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Has public health messaging during the COVID-19 pandemic reflected local risks to health?: A content analysis of tweeting practices across Canadian geographies

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ABSTRACT

During the COVID-19 pandemic, public health agencies and decision-makers have used social media to disseminate information, encourage changes to behaviour and promote community supports and resources. Their communications have served to educate the public on risks and initiate the widespread adoption of public health measures to 'flatten the curve'. We conducted a content analysis of COVID-19 Tweets by Canadian public health accounts during the first 6 months of the pandemic to explore differences in Tweeting practices by geography and identify opportunities to improve risk communication. We found that Canadian public health accounts in particular geographic settings did not always apply best practices for health communication. Tweeting practices differed considerably between jurisdictions with varying burdens of COVID-19. Going forward, Tweets authored by public health accounts that promote behaviour change and community-building ought to be utilized whenever risks to health are high to reflect an increase in disease transmission requiring intervention. Our study highlights the need for public health communicators to deliver messaging that is relevant for the levels of risk that their audiences are encountering in a given geographic context.

1. Introduction

Since the global coronavirus (COVID-19) pandemic was declared on March 11, 2020, people have had to make adjustments to routines and behaviours in order to minimize and mitigate risks to their health and that of others. Decision-making about whether to adopt certain risk-taking or risk-mitigating measures is partly influenced by what messages are communicated by experts and leaders, and how they are accessed and understood by individuals. Therefore, the characteristics of a message, including its content and intended purpose, play an important role in shaping an individual's health beliefs and risk perceptions (Vahabi, 2007). During this pandemic, it has been especially important for public health officials to provide quick and clear information on disease transmission, what constitutes safe versus risky activities and what community supports are available to slow the spread of the disease and 'flatten the curve'. However, public health messaging has not always been consistent nor clear over the course of the COVID-19 pandemic, which has led to the varying adoption of protective measures and divergent views on risk with respect to emerging and uncertain threats (Gollust et al., 2020). This study will present geographic trends in Tweets by Canadian public health officials and agencies during the first 6 months of the COVID-19 pandemic.

Public health officials are uniquely positioned to lead most of the communication efforts during pandemics and meet the public's need for expert information; they are also often perceived as trusted and credible leaders (Jin et al., 2019). Fortunately, there exist many best practices for risk communication during crises, which can help experts and public health officials communicate risks effectively. These best practices suggest that in addition to informing citizens on the severity and probability of risks (Bavel et al., 2020), risk communication should include messages that promote self-efficacy (e.g. messages that encourage individuals' beliefs that they have the ability to take action), acknowledge

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public concerns and uncertainties surrounding a situation, and indicate expert agreeance and/or coordination between those in charge (Seeger, 2006; Sheppard et al., 2012). These strategies are viewed as important tools for organizations to enhance public trust in institutions and leaders (Bish and Michie, 2010), clarify facts and debunk myths, and diffuse fears and anxieties (Comrie et al., 2019). Additionally, conducting effective risk communication during a crisis is key to helping people regain a sense of control over a highly uncertain situation (Lin et al., 2016).

Since pandemics constitute a period of immense uncertainty, there is a heightened need for up-to-date information that is relevant to the set of local risks that individuals face in their community. Bento et al. (2020) found that the first case of COVID-19 in a given US state coincided with an increase in information-seeking for facts about COVID-19 (e.g. disease symptoms) in that state. This would suggest that when the distribution of health risks varies from place to place, it may be helpful to tailor public health communications by geography to reflect both the level of threat and the distinct information needs of individuals located in a particular area. If these needs are not met with relevant information from official sources, individuals may fill the gap with less credible sources or misinformation (Heldman et al., 2013) or assume that governments and/or leaders are withholding important information (van der Weerd et al., 2011).

Social media has proved to be particularly useful in times of crises since it provides a direct link between officials leading the crisis response and the community members they serve (Vos et al., 2018). This direct connection to local community members largely circumvents the need for those individuals to follow other communication channels that may share less relevant information (Hagen et al., 2018). Twitter is a popular social media platform, which reported a record increase in daily users during the COVID-19 pandemic – usership was up by 24% after the first three months of 2020 compared to the same period in the year prior (Mohamed, 2020). This increase in users could reflect an increase in information-seeking on this platform; previous research has demonstrated Twitter's effectiveness as a key information dissemination tool during past and current disease outbreaks (Chew and Eysenbach, 2010; Jang and Baek, 2019; Rosenberg et al., 2020; Slavik et al., 2021).

Despite the risks of many diseases varying by location, few studies have assessed geographic variability in the Tweeting practices of public health officials and agencies, and the majority of the existing research has focused on differences in Tweet content. For example, Neiger et al. (2013) found that local health departments in the United States that served smaller populations were less likely to Tweet messages promoting actions and/or behaviour modifications than those serving larger populations. Conversely, in a study about Ebola Tweets, Wong et al. (2017) found that local health departments in the United States that served *larger* populations were more likely to Tweet information on the outbreak than those serving smaller populations. Harris et al. (2013) also suggested that there was a link between Tweet content and local community health characteristics after finding that local health departments representing jurisdictions with higher diabetes rates tended to Tweet more about diabetes than health departments representing areas with a lower burden of diabetes. Interestingly, citizens' Tweets about health-promoting behaviours have also been linked to lower disease rates in areas where those Tweets were authored (Ireland et al., 2016), suggesting that Twitter can be a powerful tool for shaping local health outcomes.

However, part of the problem with crafting a message on health risks that reflects local circumstances is that risks often vary significantly across different populations and regions. The COVID-19 outbreak started as a localized threat among residents of Wuhan, China, which quickly devolved into a global public health crisis that required national border closures and restrictions on everyday life across various local communities. Furthermore, there has been a significant diversity in approaches to managing and responding to the pandemic by location (Crayne and Medeiros). In fact, the inconsistent measures implemented by some governments and not others, as well as the frequent changes to instructions on risk-mitigating behaviours, may have led to the emergence of risk-taking amongst individuals who hold numerous misperceptions about the risks of contracting COVID-19 (Ölcer et al., 2020). Unfortunately, inconsistent messaging and perceived disagreement between experts can lead to widespread confusion about COVID-19 among members of the public and erode trust in public health institutions and decision-makers (Malecki et al., 2020). Despite these challenges of communicating COVID-19 risks to health across various geographies, populations benefit from information that communicates the local circumstances around an unfolding crisis (Graham et al., 2015).

In Canada, the absolute risk of COVID-19 infection has varied substantially by geography, with some provinces recording a significantly higher proportion of cases compared to others (Government of Canada, 2020). While some major cities like Toronto and Montreal have made headlines for high caseloads, even largely rural areas with low population densities (and lower transmission rates) have occasionally experienced outbreaks of COVID-19 cases, mostly linked to particular localized industries or occupations (e.g. farm workers) (Government of Ontario, 2020). Further, different circumstances within and between provinces led to different epidemic timing and trajectories across the country (Adeel et al., 2020); COVID-19 case numbers peaked at different times in different regions during the first wave and thus the public health response has varied across geography and time. Therefore, it is important to assess whether public health communications were tailored to reflect geographic variability in the risk of COVID-19 across Canada. Given that some 15 million Canadians use Twitter monthly –making it one of the most popular social media platforms used (Slater, 2018)– this study analyzed Tweets by Canadian public health officials and agencies to assess trends in COVID-19 communication.

Other studies that have examined health and public health communications on Twitter have classified Tweets into one of three message function categories (Neiger et al., 2013; Park, Reber and Chon, 2016; Thackeray et al., 2013). These message function categories were originally developed by Lovejoy and Saxton (2012) who classified organizational Tweets based on whether their purpose was to (1) provide information ("information"); (2) encourage a reader to take an action or their change behaviour ("action"); or (3) promote community-building or local programs ("community"). Previous researchers have also examined risk communication practices on Twitter during past public health crises (Meadows et al., 2019; Vos and Buckner, 2016; Vos et al., 2018) and have explored the use of some strategies for communicating health risks and addressing public concerns. The goal of our study was to explore differences in COVID-19 Tweets from Canadian public health accounts by geography and identify missed opportunities for risk communication on Twitter. The research questions for this study were:

RQ1: Did the message function of Tweets about COVID-19 by Canadian public health agencies and decision-makers change over time?
RQ2: How did the message function of Tweets about COVID-19 vary across different geographic settings (e.g. scale, urban/rural) and populations served?
RQ3: How did the use of risk communication strategies vary by jurisdiction?

2. Methods

A scoping review of Canadian provincial government websites was conducted to develop a comprehensive list of Canadian public health institutions, agencies and leaders. Using the Twitter interface to manually search the names of these Canadian public health agencies and decision-makers, we identified 128 Twitter accounts which belonged to the following types of organizations and individuals: federal and provincial public health agencies, provincial health authorities and ministries, regional and local health departments, medical officer of health (MOH) of Canada, MOHs from a province or territory, MOHs

representing regional or local health departments and provincial health ministers.

We downloaded Twitter data from the 128 Twitter accounts selected for our study using a Twitter API accessed through R using the *rtweet* package (Kearney et al., 2020). An R script was created to download the most recent 3200 Tweets from each of the 128 accounts, which is the maximum number of Tweets permitted for account-specific searches as imposed by Twitter's API. Twitter data, searched for and collected during the months of May 2020 to July 2020, yielded 303,428 Tweets published between February 2010 and July 2020. This dataset included Tweet-level data containing the author's account name, Twitter handle and number of followers at the time of download, whether the Tweet was an original Tweet or a retweet, the date and time the Tweet was published, the Tweet's text, user-mentions, hashtags, URLs, favorite and retweet count, and whether the Tweet contained media (e.g. image).

We limited our analysis to include only Tweets authored between January 1st, 2020 and June 30th, 2020, resulting in 71,014 Tweets. This period was selected since China first reported the outbreak of the novel coronavirus to the WHO on January 1st, 2020. We had comprehensive Tweet history for 118 accounts during this period. Retweeted Tweets were then excluded, leaving 45,310 Tweets. Although most Tweets in this sample were standalone Tweets, some comprised Tweet threads, which are a series of individual Tweets that have been connected together by the author in order to extend a point or provide additional context across multiple Tweets. For the purposes of this research, the Tweets comprising a thread were combined into a single Tweet thread to evaluate the full content of the entire message. These Tweets and Tweet threads (n = 32,737) will be referred to simply as Tweets throughout the remainder of this paper. We restricted our analysis to Tweets about COVID-19, based on whether they contained one or more of the following keywords: "covid*", "coronavirus", "ncov", "distanc*", "pand*", "tracing", "testandtrace", "curve", "stayhome", "handwashing", "mask", "masque". These keywords were identified by scanning Tweets within the sample and noting commonly used words in Tweets describing COVID-19, which resulted in a final sample of 6982 Tweets about COVID-19.

In order to identify the message function and risk communication strategies contained within Tweets, a manual coding of Tweet features was conducted on a sample of Tweets. To select a sample of Tweets for the manual content analysis, Twitter accounts were first classified based on the province where they were based, where applicable, or were otherwise identified as a "national" account (e.g. the Public Health Agency of Canada and Canada's chief medical health officer). Using these classifications, we then used a stratified random sample with replacement using proportional weighting to randomly select 501 Tweets across various strata based on the number of Tweets each stratum contributed to the total sample. These comprised eight regional strata: British Columbia, Alberta, the Prairies (i.e. Saskatchewan and Manitoba), Ontario, Quebec, the Atlantic provinces (i.e. Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland and Labrador), the Territories (i.e. Yukon and Northwest Territories) and Canada. No public health Twitter accounts from the Canadian Territory of Nunavut were identified. Additionally, we randomly selected Tweets across two broad account types (i.e. agencies and decision-makers). These strata were applied so that our sample of Tweets captured enough geographic variation in the accounts across various provinces and represented both public health agencies and individuals. The resulting stratified random sample of 501 Tweets about COVID-19 contained 58 Tweets from Canadian national-level accounts, 52 from Alberta, 66 from British Columbia, 50 from Atlantic provinces, 199 from Ontario, 47 from the Prairies, 17 from Quebec, and 12 from Territorial accounts. This sample, broken down by account type, reflected 377 Tweets from agencies and 124 Tweets from decision-makers.

Twitter accounts were further classified by additional geographic variables including scale (i.e. whether they were national, provincial or regional/local-level accounts), urban/rural and size of population served. Only accounts whose communities were represented by agencies or decision-makers at the regional and local scale were classified as either urban or rural by applying Statistics Canada's (2019) definition of urban areas as population centers with a population of at least 1000 and a population density of 400 persons or more per square kilometer, with all other areas classified as rural. We used the most recent population counts available through the 2016 Canadian Census published by Statistics Canada (2020a) for each location represented by the agency or decision-maker to classify accounts using three population served categories: <150,000 residents, 150,000–500,000 residents and >500,000 residents.

Three researchers (CS, CB, SS) were trained on a set of 50 Tweets randomly selected from the overall sample of 6982 COVID-19 Tweets prior to beginning the content analysis. This training enabled the researchers to familiarize themselves with each of the variables for coding and define the coding criteria. To distribute the 501 Tweets for the content analysis equally among the three researchers, French-language Tweets (n = 27) were identified and allocated to one of the researchers with fluency in French. Next, 50 Tweets from the remaining English-language Tweets in our sample were randomly selected and allocated to each of the three researchers so that these overlapping Tweets could be used to calculate the value for Krippendorff's alpha to assess interrater reliability. The remaining 424 Tweets were randomly allocated among the researchers such that one researcher coded 201 Tweets (including the 27 French-language Tweets), and the other two researchers coded 200 Tweets each (including the shared Tweets used for the interrater testing). The Krippendorff's alpha reliability coefficient was calculated using the R package *irr* (Gamer, Lemon and Singh, 2019) and found to be acceptable ($\alpha = 0.829$), with all three coders reporting total agreement on 453 out of the 500 (90.6%) possible manually coded answers (i.e. 10 coded variables for each of the 50 Tweets). Generally, a reliability coefficient greater than or equal to 0.80 is deemed acceptable (Krippendorff, 2011). To re-integrate the 50 Tweets that all three researchers had coded for the Krippendorff's calculation into the overall sample, one researcher's coded answer was randomly selected from the three possible coded answers for each variable, such that the probability of selection was proportional to the frequency of that answer (e.g. if two thirds of coders agreed on an answer, there was a two in three chance of that answer being selected).

The content analysis involved coding 10 variables. The first variable, media, indicated the presence or absence of media in the Tweet and the type of media (if present) (e.g. image, video or document). The next variable, message function, comprised three mutually exclusive coding variables based on those proposed originally by Lovejoy and Saxton (2012): information, action, or community. Information Tweets primarily served to inform, educate, or update the reader on COVID-19 case counts, symptoms, policy changes and disease transmission. Action Tweets primarily served to prompt changes in the behaviours or actions of readers, which included encouraging social distancing, instructions on hygiene practices, or other harm-reducing behaviours. Finally, community Tweets were those whose main purpose was community-building, promoting community supports and programs, or highlighting stories from or about the local community. Threaded Tweets were coded based on the most prominent theme for the entire thread.

The final set of coding variables assessed the use of risk communication strategies in Tweets using 6 non-mutually exclusive variables: corrective, risk, efficacy, concern, uncertainty, and experts. Tweets classified as corrective were correcting some inaccurate information about COVID-19 or addressed misinformation. Tweets classified as risk contained information that would help a reader make a judgment about a change in the risk of contracting COVID-19 or suffering health complications from COVID-19. For example, these Tweets contained information regarding absolute risks, relative risks, as well as the identification of high-risk sub-populations. Tweets classified as efficacy contained a reference to an individual's or community's ability to

successfully execute an action or activity, which would result in some tangible benefit to health or a reduction of harm related to COVID-19. Tweets classified as concern included some acknowledgement of the fears, concerns, worry or anxiety people may have struggled with during the pandemic. Tweets classified as uncertainty acknowledged uncertainty, confusion or a lack of available information about something related to COVID-19. Lastly, Tweets classified as experts either implicitly or explicitly mentioned some agreement, coordination or collaboration between public health experts and/or other credible health organizations or individuals. The presence of any one of these six variables was used to indicate the use of any risk communication strategy in the Tweet and were based in-part on best practices in communication developed by Seeger (2006) to improve organizational and individual responses during crisis events.

To test whether Tweet frequencies by message function significantly differed across various geographic variables (i.e. whether message function and geography were independent), Chi-squared independence tests were applied. To display Tweet trends across Canadian jurisdictions, maps displaying the period prevalence of COVID-19 were produced using QGIS, an open-source geographic information system. Regional period prevalence estimates (%) were calculated by dividing the total number of COVID-19 cases reported in that region as of June 30th, 2020 (Government of Canada, 2020) by the population of that region using estimates from June 2020 (Statistics Canada, 2020b), multiplied by 100. Period prevalence percentages were mapped using Natural Breaks (Jenks) classes to highlight ranges of prevalence across Canada.

3. Results

Of the 501 Tweets coded in the content analysis, 16 were unrelated to COVID-19 and were thus omitted from further analysis. Twenty-one Tweets were found to not have a classifiable purpose, which included Tweets containing only a hyperlink or a reply to a Twitter user without much contextual information.

3.1. Tweet message function over time

Of the remaining 464 Tweets, 181 were classified as information Tweets, which served to inform or educate the reader about matters related to COVID-19 risks or transmission. For example: "*Wearing a face covering may offer some protection when physical distancing is not possible, as it may prevent others from being exposed to the droplets from your mouth and nose. They do not replace physical distancing and hand hygiene practices. #COVID19*KFLA https://t.co/CrW859kpfY".

There were 182 Tweets classified as action Tweets in our sample, which prompted readers to perform an action or behaviour change. For example: "*If you normally head to a cottage this time of year, please change your plans. You could get sick while there, or catch or spread the illness while stopping for supplies.* https://t.co/HixOfqqxf5. #COVID19 #stayhome https://t.co/K5HUYKe7PP".

Lastly, there were 101 Tweets whose purpose was classified as a community Tweet. These Tweets promoted community supports and community-building initiatives. For example: "*Community entertainer Greg is bringing the joy of music to care homes every week during the pandemic. He serenades seniors from a physical distance to get everyone grooving to history's greatest tunes!* https://t.co/5BM1ZSOwNY *#COVID19IslandHealth #communityhero*".

Fig. 1 displays trends in the frequency of COVID-19 Tweets authored by Canadian public health agencies and decision-makers by message function over time. During the first 10 weeks of the COVID-19 pandemic, Tweets classified as information were Tweeted most frequently, which indicates that information dissemination was prioritized as knowledge around risks to health was slowly emerging. All Tweet types increased in frequency during the week before the WHO declared a pandemic (week 10, March 11th, 2020). After the pandemic was declared, the frequency

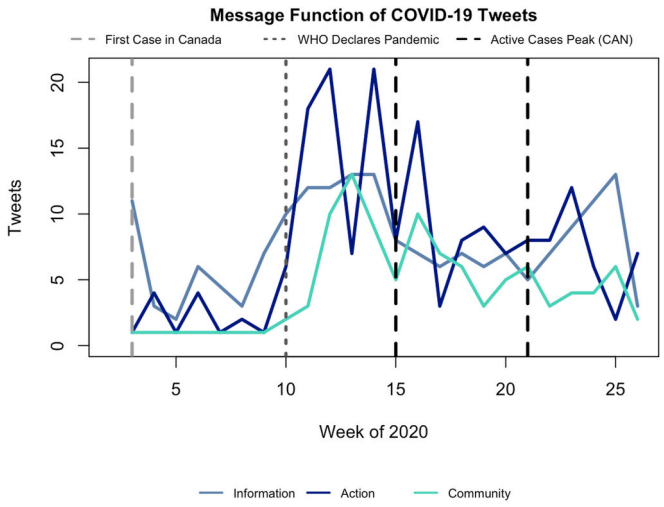

Fig. 1. Frequency of COVID-19 Tweets authored by Canadian public health accounts by message function over time.

of action Tweets surpassed information and community Tweets, peaking during week 12 and 14. This would suggest that public health accounts shifted their messaging to encourage users to adopt newly recommended public health measures such as staying at home and physically distancing. Action Tweets also dominated for a brief period after the first peak in Canadian COVID-19 cases occurred (during week 15). The frequency of all Tweet types declined in subsequent weeks despite a second peak in Canadian COVID-19 cases during week 21. The frequency of information Tweets increased slightly ahead of action Tweets towards the end of the study period (week 24–25). Tweets classified as community were used the least by Canadian public health Twitter accounts throughout the observed study period, suggesting that promoting community initiatives and community-building may not have been prioritized.

3.2. Tweet message function across geographic scale and population served

Table 1 summarizes the frequency of COVID-19 Tweets by message function across geographic scale. Among national and provincial public health accounts, most Tweets were classified as information Tweets (56% and 48%, respectively). Conversely, most Tweets authored by regional and local level public health accounts were classified as action Tweets (42%). National accounts authored very few community Tweets (5% of their total Tweets), while nearly a third of Tweets authored by regional and local accounts were classified as community Tweets (29%). These differences were statistically significant (p value $< .001$) and reflect variations in accounts' communication strategies by geographic scale.

Similar trends were observed when Tweets were stratified by population served. The public health accounts that serve populations smaller than 150,000, and those serving between 150,000 and 500,000 residents, authored mostly Tweets promoting actions (51% and 45%, respectively), while those serving populations greater than 500,000 residents authored Tweets mostly serving to inform readers about COVID-19 (45%) (Table 2). A quarter of Tweets authored by accounts serving 150,000 to 500,000 residents were classified as community Tweets, while accounts serving <150,000 and > 500,000 authored a similar share of community Tweets (20% and 21% respectively). The differences observed were statistically significant (p value $= .012$) and suggest that accounts serving communities with smaller audiences sought to promote more behavioural changes, while accounts serving larger communities primarily served to inform readers about COVID-19.

Table 1
Summed Tweet frequency (and percentages) by message function and geographic scale, January 1st, 2020 to June 30th, 2020.

Account features			Tweet message function			
Geographic scale	Total followers	Number of accounts	Information	Action	Community	Total Tweets
Regional/local accounts	376,854	52	72 (29%)	104 (42%)	71 (29%)	**247**
Provincial accounts	494,819	25	77 (48%)	56 (35%)	27 (17%)	**160**
National accounts	531,400	2	32 (56%)	22 (39%)	3 (5%)	**57**
Total Tweets			**181**	**182**	**101**	**464**

Table 2
Summed Tweet frequency (and percentages) by message function and population served, January 1st, 2020 to June 30th, 2020.

Account features			Tweet message function			
Population Served	Total followers	Number of accounts	Information	Action	Community	Total Tweets
<150,000	17,975	14	20 (29%)	35 (51%)	14 (20%)	**69**
150,000–500,000	133,300	29	36 (30%)	53 (45%)	30 (25%)	**119**
>500,000	1,251,798	36	125 (45%)	94 (34%)	57 (21%)	**276**
Total Tweets			**181**	**182**	**101**	**464**

3.3. Tweet message function in urban versus rural accounts

Table 3 summarizes the frequency of COVID-19 Tweets by message function among a subset of public health accounts (those classified as regional and local accounts, n = 247 Tweets) representing urban and rural communities. Accounts in urban communities authored mostly Tweets serving to inform readers about COVID-19 (44%), while rural accounts authored mostly Tweets prompting readers to perform an action (45%). These differences were statistically significant (p value = .003).

We also examined Tweet trends over time to compare the proportions of message functions for urban versus rural public health accounts before and on/after COVID-19 cases first peaked during Canada's first wave (on April 17th, 2020). Fig. 2 shows that there was an increase in the percentage of Tweets promoting community-building, relative to other message functions, among both urban and rural accounts after the peak in COVID-19 cases occurred. Among urban accounts, the percentage of community Tweets more than doubled from 13% to 30% when comparing pre- and post-peak trends, while the percentage of Tweets prompting actions decreased from 41% to 27%. Among rural accounts, however, community Tweets increased by 5% after COVID-19 cases peaked, which coincided with a decrease in Tweets serving to inform readers about COVID-19 from 28% to 19%.

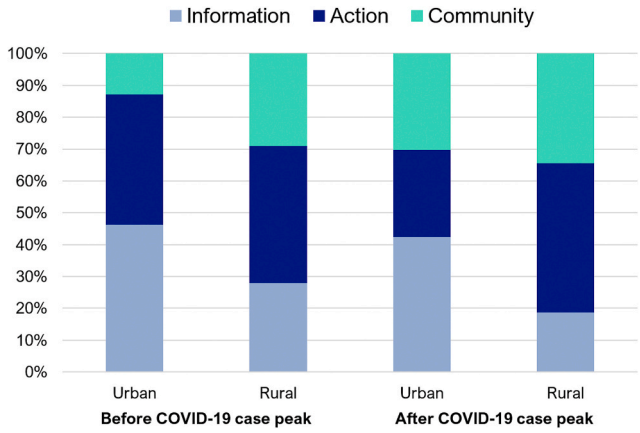

Fig. 2. Percentage of Tweets by message function before and on/after the day that COVID-19 cases peaked during the first wave in Canada (April 17, 2020) by rural and urban accounts.

3.4. Tweet message function across jurisdictions

Fig. 3 displays the period prevalence of COVID-19 between January 1 st, 2020 to June 30th, 2020 across Canadian jurisdictions as well as the frequencies of Tweets by message function authored by public health accounts in each jurisdiction. The Province of Quebec had both the highest burden of COVID-19 and the highest proportion of Tweets serving to inform readers about COVID-19 of all jurisdictions (13 out of 15 Tweets, 87%). Public health accounts in Alberta authored the second highest percentage of information Tweets relative to other message functions (28 out of 43 Tweets, 65%), and recorded the third highest prevalence of COVID-19 (after Quebec and Ontario). Tweets prompting readers to perform actions were the most frequently used message function by accounts located in the Prairies (23 out of 44 Tweets, 52%), Ontario (83 out of 184 Tweets, 45%), and the Atlantic provinces (21 out of 48 Tweets, 44%). The prevalence of COVID-19 varied considerably across these three jurisdictions. British Columbia was the only jurisdiction whose Tweets were mostly classified as community-building Tweets (27 out of 62 Tweets, 44%), where the prevalence of COVID-19 was similar to the Atlantic provinces during the first 6 months of the pandemic.

3.5. Risk communication strategies

Table 4 summarizes the frequency of select risk communication

Table 3
Summed Tweet and Tweet thread frequency (and percentages) by message function and rural and urban accounts[a], January 1st, 2020 to June 30th, 2020.

Account features			Tweet message function			
Community type	Total followers	Number of accounts	Information	Action	Community	Total Tweets
Urban	266,889	16	32 (44%)	25 (35%)	15 (21%)	**72**
Rural	109,965	36	40 (23%)	79 (45%)	56 (32%)	**175**
Total Tweets			**72**	**104**	**71**	**247**

[a] Only accounts corresponding to regional and/or local public health Twitter accounts were classified as rural or urban based on Statistics Canada definition of a population centre.

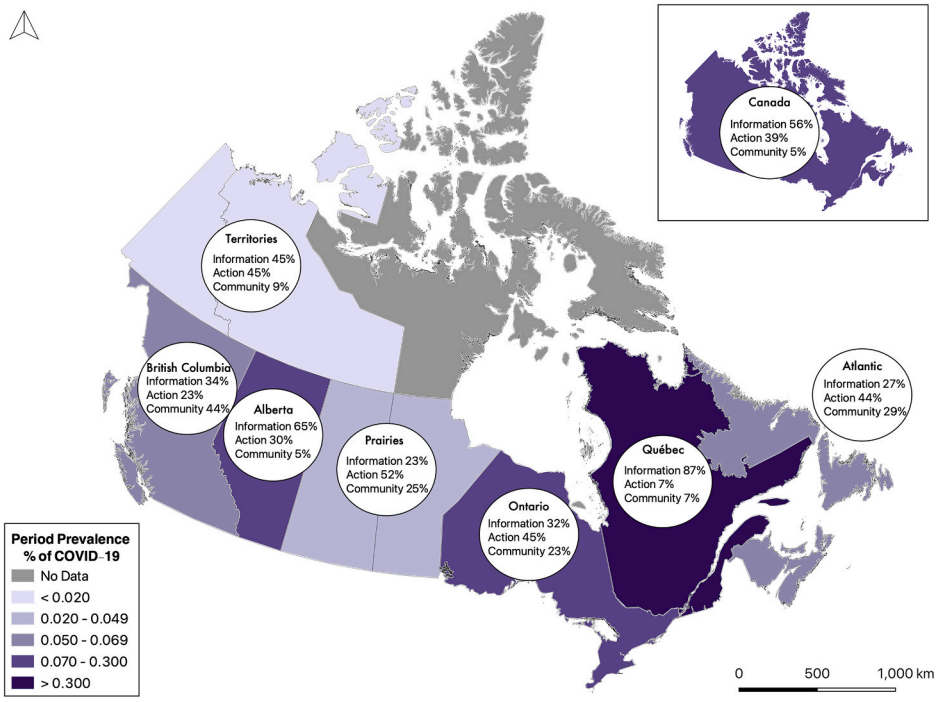

Fig. 3. Map of COVID-19 period prevalence across Canadian jurisdictions between January 1st, 2020 and June 30th, 2020, and the percentage of Tweets by message function authored by accounts in each jurisdiction.

Table 4
Summed Tweet frequency (and percentages[a]) by risk communication strategy and geographic scale, January 1st, 2020 to June 30th, 2020.

Account features			Risk communication strategy[b]							
Geographic scale	Total followers	Number of accounts	Corrective	Risk	Efficacy	Concern	Uncertainty	Experts	Summed strategies	Tweets with any strategy
Regional/local accounts	376,854	41	8 (5%)	14 (8%)	91 (54%)	28 (17%)	11 (7%)	17 (10%)	169	139 (54%)
Provincial accounts	494,819	20	1 (<1%)	24 (22%)	44 (41%)	19 (18%)	5 (5%)	15 (14%)	108	86 (51%)
National accounts	531,400	2	1 (2%)	13 (23%)	28 (49%)	3 (5%)	2 (4%)	10 (18%)	57	37 (65%)
Total Tweets			**10**	**51**	**163**	**50**	**18**	**42**	**334**	**262**

[a] Percentages correspond to the percentage of Tweets classified with that risk communication strategy out of the sum of strategies used in Tweets authored by accounts at that geographic scale and may not add up to 100 due to rounding.
[b] Risk communication strategies were not mutually exclusive; therefore, a single Tweet could contain multiple strategies at once.

strategies that appeared in Tweets by the public health accounts by geographic scale. Of the 485 COVID-19 Tweets in our sample, 262 Tweets contained at least one risk communication strategy. A total of 334 risk communication strategies were used. National public health accounts had the highest percentage of Tweets containing any of the six risk communication strategies examined (65%), followed by regional/local level accounts (54%) and provincial accounts (51%). When examining individual types of strategies, we found that nearly half of the strategies used by national accounts were efficacy messages (49%), which referenced one's ability to successfully perform an action. Nearly a quarter of Tweets provided risk information (23%), and 18% referenced agreement between experts. Similarly, provincial public health accounts used efficacy and risk messages most frequently (41% and 22%, respectively), followed by messages acknowledging concerns about COVID-19 (18%). Among regional and local accounts, more than half of the risk communication strategies employed efficacy messages (54%), 17% acknowledged concern and 10% referenced expert agreement. Overall, these results suggest risk communication strategies were not widely used in Tweets by Canadian public health accounts.

Fig. 4 displays the burden of COVID-19 cases across Canadian jurisdictions, as was displayed in Fig. 3, while highlighting the frequencies of Tweets containing any risk communication strategy authored by public health accounts in each jurisdiction. Tweets by national accounts had the highest proportion of Tweets containing a risk communication strategy (37 out of 57, 65%), relative to the other jurisdictions. Quebec had the highest prevalence of COVID-19, however, it had the lowest percentage of Tweets containing a risk communication strategy in our sample (5 out of 15 Tweets, 33%). The Prairie provinces had the highest percentage of Tweets containing any risk communication strategy (27 out of 45 Tweets, 60%) despite having a relatively low COVID-19 disease burden, followed by Ontario (107 out of 194 Tweets, 55%) and Alberta (26 out of 49 Tweets, 53%). When looking at the use of risk communication strategies over the course of the study period, Alberta and Ontario were the only jurisdictions where the percentage of Tweets containing any risk communication strategy appeared to increase after Canadian COVID-19 cases first peaked on April 17th, 2020, compared to before the peak in cases (data not shown).

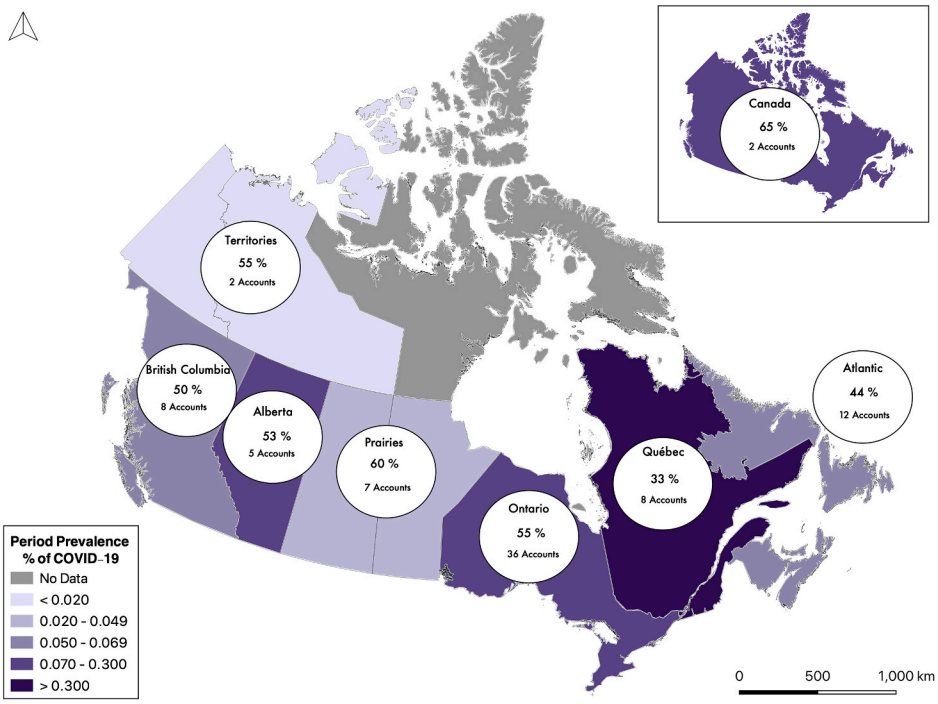

Fig. 4. Map of COVID-19 period prevalence across Canadian jurisdictions between January 1st, 2020 and June 30th, 2020, and the percentage of Tweets that contained a risk communication strategy authored by accounts in each jurisdiction.

4. Discussion

This study explored how public health communications during the early stages of the COVID-19 pandemic varied across time and space in Canada. We found that the use of risk communication strategies in COVID-19 Tweets differed by geography, scale and jurisdiction. We also found significant disconnects between the messages communicated by public health accounts and messages that would have benefitted the individuals that those messages were intended for. Despite the need for public health communications to effectively convey the level of COVID-19 infection risk in particular jurisdictions, the Tweets we analyzed did not always contain relevant messaging or risk communication strategies that would have helped citizens in those jurisdictions assess risks to health. Below we discuss the results in more detail and suggest improvements to Tweet content to meet the diverse needs of audiences residing in areas facing a range of COVID-19 health risks.

Prior to the WHO declaring a pandemic, we found that most public health Twitter accounts used Tweets to inform audiences. This result is consistent with the risk communication literature, which emphasizes the importance of information dissemination in the beginning stages of an unfolding public health crisis when government authorities do not want to appear to be withholding information from the public (van der Weerd et al., 2011). Our results found an increase in the use of action Tweets after the pandemic was declared, which likely reflects a communication shift towards promoting preventive actions like staying home and carrying out public health measures such as avoiding public gatherings. At this stage, crafting communications that promote trust in authorities and beliefs in the effectiveness of recommended public health measures is key to achieving compliance with preventive behaviours (Bish and Michie, 2010). However, the relatively small percentage of community-building Tweets relative to other message functions suggests that Canadian public health accounts may not have been using Twitter as a means to drive community-building and promote institutional trust. This finding presents a missed opportunity for these accounts to do more than just disseminate information about COVID-19. Going forward, Tweets authored by public health accounts that promote actions and community-building ought to be utilized particularly when infection rates rise to reflect an increase in disease transmission requiring intervention and behaviour change.

These results can be further contextualized by Tweeting patterns that were observed based on public health account type. The relatively high percentage of information Tweets authored by national and provincial accounts in our sample, when compared to regional/local accounts, could be explained by the administration of public health responsibilities in Canada. This is because federal agencies and leaders are mostly responsible for communicating national-level statistics during a public health outbreak (Tam, 2018), while Canadian provinces are responsible for establishing emergency orders, disease control measures and testing policies (Marchildon, 2013). Therefore, it makes sense that the majority of Tweets by accounts at federal and provincial scales would serve to inform audiences. Conversely, since regional and local public health agencies are responsible for implementing public health measures and directing changes to behaviour among the local population, it makes sense that they would author mostly Tweets prompting actions and changes to behaviour.

While this approach to public health information dissemination may follow patterns in the jurisdictional administration of public health responsibilities in Canada, it likely falls short in addressing the information needs of Twitter users since users are not necessarily seeking information in accordance with these jurisdictional boundaries. This observation has important implications on how to improve the relevance of online information consumed by users across various geographies and jurisdictions. In order to receive COVID-19 updates and instructions that are most relevant to their local circumstances, Twitter users would have to be aware of and follow regional/local Twitter accounts. Yet, we observed that accounts at the regional/local scale garnered on average fewer Twitter followers per capita (i.e. per population served) compared to provincial accounts (data not shown). This disconnect –between the delivery of specific health messaging at certain geographic scales and the apparent absence of information-seeking on Twitter at some of those scales– suggests that regional and local accounts might need to make extra effort to promote their social media presence and connect with the local populations they serve. Additionally, national and provincial public health accounts with larger followings could play a role in re-

directing online traffic to local/regional accounts by encouraging their audiences to find and follow their local public health agency and/or officials.

Another key communication disconnect was observed in the messaging intended for Twitter users in urban and rural communities in Canada, which faced different burdens of COVID-19 requiring different approaches to communication. Importantly, given that the risks of community transmission of COVID-19 are higher in denser urban areas with larger populations (Peters, 2020), action Tweets could be viewed as a useful communication tool to help drive changes to behaviour among urban individuals to reduce disease spread. However, we found that information Tweets were used more frequently in urban areas relative to other message functions, and the percentage of action Tweets used by urban accounts decreased over the study period. Other research has found that Tweets promoting calls to action to combat disease transmission in specific areas correlated with a decreased prevalence of that disease in those areas, which underscores the importance of targeting messages with specific audiences in mind (Ireland et al., 2016). In addition, given that trust in authorities and perceived efficacy in changing personal behaviours have been found to be two of the strongest predictors for adopting preventive public health measures during previous pandemics (Rubin et al., 2009), Tweeting messages about community-building and promoting actions in areas with a higher risk of disease could be an effective way for public health accounts to drive a reduction in disease transmission.

In contrast, since the risk of COVID-19 transmission was lower in rural populations and generally fewer people in these communities would have personally known someone who was infected with COVID-19, rural audiences may have benefited from more information about the disease, its risks and consequences. Instead, accounts serving rural communities primarily used action Tweets intended for behaviour change, while the frequency of information Tweets decreased over time. This finding signals another potential gap in public health messaging that may have left some rural community members without the information needed to assess local COVID-19 risks most relevant to them.

On the other hand, rural areas tend to have higher proportions of older-aged individuals living in the community who are at an increased risk of developing serious complications if infected with COVID-19. Therefore, the higher percentage of action Tweets used by rural accounts may have been a pre-emptive attempt to prevent increasing COVID-19 case counts that could overwhelm the limited capacities of the health care system in those regions (Miller et al., 2020). That being said, the vulnerable older-aged individuals in rural regions who would have perhaps benefitted from more calls to action are unlikely to be the primary target of public health communications on Twitter.

This study also demonstrated that risk communication strategies were not widely used by the public health accounts, appearing in only 54% of the Tweets analyzed (262 out of 485). Importantly, only 2% of Tweets in our study contained corrective information (10 out of 485) to tackle the spread of misinformation online and this strategy was used most often by accounts at the regional/local scale. Given that accounts at national and provincial scales are primarily responsible for information dissemination, it is somewhat surprising that tackling misinformation on COVID-19 using corrective information was done more frequently by accounts intended for local community members. Since some Twitter users may rely on accounts Tweeting less credible information or misinformation to fill their information needs (Heldman et al., 2013), it is important that public health accounts of all types Tweet corrective information that could help de-bunk some of the myths perpetuated about COVID-19 and other health issues that easily spread on social media.

Another important result from our analysis of the risk communication strategies used by public health accounts revealed the lack of Tweets that acknowledged uncertainties and public concerns surrounding the COVID-19 pandemic. During a public health crisis, communicating risks while acknowledging uncertainty is an important way to increase trust in institutional communicators (Lin et al., 2016) and promote the adoption of public health measures. Additionally, acknowledging concerns is one way to display empathy by the communicator (Hyer and Covello, 2017) and also to give information users a sense of control over an uncertain situation (Hooker et al., 2017). Therefore, our results would suggest that national-level accounts in particular, which authored only 3 Tweets acknowledging public concerns in our sample, could be missing a key opportunity to connect with Twitter audiences and display care and compassion about the hardships people have faced during the pandemic.

One key research gap this study sought to fill was to apply geographic techniques to analyze patterns in communication. We used maps to summarize differences in Tweet frequencies by message functions and risk communication strategies across Canadian jurisdictions to explore how their communication strategies may have differed in the context of varying COVID-19 disease burdens. Although some jurisdictions in our sample (e.g. Quebec) contributed a relatively small number of Tweets to our study compared to others, the frequencies of information, action, and community Tweets could reflect how each jurisdiction intended to promote health behaviour change to 'flatten the curve' during the first COVID-19 wave. For example, in British Columbia, which had the lowest COVID-19 disease burden among provinces with a similar population and size, we found that there was a high frequency of community Tweets. The use of community Tweets, which encourage relationship building and positive dialogic messages (Lovejoy and Saxton, 2012), could have played some role in the adherence to public health measures among Twitter users in that province. The fact that Ontario and Alberta were the only provinces to increase their use of risk communication strategies after the first national peak in COVID-19 cases suggests that these provinces were responding to an ongoing need for risk communication, which makes sense given their relatively high prevalence of COVID-19. In comparison, other provinces with a lower COVID-19 prevalence, may have employed more risk communication strategies in the first few months of the pandemic in an attempt to address heightened perceptions of risk and uncertainty, which decreased over time.

This study builds on the work of previous studies examining Tweets by public health accounts. Our results demonstrating that accounts serving the largest populations authored the most information Tweets was consistent with Wong et al. (2017), who found that health departments in the United States with larger population sizes were more likely to Tweet information during the Ebola outbreak. However, our finding that accounts serving <150,000 residents authored the highest percentage of action Tweets was not consistent with results by Neiger et al. (2013), who found that health departments serving smaller populations in the United States were less likely to post action Tweets than larger health departments. This difference may reflect differences in Tweeting patterns and communication needs during public health emergencies compared to non-crisis events. In addition, local-level agencies and decision-makers in Canada are primarily responsible for communicating specific actions and instructions, while communicating information on COVID-19 is of national concern; therefore, the Tweeting patterns observed by population served reflect trends that are consistent to our results stratified by geographic scale.

5. Limitations

One of the main limitations of using Twitter data is that it only reflects one communication channel out of the multiple channels used by public health agencies and decision-makers to distribute information on the COVID-19 pandemic. However, our research offers insights into the Tweeting patterns of those accounts that do utilize Twitter, and how their communications varied significantly over time and space. Our study also does not represent complete Tweet trends during the entire COVID-19 pandemic, but rather offers a glimpse into Canadian public health accounts' Tweeting practices during the first 6 months of the

outbreak. The findings of our study could be improved upon through the additional refinement of geographic variables that were analyzed or through the analysis of communications through additional social media platforms (e.g. Facebook, Instagram, etc.). Additionally, our study explored geographic trends in Tweeting, yet, Twitter audiences are global and this research did not attempt to quantify the reach of public health Tweets nor geo-locate the followers who may have interacted with Tweets intended for audiences residing in a different location. Therefore, future work could also expand on our study findings by addressing the other side of the information exchange and examining how public health Tweets are engaged with.

6. Conclusions

The adoption of Twitter by many public health agencies and officials should be viewed as a positive step towards leveraging the naturally dialogue-forming and engagement-centered communication platforms that social media can offer. But the results of this study have highlighted how Twitter communications by public health accounts could be improved for the purposes of information dissemination and changing health behaviours. Tweets containing particular messaging deployed at specific times for audiences located in specific places could be better utilized to tackle periods of increased disease transmission during the COVID-19 pandemic and other future public health crises. Crafting communications that are relevant for the levels of risk that audience members are likely encountering in a given geographic context could increase the uptake of those communications and result in better population health outcomes. As different jurisdictions continue to carve out unique approaches to health messaging, it will become increasingly important for public health agencies and decision-makers to evaluate whether their communications serve their intended purpose and meet the needs of the local population.

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Declaration of competing interest

The authors have no competing interests.

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