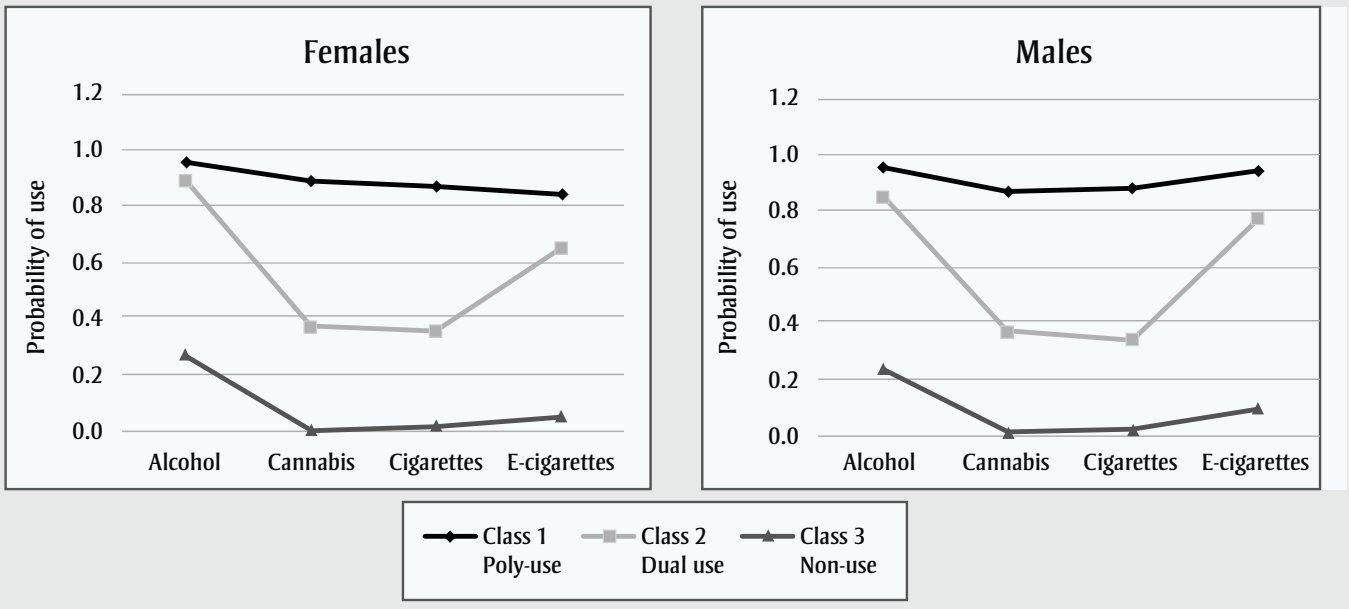
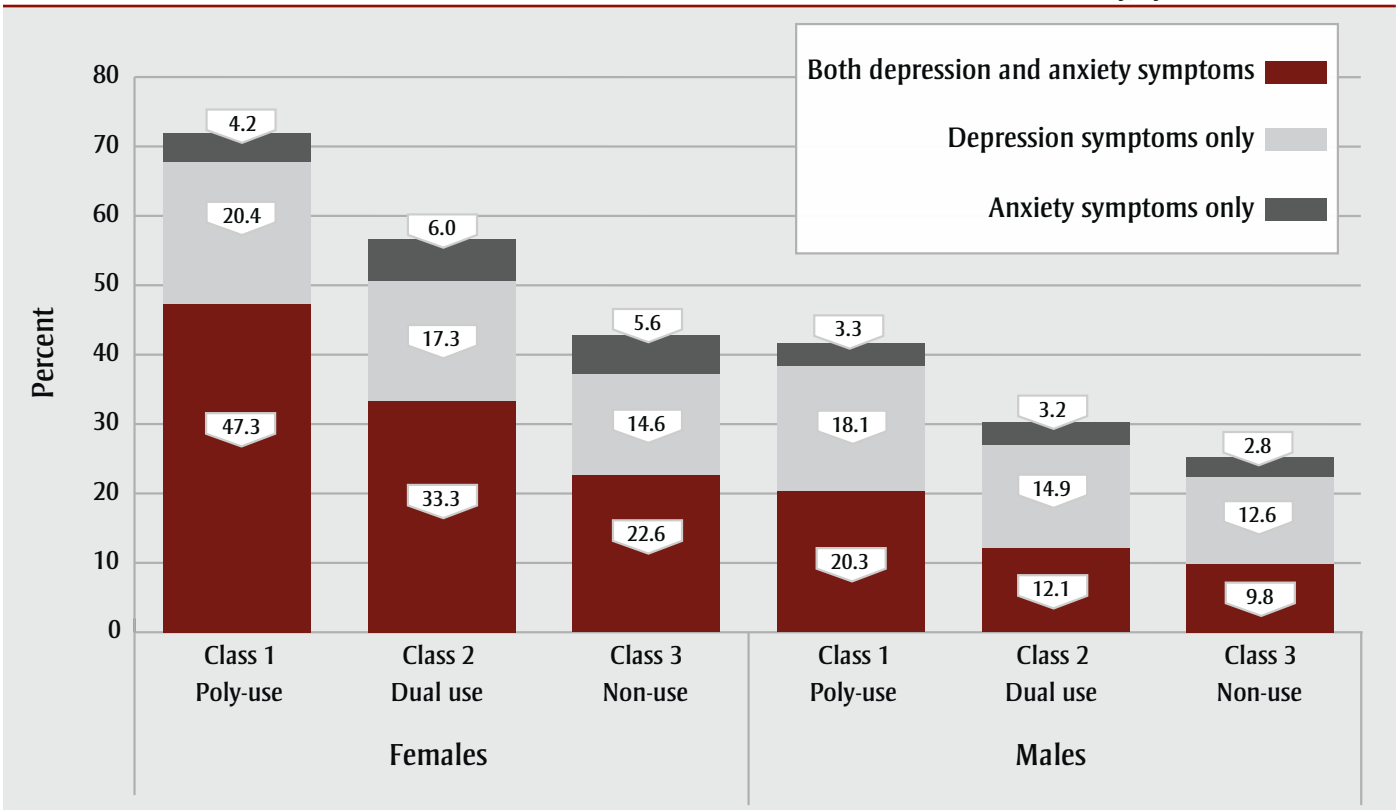


FIGURE 2
Estimated proportion of students reporting clinically meaningful symptoms of anxiety, depression or both in each of the three latent classes of substance use in Year 6 (2017/18) of the COMPASS study, by sex



findings, female students should be a priority population for mental health programming.

This study identified an association between substance use classes and anxiety and depression. These results are in line with many other studies that have examined adolescent substance use and anxiety and/or depression.[11,38,39] While the current research does not address direction of effect, some explanatory theories for this relationship have been proposed. First is the hypothesis that individuals use substances to cope with existing symptoms.[68] This is supported by evidence that has found that depression during adolescence predicts future increased substance use, although there are variations by sex and substances used.[28,69,70] Nevertheless, the evidence does not always support this direction of effect.[35] Other researchers hypothesize lowered mood is a direct result of substance use in adolescence.[71] Regardless of the direction of effect, these results emphasize the need to assess symptoms of anxiety and/or depression among students who are found to be using substances and vice versa.

TABLE 4
Substance use class membership by symptoms of anxiety and/or depression in Year 6 (2017/18) of the COMPASS study, by sex

Symptoms	Odds ratio (95% CI)	
	Class 1 vs. class 3[a]	Class 2 vs. class 3[a]
Female students		
None	1.00	1.00
Anxiety symptoms only	1.48 (1.20–1.83)	1.33 (1.16–1.51)
Depression symptoms only	2.65 (2.31–3.04)	1.48 (1.34–1.64)
Both	4.09 (3.59–4.65)	1.81 (1.65–1.99)
Male students		
None	1.00	1.00
Anxiety symptoms only	1.41 (1.14–1.73)	1.13 (0.94–1.37)
Depression symptoms only	1.69 (1.52–1.87)	1.21 (1.10–1.34)
Both	2.48 (2.19–2.80)	1.18 (1.05–1.32)

Abbreviation: CI, confidence interval.

Note: Models adjusted for grade, ethnicity, weekly spending money, family support, friend support and truancy.

[a] Class 1 is the poly-substance use class, class 2 is the dual use class and class 3 is the non-use class.

It should be noted that, in contrast to our results, Halladay et al.[6] identified subgroups of adolescents with distinct substance use and mental health concerns. While we were not able to identify these students in regression analyses, they were present in our descriptive examination of our sample. For example, 28% of females and 58% of males in the poly-substance use class did not report anxiety or depression.

Strengths and limitations

This study has several strengths. The COMPASS study has a large sample size

and uses measures based on national surveillance tools.[52] The questionnaire uses an active-information passive-consent protocol to encourage participation and honest reporting, which has been shown to be particularly important in substance use and mental health research.[42,72,73] In addition, this study had a good participation rate, with data available for 78% of all participants. Finally, we made use of validated scales for anxiety and depression to assess students' symptoms.

This study was not without limitations. First, we made use of cross-sectional data, preventing causal inferences. Second, the COMPASS study was designed to evaluate changes in school programs and policies and therefore uses a convenience sample that is not representative of Canadian high school students. Third, there are limitations to the questionnaire used. There could be reporting bias in the substance use questions due to the illicit nature of substances for underage youth, whereby participants may have underreported their use. Other illicit substances were not examined in this study, potentially further contributing to the underreporting of substance use. The questionnaire also lacked a definition of e-cigarette use and may have also captured some cannabis use in this measure. Additionally, measures of anxiety, depression and substance use were not indicative of diagnosed clinical disorders. These disorders are prevalent and have a large impact on health service use among young people.[74,75] We were also lacking measures of peer or family substance use, which is associated with early initiation and escalating use through adolescence.[26] However, this study made use of variables indicating family and friends support, which have been negatively and positively associated with poly-substance use, respectively.[4] Furthermore, there were no measures available of parental psychopathology, which is a significant risk factor for children.[76,77] Fourth, there was much missing data on the outcome variables in this study (19%); however, there were no significant differences in the outcome variable in chi-square tests comparing those included and those excluded based on missing data.

Conclusion

Half of female students and almost one-third of male students reported clinically relevant symptoms of anxiety and/or depression. Co-occurrence of anxiety and depression was common, and few students reported anxiety only. We identified three substance use classes: poly-use, dual use and non-use. Those with both anxiety and depression or depression only were more likely to belong to the poly-substance use and dual use classes than the non-use class. Anxiety was associated with belonging to the poly-substance use class among female and male students and belonging to the dual use class among female students.

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Conflicts of interest

Scott Leatherdale is an Associate Scientific Editor with the HPCDP Journal, but has recused himself from the review process for this paper. The authors declare there are no other conflicts of interest.

Authors' contributions and statement

GCW conceived this work, conducted the analyses and drafted the manuscript as part of her PhD dissertation at the University of Waterloo. STL supervised GCW in conceptualizing this project and drafting the manuscript. KAP and MAF provided ideas and thoughts for discussion and revised the manuscript for important intellectual content. STL is the principal investigator of the COMPASS study, wrote the funding proposal, developed the tools and led study implementation and coordination. All authors supported GCW in study design and analysis plan and read and approved the final manuscript.

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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Commentary

Nimble, efficient and evolving: the rapid response of the National Collaborating Centres to COVID-19 in Canada

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Abstract

Since December 2019, there has been a global explosion of research on COVID-19. In Canada, the six National Collaborating Centres (NCCs) for Public Health form one of the central pillars supporting evidence-informed decision making by gathering, synthesizing and translating emerging findings. Funded by the Public Health Agency of Canada and located across Canada, the six NCCs promote and support the use of scientific research and other knowledges to strengthen public health practice, programs and policies. This paper offers an overview of the NCCs as an example of public health knowledge mobilization in Canada and showcases the NCCs' contribution to the COVID-19 response while reflecting on the numerous challenges encountered.

Keywords: *knowledge mobilization, COVID-19, SARS-CoV-2, knowledge networks, public health practice, evidence-based practice, organizational decision making, emerging infectious diseases*

Highlights

- The explosion of research on COVID-19 in Canada and around the world called for an improved capacity to support evidence-informed decision making (EIDM).
- Canada is fostering various mechanisms to achieve this goal; the National Collaborating Centres (NCCs) for Public Health are central to supporting EIDM during the pandemic.
- The NCCs, a network of networks anchored on six unique knowledge hubs, are well connected to provincial, territorial, local and international partners.
- In response to COVID-19, the NCCs are making an important contribution to building knowledge, skills and capacity in the public health sector, and to supporting public health professionals in synthesizing and using evidence-informed knowledge in policy and practice.

Introduction

The emergence of SARS-CoV-2 in late 2019 resulted in a pandemic that precipitated, among other things, an unprecedented explosion of research and a deluge of information in popular science journalism and the mainstream press. The continual evolution of knowledge and information related to the virus significantly hampered the ability of policy makers and other decision makers to utilize the best available evidence. Furthermore, the task of gathering, synthesizing and translating emerging science-informed evidence relating to COVID-19 became particularly challenging. The exponential growth of data and other information made it increasingly difficult to quickly locate evidence of sufficient trustworthiness to inform policy and practice decisions. In the midst of this challenging reality, opportunities arose for a collaborative approach to knowledge mobilization that takes into account the respective knowledge, skills, expertise, capacity and networks of the National Collaborating Centres (NCCs) for Public Health in Canada.

While many organizations have contributed significantly to the public health response to COVID-19, this article will focus specifically on the six National Collaborating Centres for Public Health. The NCCs were established in 2005[1] following the first SARS outbreak in Canada with a key purpose of quickly and efficiently mobilizing rigorous knowledge to public health decision makers in Canada in the event of a national or global crisis.[2]

The purpose of this article is to summarize what the NCCs have done to support the public health response to COVID-19 in Canada, to explore challenges related to rapid knowledge mobilization and to review lessons learned throughout this experience. This article also aims to describe how the vast networks of the NCCs and their ability to develop new partnerships during the pandemic have supported public health professionals throughout Canada in a way that could not have been achieved by any one organization alone.

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5. National Collaborating Centre for Determinants of Health, Antigonish, Nova Scotia, Canada
6. National Collaborating Centre for Infectious Diseases, Winnipeg, Manitoba, Canada
7. National Collaborating Centre for Environmental Health, Vancouver, British Columbia, Canada

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The National Collaborating Centres for Public Health

The NCCs are funded by the Public Health Agency of Canada (PHAC) and are geographically located across the country (Figure 1). They were designed to promote and support the use of scientific research and other knowledges to strengthen public health practice, programs and policies in Canada within specific public health domains: Determinants of Health, Environmental Health, Healthy Public Policy, Indigenous Health, Infectious Diseases, and Methods and Tools (Table 1).

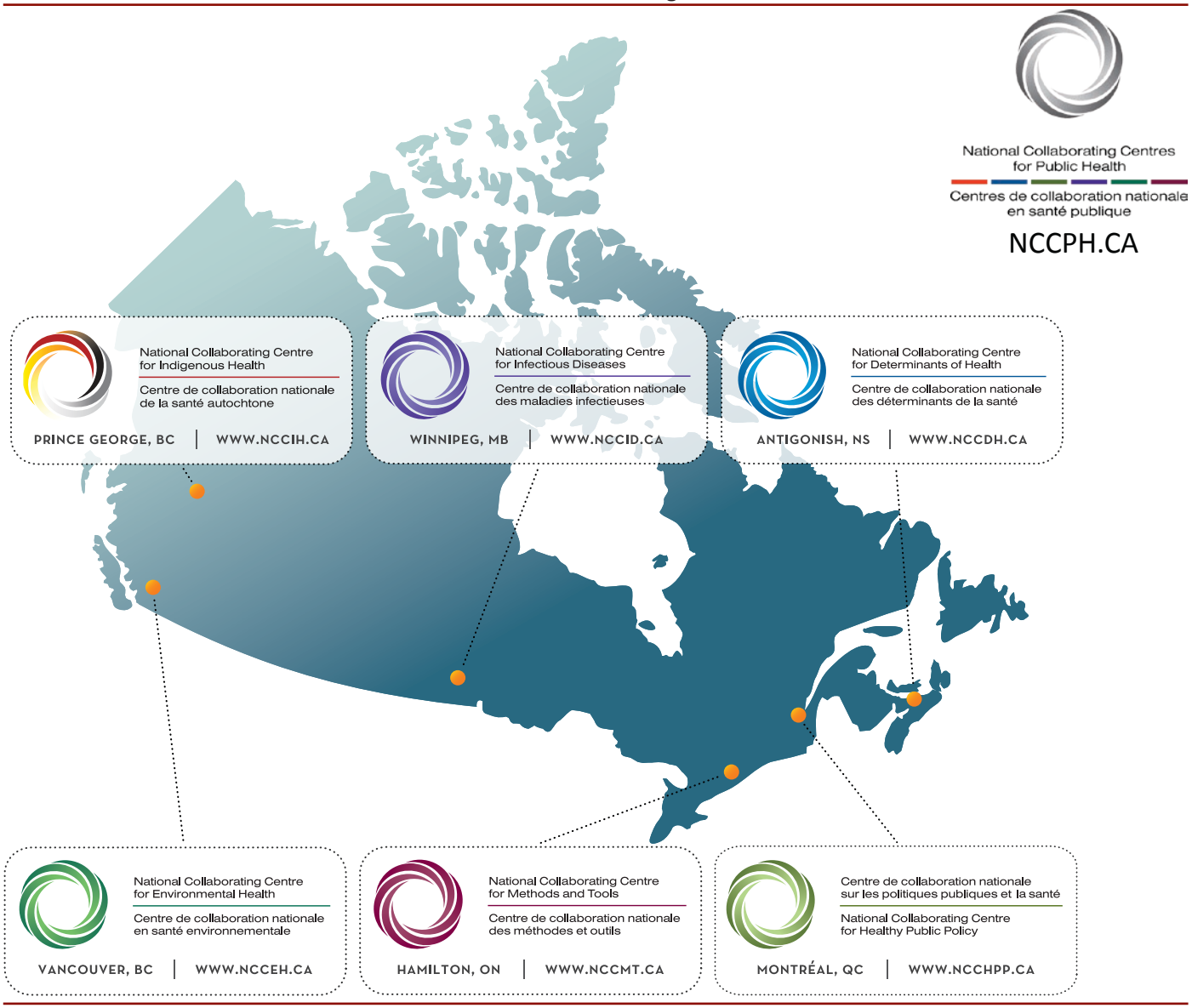
The NCCs carry out their mission by fostering collaboration and networking among diverse stakeholders and drawing on regional, national and international expertise to build knowledge, skills and capacity at the individual, organizational and system levels. NCCs turn research and other information and evidence into knowledge products tailored to specific audiences, contextualized to their settings and available in both official languages. They work with a wide range of partners and organizations across jurisdictions to create opportunities to share knowledge and learn from one another.[3]

The NCCs' contribution to Canada's response to COVID-19

Although each NCC is unique and has its own focus, distinctive characteristics and expertise, their flexibility and responsiveness to emerging issues are their common denominator. This joint attribute makes the NCCs ideally suited to support the system response. Indeed, from the onset of the COVID-19 pandemic, each NCC reoriented its priorities to support the evidence needs of public health professionals and address gaps as they emerged.

Some of the key resources produced by the NCCs include curated online lists or repositories of COVID-19 evidence pertaining to topics specific to the focus of each NCC;[4-8] evidence syntheses on priority questions identified by public health decision makers and public health practitioners;[9-13] a backgrounder on SARS-CoV-2 that

FIGURE 1
Locations of Canada's National Collaborating Centres for Public Health



Note: This figure depicts a map of Canada, indicating the location, name and unique logo of each of the six National Collaborating Centres (NCCs). It also includes the logo of the National Collaborating Centres for Public Health (nccph.ca), which encompasses the six specific NCCs.

TABLE 1
Canada's National Collaborating Centres for Public Health

NCC name	Acronym	Host organization	Location	Main focus/priorities
Determinants of Health	NCCDH	St. Francis Xavier University	Antigonish, Nova Scotia	• Support public health to address the structural drivers of health inequity. • Promote public health evidence-informed action on the "everyday conditions of daily life" that influence health and equity. • Support a "culture of equity" in public health organizations and the health system. • Contribute to emerging knowledge translation methods and tools to advance equity.
Environmental Health	NCCEH	British Columbia Centre for Disease Control	Vancouver, British Columbia	• Raising awareness and increasing understanding of (1) existing and emerging environmental threats and benefits, and (2) how to mitigate these threats and optimize the benefits. • Translating and highlighting research that informs the effective practice of environmental health. • Bringing together the aggregate experience of environmental health practitioners across Canada to inform practice that is effective and attuned to the evolving orientation of public health.
Infectious Diseases	NCCID	University of Manitoba	Winnipeg, Manitoba	• Emerging diseases and outbreaks. • Tuberculosis. • Mathematical modelling for public health. • HIV and sexually transmitted and blood-borne infections prevention and control. • Antimicrobial use and resistance. • Population migration and mobility. • Disease debriefs (that connect readers to clinical and public health guidance, evidence and other sources of information). • The Notifiable Diseases Database.
Methods and Tools	NCCMT	McMaster University	Hamilton, Ontario	• Supporting evidence-informed decision making in public health in Canada. • Making easily accessible, and, where gaps exist, developing methods and tools that facilitate increased capacity for evidence-informed decision making. • Facilitating and supporting organizational change among public health organizations.
Indigenous Health	NCCIH	University of Northern British Columbia	Prince George, British Columbia	• Increasing understanding and application of Indigenous-informed evidence on First Nations, Inuit and Métis health across their lifespan to support public health policy, practice and program decision making. • Fostering partnerships, collaborations and networks to mobilize Indigenous-informed evidence across sectors and jurisdictions to support Indigenous health equity.
Healthy Public Policy	NCCHPP	Institut national de santé publique du Québec	Montréal, Quebec	• Supporting the development of competencies and organizational capacity in policy analysis. • Supporting the implementation of intersectoral approaches to promote healthy public policies. • Developing policy approaches for emerging issues in public health.

Abbreviation: NCC, National Collaborating Centre.

provides an introduction to the basic virology and transmission of SARS-CoV-2 to inform the measures taken to mitigate the spread of the virus;[14] new webpages that identify topic-specific websites with trustworthy information on COVID-19;[15] mathematical modelling resources;[16] and fact sheets.[17] Key activities the NCCs engage in to support knowledge mobilization of COVID-19 evidence and resources include webinars,[18,19] blog posts,[20] guidance documents,[21] podcasts,[22,23] and social media.

The NCCs contributed to multiple research proposals for COVID-19 funding competitions and partnered with the Canadian Institutes of Health Research to support research teams in the dissemination and uptake of findings from COVID-19 proposals funded in 2020. The NCCs also fostered various networks (e.g. COVID-19 and Health Equity Network,[24] Global Network for Health in All Policies), supported communities of practice,[25] and have been working to facilitate the integration of well-being indicators in government budgeting and policy decisions related to the recovery phase of the pandemic.[26]

While each NCC operates as an autonomous and independent entity, throughout the pandemic the NCCs have met regularly to explore opportunities to work together on many of the initiatives described above. A continuing intention is to avoid duplication, and to share efforts to address local, regional, provincial/territorial and national public health needs. Several resources have been developed by two or more NCCs together, and many initiatives to disseminate evidence on COVID-19 have been conducted by several NCCs in partnership.

Challenges encountered

Because the coronavirus that caused the global pandemic was a novel pathogen, its

features and the disease transmission mechanisms only began to be understood in early 2020, and our understanding has continued to evolve over time. Particularly during the first six months of the pandemic, new evidence emerged almost on a daily basis, making evidence syntheses out of date before they were even released. Pre-prints, which are articles submitted to journals that are released ahead of peer review, became the norm and many were released with little to no detail about their research methods, drawing into question the trustworthiness of the findings. Because the pathogen was novel, the evidence needs of policy and decision makers and the speed at which those needs had to be addressed were far greater than the capacity of those trying to address them.

Challenges were also experienced in deciding which questions to address first and understanding whose needs should be given the greatest priority. For example, there was a lack of peer-reviewed COVID-19 information relating to Indigenous health available to synthesize, particularly research written by Indigenous scholars. In addition, there were challenges in ensuring First Nations, Inuit and Métis community perspectives and experiences informed policies and decision-making. The depth of existing inequities experienced by Indigenous peoples increased their risk and required that information be contextualized in order that the unique vulnerabilities and determinants of First Nations, Inuit and Métis health could be understood and appropriate responses made.

At the same time, keeping a proportionate focus on the needs of public health personnel and populations at greater disadvantage (due to local availability of health care resources or ongoing stigma and discrimination) was also necessary in order to avoid perpetuating further health inequities and inequalities. Furthermore, the arrival of COVID-19 did not—with the apparent exception of seasonal influenza[27]—diminish the need to provide timely evidence and knowledge about other pervasive infectious diseases (e.g. sexually transmitted and blood-borne infections, tuberculosis and antimicrobial resistance[28,29]) and other public health programs and services.

In addition, while there was an urgent need to quickly distribute knowledge products to policy makers and decision makers, they were also overwhelmed with too much information and misinformation. The term "infodemic" re-emerged to define this particular context.[30] It was not immediately clear how best to disseminate knowledge products, and to whom. There was also substantial duplication of evidence syntheses occurring (internationally, nationally, provincially, regionally and locally) as well as duplication in the development of French and English resources. It was impossible to stay aware of what everyone was doing and producing all of the time.

Many have described the pace at which organizations functioned during the first six months of the pandemic as that of a "sprint." It became impossible to maintain this pace; staff became fatigued and experienced signs of burnout. In addition, this effort occurred while learning how to function virtually. There was much to learn about working efficiently and effectively from home as a team, including ensuring that staff had the necessary equipment to work virtually.

Lessons learned and emerging strategies

In the early months of the pandemic (March and April 2020) reviewing research, recommendations and lessons learned from the SARS and H1N1 epidemics was time well spent to capitalize on dos and don'ts from past strategies. In the same way, reflection on the first several months of the current pandemic gives rise to several lessons learned that the NCCs will use to guide efforts to support the current and medium- and long-term responses to COVID-19 as well as those of the recovery phase.

First, there is a need for forward thinking in order to anticipate the next steps in the pandemic response and future knowledge needs of policy makers and decision makers. A proactive rather than reactive approach will facilitate the availability of evidence syntheses and knowledge products, as well as engagement and collaboration, when policies and decisions are being made. It is important to create resources that not only meet current needs related to COVID-19 but have usability beyond the pandemic.

Second, public health actors have been heavily mobilized to contain the spread of the virus and to mitigate its immediate impacts on all sectors of society since the start of the pandemic, but they have also been solicited to contribute to policies, programs and practices to support recovery to a healthier and more equitable, resilient and sustainable society. However, containing the virus and dealing with its immediate impacts has not left much time or energy for public health organizations to contribute to this second role, which is more focussed on the medium- to long-term response. As a network of networks, some NCCs were well placed to contribute to the surge capacity needed to support public health actors in their immediate response, while others were able to mobilize to support them in their contribution to the medium- and long-term response.

Third, established relationships and partnerships are essential. Being able to tap into the public health field has been critical to the work of the NCCs, as has the ability to draw on Indigenous knowledges and experiences of past pandemics (e.g. H1N1, smallpox). Regular check-ins with other NCCs and PHAC have been instrumental in coordinating work, fostering collaboration and avoiding duplication of effort. Dedicated staff with established relations of trust who can work across jurisdictions are needed to proactively seek out who is working on what, compile the information and share it.

Leveraging networks and developing new partners

A comprehensive response to COVID-19 requires engagement, collaboration and partnership across disciplines, sectors and jurisdictions. Building on well-established relationships with many partners and colleagues such as public health professionals, governmental departments, evidence synthesis organizations, researchers and post-secondary educational institutions, the NCCs have contributed to connecting researchers, policy makers and practitioners to support knowledge sharing and evidence-informed policies, decisions, practice and emerging research.

The NCCs have been active participants and leaders in national and international collaborations that have emerged as a result of the pandemic. One such initiative is the COVID-19 Evidence Network to support Decision-making (COVID-END).[31] This international network is helping those supporting decision making to find and use the best evidence on COVID-19, facilitating coordination of evidence syntheses

efforts worldwide,[32] and reducing duplication of effort. Through participation in COVID-END, the NCCs are contributing to the evidence ecosystem and avoiding duplication of evidence syntheses.

Conclusion

Evidence-informed public health is rooted in the seminal work of Archie Cochrane, who since the early 1970s noted that many medical treatments lacked scientific evidence of effectiveness.[33] Over the years, Canada and many other countries have developed evidence-informed capacity to improve the use of scientific evidence in day-to-day public health practice, policy and decisions. With each pandemic (SARS, H1N1, COVID-19) there has been a growing commitment both nationally and internationally to an evidence-informed response. In fact, it was the SARS epidemic of 2003 that triggered the creation of the Public Health Agency of Canada, the pan-Canadian Public Health Network and the NCCs as structural pillars of the Canadian public health system.

In the 16 years since their creation, the NCCs have demonstrated a proven track record of working with the other pillars, supporting and responding to the needs of public health with evidence, knowledge systems and network building. Today, we are witnessing the benefits of the investment in the NCCs as they fill a critical role in the public health system in Canada during this pandemic by identifying gaps, compiling and synthesizing evidence and facilitating knowledge mobilization and exchange so as to bridge the divide between evidence, policy and practice.

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Authors' contributions and statement

AD was responsible for conceptualization, methodology and project administration, and writing, reviewing and editing the original draft. MD significantly revised the original draft and added several new sections based on feedback received from reviewers. All other listed authors were responsible for validation of the research design, and review and editing of both drafts of the paper. All authors helped critically revise the article throughout the development and peer review process.

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Conflicts of interest

None.

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