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Applying a diffusion of innovations framework to characterise diffusion groups and more effectively reach late adopters: a cross-sectional study on COVID-19 vaccinations in Canada in late 2021

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ABSTRACT

Background Rogers' diffusion of innovation theory suggests innovations are adopted in stages by different groups (innovators/early adopters, early majority, late majority and late adopters). In healthcare, this could mean that there is the potential to worsen health disparities as later groups tend to also face more social and structural barriers. Determining the unique sociodemographic characteristics, beliefs and attitudes of those in each diffusion category could be useful for theorising how to reach later groups more effectively.

Methods Using a cross-sectional survey among Canadian adults in late 2021, we assigned respondents to diffusion groups based on when they received their first dose, relative to others within their age group in accordance with Rogers' model (ie, cut points: 16%, 50%, 84% with 100% being all those vaccinated within the age group). Participants answered questions about their COVID-19 vaccinations and questions related to their motivations, beliefs, values and attitudes towards COVID-19. A multinomial logistic regression model assessed the likelihood of participants being associated with each diffusion category (with the significance level set at $p<0.05$).

Results The final sample included 2131 respondents. Late adopters were significantly more likely to identify as non-white, live in rural locations and receive vaccinations at pharmacies. Innovators and early adopters were significantly more likely to get vaccinated in settings other than pharmacies or community centres.

Conclusion A diffusion group-based analysis brought insight into how vaccination strategies could be tailored to reach each diffusion group sooner, particularly late adopters who encounter more barriers.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The diffusion of innovation theory posits that the uptake of an innovation by a population happens gradually and that the population can be divided into five categories: innovators (the gatekeepers), early adopters (leaders), early majority (average member of society), late majority (those just below average) and laggards/late adopters (those with traditional views). This theory has been adopted to relate to health innovations and can partially explain health inequities: the most state-of-the-art healthcare is available first to the healthiest and most privileged populations and takes longer to reach higher-need groups.

WHAT THIS STUDY ADDS

⇒ This study was conducted after the vaccine roll-out began and applied a diffusion group framework to COVID-19 vaccines. The timing of the study is important because it is likely that all individuals who were planning on receiving the vaccine had done so by this point, meaning the vaccine had likely diffused throughout the population to the greatest extent possible. Very few studies have examined COVID-19 vaccination beliefs after the vaccine roll-out began, and even fewer have applied a diffusion group framework.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Understanding the characteristics and beliefs of the different groups can hopefully inform future public health strategies, particularly those related to vaccines or other health innovations that require individual uptake and can promote health equity. Working with rural pharmacies may increase uptake in late adopters.

BACKGROUND

One of the most impressive mobilisations of biomedical science was the development, testing, approval and roll-out of vaccines against COVID-19 in 2020–2021.[1 2] Interim analyses of the efficacy of these vaccines reflected a level of protection rarely observed

in clinical trials against severe outcomes resulting from infection by the original wild strain of the virus.[3 4] The development of vaccines against COVID-19 in 2020 was a truly 'game-changer'[5]; however, many of the social groups most impacted by COVID-19 infections were among the most difficult to reach given the number of social and structural barriers (eg, low income).[6] Given this dynamic, two theoretical concepts became key discussion points for scholars and some decision-makers about the potential for such a game-changer to exacerbate the health disparities related to COVID: the 'inverse care law'[7 8] and the 'diffusion of innovations'.[9 10]

While most population health inequities emerge due to the social determinants of health,[11] some disparities may emerge or worsen following the introduction of a significant new technology or innovation.[12] As the easiest populations to reach with new technologies are often at the lowest risk for disease, the so-called 'inverse care law' observes the unfortunate irony that the most state-of-the-art healthcare will tend to serve the healthiest and most privileged populations first, while the innovation may take longer to reach higher need groups.[13 14] Thus, the equitable roll-out of game-changing interventions is critical to ensure that health systems are not reinforcing health inequities (a circumstance that has been described as an 'intervention generated inequality'[12]) but are rather eliminating or mitigating health inequities by prioritising the highest-need groups first.

When a new innovation is introduced, its uptake across society tends to happen gradually.[15 16] One well-known theory explaining this trend is Rogers' diffusion of innovation theory.[16] Diffusion is the social process among people in response to learning about a new innovation.[15] The uptake of an innovation by a population is divided into five categories: innovators, early adopters, early majority, late majority and laggards.[15] Previous papers have indicated that the term 'laggard' is outdated and, therefore, we will term them as 'late adopters'.[17] Rogers believed the early majority represented the average member of a social system, with innovators representing gatekeepers, early adopters representing leaders in a social system, the late majority representing those just below average and the late adopters representing those with traditional views.[15] While Rogers originally developed this theory in a non-healthcare and community-specific context, others have since adapted it for health innovations at much larger levels, including national and international diffusion studies.[13 18 19] Later development of diffusion theory by Moore argues that once the innovators and early adopters (typically approximately 16% of the target population) have been reached, an innovation will become mainstreamed, triggering adoption by the subsequent diffusion groups.[20 21] Therefore, gaining insights into how to reach the innovators and early adopters sooner could theoretically compress diffusion curve timelines and ultimately reach late adopters sooner.

Understanding the characteristics of late adopters can provide insights into increasing vaccine uptake among higher-risk populations sooner. Existing studies on the diffusion of innovation in the context of COVID-19 vaccinations have focused on healthcare workers, who had early access to the vaccine, on innovators and early adopters rather than late adopters.[22] Other investigations have been aimed at vaccine awareness and patient engagement but have not specifically addressed the characteristics of different groups.[23 24] To our knowledge, there is no published literature on the traits of late adopters of vaccines. Reducing intervention-generated inequalities requires reaching late adopters sooner, which should, in theory, lessen the burden of the inverse care law.

Other theories of diffusion exist, such as the Bass model, but these models are often used to determine the time to adoption rather than categorising different groups of adopters, like Rogers' theory.[25 26] Therefore, Rogers' theory best addresses this study's objectives. The goal of the current study was to identify useful insights for reaching late adopters sooner by applying a diffusion group framework to understand what sociodemographic characteristics, beliefs and behaviours characterise each diffusion group.

METHODS

Study design, setting and participants

This cross-sectional study was conducted using a convenience sample of residents of Canada from 16 November 2021 to 23 December 2021. AskingCanadians, an online data collection company that can be hired to administer surveys, executed the survey.[27] AskingCandians is a trusted resource for pharmaceutical companies when designing marketing campaigns or gaining perspectives on public opinions. AskingCanadians has more than one million Canadians in its panel who come from a wide range of socioeconomic strata. Participants are motivated to take part in AskingCanadians' surveys to earn rewards from a variety of retailers.[27] The research team was not involved in compensating the AskingCanadians survey participants.

Potential participants were invited based on their AskingCanadians profile to be nationally representative based on province of residence, biological sex, income level and visible minority status. Study participants were 18 years or older. Subgroup sample size targets were based on the 2016 Canadian census (the most recently available census at the time). Once subgroup sample size targets were met to correspond to national averages, the survey was closed to that group. The cohort sample size goal was 2500 survey responses. Given that this study employed a convenience sample, we believe this sample provides sufficient estimates while fitting within the practical and budgetary considerations of this study. However, no power analyses were conducted a priori. This study complies with the Strengthening the Reporting of

Observational Studies in Epidemiology checklist, which has been provided in online supplemental appendix 1.[28]

Questionnaire

The questionnaire was based on similar questionnaires used in other survey studies regarding COVID-19 vaccinations.[29 30] Before launching to the broader survey panel membership, the questionnaire was piloted in the field through a 1-week soft launch. Panel completion metrics (eg, time-to-completion, skipped questions and dropped surveys) were assessed to ensure that the questionnaire was technically sound and contained no components preventing users from proceeding towards completion.

The survey asked participants directly whether they had received a COVID-19 vaccine, why or why not, when they received their first and second/third doses (if applicable), where they received the vaccine (eg, mass vaccination clinic, pharmacy and employer), whether they were considered part of a priority group, various sociodemographic questions and questions about other beliefs, values and attitudes towards COVID-19 and the COVID-19 vaccine. Participants were given the option to voluntarily upload proof of their COVID-19 vaccination records for validation to avoid errors in self-reporting. The full survey is available in online supplemental appendix 2.

For data quality purposes, all respondents who completed the survey in less than 30% of the median survey completion duration were automatically excluded from the sample. This policy was developed by professional pollsters at AskingCanadians and was considered best practice within their organisation at the time of study.[31 32] Additionally, open-ended questions were assessed and cases where respondents provided a low-quality answer were removed (eg, responses that were non-words). These steps were conducted manually by the AskingCanadians team.

Diffusion group categorisation

Based on Rogers' theory of diffusion of innovation, the sample was categorised into innovators, early adopters, early majority, late majority and late adopters based on the respondents' date of their first dose of the COVID-19 vaccine. To categorise participants into the different diffusion categories, survey participants were first stratified into age categories to account for the initial roll-out of the COVID-19 vaccine being based on age.[33] After determining the earliest allowable vaccination date cut-offs for each age strata, each diffusion category was assigned based on the date and cumulative proportion of vaccinated individuals based on Rogers' theory of diffusion: the first 2.5% vaccinated before a certain date were labelled as innovators, the next 13.5% were early adopters, the next 34% were early majority, the next 34% were the late majority and the last 16% were late adopters. Participants were assigned prior to final data cleaning, and thus the actual breakdown does not perfectly match Rogers' theory. As Roger's theory excludes non-adopters, unvaccinated individuals were excluded from this study but were the focus of two other studies using the same survey data.[34 35] Additionally, the early adopter and innovator groups were combined due to small cell counts and because the combination of these two groups defined Moore's theorised 16% tipping point that must be breached to trigger mainstreaming to the later diffusion groups.[20 21]

Independent variables

Independent variables were selected based on existing studies of COVID-19 vaccine acceptance and hesitancy.[29 30] Sociodemographic factors of interest included vaccination status, gender, ethnicity, age, education, income, rurality, immigration status, marital status and current employment status based on a previously published framework of factors influencing public attitudes towards COVID-19 vaccination[36] (online supplemental appendix table 1).

Beliefs about the threat posed by COVID-19 to self and others were ascertained by asking respondents 'How serious of a threat do you think the coronavirus (COVID-19) is to yourself?' and 'How serious of a threat do you think the coronavirus (COVID-19) is to Canadians?' Respondents chose between 'not serious at all', 'not very serious', 'somewhat serious' and 'very serious'. 'Not serious at all' and 'not very serious' were combined to ensure eligible cell sizes and allow for easier comparison as the reference category. These questions were based on previous research that revealed these questions were especially powerful in predicting vaccine uptake.[37]

For questions with a 'prefer not to say' option, participants who selected 'prefer not to say' were coded as missing for the purposes of this analysis.

Data analysis

Data were collected directly from an online platform and exported as a .csv file. Data were imported into R V.4.1.2 for initial data cleaning. Descriptive statistics including missingness were created using the gtsummary package in R.[38]

To assess the likelihood of a participant being associated with each diffusion category based on sociodemographic factors of interest, we created a multinomial logistic regression model. We used the early majority as the reference group as Rogers theorised this group to represent the average member of society. Further, the innovator/early adopter group likely represents the participants who were especially high-risk or healthcare workers who were given priority before the vaccines were open to the broader public.

Multinomial logit regression was performed using mlogit in STATA V.18. After confirming that the multinomial regression model met the assumption of independence from irrelevant alternatives, relative prevalence ratios (RPR) and 95% CIs were calculated for the independent variables. The independence of irrelevant alternatives was tested using the suest (seemingly unrelated estimation) command. The assumption testing

is available in online supplemental appendix 3. The multinomial outcomes of interest were innovators/early adopters, early majority, late majority and late adopters.

A RPR is a ratio of ratios—the ratio of the prevalence ratio between the outcome level of interest and the outcome reference category (in this case, the early majority outcome category). The interpretation of these RPRs is not based on assumptions of direct effects on the outcome; rather, they are mutually adjusted and should be interpreted as conditional on the inclusion of the other variables in this model.[39 40]

Privacy

All data transferred by AskingCanadians were deidentified, anonymised and tokenised before being sent to the research team for analysis.

Patient and public involvement

The public was not involved in the design and conduct of the study, choice of outcome measures or recruitment to the study.

RESULTS

The survey yielded 2711 completes, representing 61% of all participants who accessed the survey (table 1). Of the total number of participants, 8.9% (n=241) of respondents remained unvaccinated. These non-adopting participants were excluded from the analysis. Overall, the mean age of survey respondents was 51.3 years (SD 17.13), with 52.7% of participants being female, 71.9% identifying as white and 82.5% living in an urban area. Approximately 40% of participants had at least a bachelor's degree and over half of participants (57.5%) had an income of less than CAD$50 000.

After excluding unanswered questions and for the 'other' gender category, which was unfortunately too small to analyse (n=11), the final analytical sample included 2131 respondents (online supplemental appendix table 1). Of vaccinated respondents, 383 (18.0%) were categorised as innovators or early adopters, 816 (38.3%) were early majority, 860 (40.4%) were late majority and 397 participants (18.6%) were late adopters (figure 1).

Table 1 Sociodemographic characteristics

	Total N=2711, % (n)	Innovators n=65, % (n)	Early adopters n=320, % (n)	Early majority n=821, % (n)	Late majority n=864, % (n)	Late adopters n=400, % (n)	Unvaccinated n=241, % (n)
Mean age, years (SD)	51.29 (±17.13)	49.98 (±18.34)	51.75 (±17.17)	51.67 (±17.54)	51.24 (± 17.07)	51.33 (±16.82)	49.9 (±16.15)
Gender							
Male	46.66 (1263)	43.08 (28)	45.00 (144)	48.84 (401)	45.18 (389)	49.75 (199)	42.50 (102)
Female	52.94 (1433)	56.92 (37)	54.37 (174)	50.55 (415)	54.70 (471)	49.50 (102)	57.50 (138)
Other	0.41 (11)	0	0.63 (2)	0.61 (5)	0.12 (1)	0.75 (3)	0
Ethnicity							
White	72.56 (1967)	70.77 (46)	69.38 (222)	71.50 (587)	74.42 (643)	68.75 (275)	80.50 (194)
Non-white	27.44 (744)	29.23 (19)	30.63 (98)	28.50 (234)	25.58 (221)	31.25 (125)	19.50 (47)
Citizenship							
Canadian	91.65 (2481)	90.77 (59)	91.22 (291)	92.31 (756)	90.61 (782)	91.00 (364)	95.02 (229)
Non-Canadian	8.35 (226)	9.23 (6)	8.78 (28)	7.69 (63)	9.39 (81)	9.00 (36)	4.98 (12)
Location							
Rural	18.48 (501)	15.38 (10)	14.69 (47)	13.76 (113)	20.02 (173)	21.75 (87)	29.46 (71)
Urban	81.52 (2210)	84.62 (55)	85.31 (273)	86.24 (708)	79.98 (691)	78.25 (313)	70.54 (170)
Education							
No high school	4.86 (131)	7.69 (5)	4.39 (14)	2.69 (22)	3.73 (32)	8.56 (34)	10.13 (24)
High school	34.04 (917)	26.15 (17)	32.92 (105)	32.44 (265)	33.99 (292)	36.52 (145)	39.24 (93)
Trade/technical degree	22.90 (617)	18.46 (12)	18.18 (58)	21.79 (178)	23.98 (206)	23.68 (94)	29.11 (69)
Bachelor	24.65 (664)	32.31 (21)	27.59 (88)	28.52 (233)	25.49 (219)	17.18 (71)	13.50 (32)
Graduate	10.76 (290)	9.23 (6)	11.60 (37)	11.14 (91)	11.53 (99)	10.33 (41)	6.75 (16)
Professional degree	2.78 (75)	6.15 (4)	5.33 (17)	3.43 (28)	1.28 (11)	3.02 (12)	1.27 (3)
Income							
<CAD$20K	22.20 (529)	18.18 (10)	20.65 (57)	20.86 (150)	19.82 (151)	25.97 (94)	32.06 (67)
CAD$20K–CAD$49K	44.40 (1058)	29.09 (16)	39.86 (110)	42.98 (309)	46.72 (356)	46.96 (170)	46.41 (97)
CAD$50K–CAD$79K	22.49 (536)	23.64 (13)	27.90 (77)	23.50 (169)	22.18 (169)	19.61 (71)	17.70 (37)
CAD$80K–CAD$99K	5.58 (133)	18.18 (10)	5.80 (16)	6.26 (45)	5.84 (43)	3.31 (12)	3.35 (7)
>CAD$100K	5.33 (127)	10.91 (6)	5.80 (16)	6.40 (46)	5.64 (43)	4.14 (15)	0.48 (1)
Marital status							
Single	63.11 (1704)	53.85 (35)	62.38 (199)	63.05 (517)	61.28 (527)	65.16 (260)	70.04 (166)
Not single	36.89 (996)	46.15 (30)	37.62 (120)	36.95 (303)	38.72 (333)	34.84 (139)	29.96 (71)

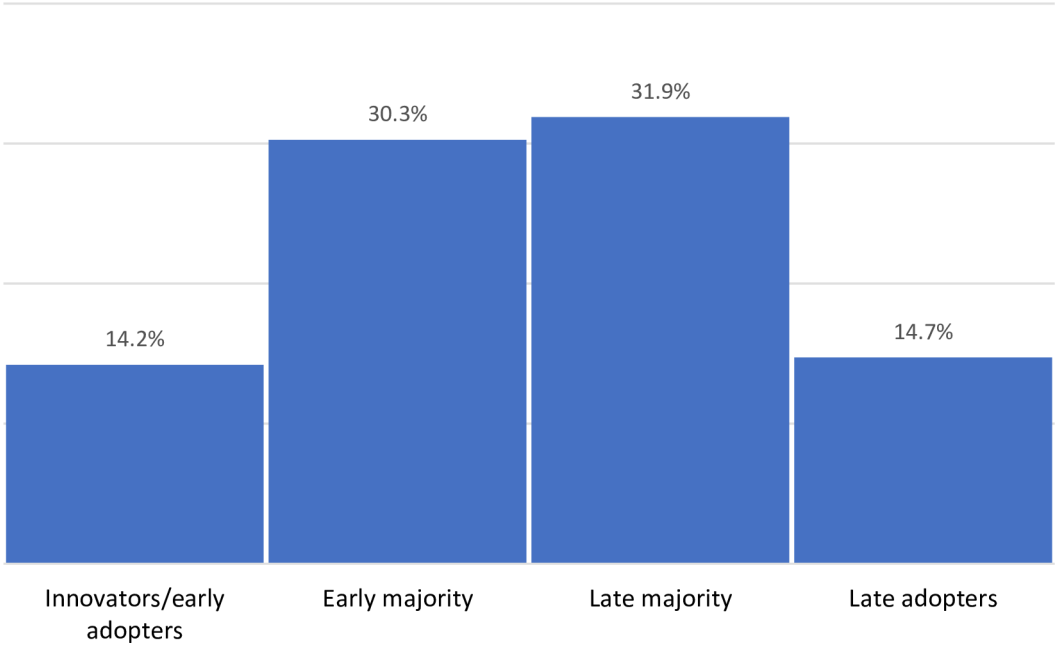

Figure 1 Per cent of participants by diffusion categories of first dose of COVID-19 vaccine, after correcting for missingness and age-group restrictions. The above distribution is the closest possible resemblance of Rogers' model after accounting for missingness and after categorising all included responses within their specific age group's vaccine eligibility dates within their province.

Model results

After removing a collinear variable ('threat to others' belief), a Hosmer-Lemeshow goodness of fit test model appropriately fits the data (χ^2 statistic: 32.204, df=24, p=0.122). Results of the full (collinear) model are presented in online supplemental appendix table 2.

Early adopters/innovators

Between the early majority and early adopters/innovators, there were no statistically significant differences in the relative prevalence of sociodemographic characteristics or beliefs regarding COVID-19 (table 2). The innovators and early adopters were significantly more likely to receive their vaccination from all other sources (RPR 3.67, 95% CI 2.55 to 5.27) relative to mass vaccination sites.

Late majority

Compared with the early majority, the late majority was significantly more likely to live in a rural location (RPR 1.61, 95% CI 1.21 to 2.14) relative to urban locations and be a permanent resident or non-citizen (RPR 1.62, 95% CI 1.08 to 2.44) relative to a Canadian citizen (table 2). The late majority was significantly less likely to be vaccinated at all other locations (RPR 0.63, 95% CI 0.44 to 0.91) relative to receiving vaccination at mass vaccination sites.

Late adopters

Compared with the early majority, the late adopters were significantly more likely to identify as non-white (RPR 1.47, 95% CI 1.04 to 2.09) relative to white and live in a rural location (RPR 1.93, 95% CI 1.37 to 2.74) relative to an urban location (table 2). This group was also significantly more likely to receive their COVID-19 vaccine from either a pharmacist (RPR 2.56, 95% CI 1.84 to 3.58) or all other locations (RPR 1.65, 95% CI 1.10 to 2.49) compared with those who received their vaccinations at mass vaccination sites. The late adopters were also significantly less likely to have an undergraduate degree (RPR 0.47, 95% CI 0.32 to 0.70) compared with high-school level education and earn more than CAD$50 000 (RPR 0.67, 95% CI 0.49 to 0.92) compared with not. Finally, late adopters were significantly less likely to believe that COVID-19 was a somewhat serious (RPR 0.60, 95% CI 0.43 to 0.83) or very serious threat (RPR 0.45, 95% CI 0.32 to 0.65) to themselves, relative to believing it was not serious at all/not very serious.

DISCUSSION

In our survey of 2131 individuals regarding self-reported COVID-19 vaccination uptake in November and December 2021 and after categorising respondents into diffusion groups, some sociodemographic characteristics distinguished the early majority from other diffusion groups. Late adopters were significantly less likely to have an undergraduate degree, more likely to identify as non-white, and less likely to earn over CAD$50 000 per year and were significantly more likely to have received their vaccination from a pharmacist. Late adopters and the late majority were also significantly more likely to live in rural locations. Beliefs and attitudes also emerged as critical predictors that were at least as potent as the other significant factors: late adopters were significantly less

Table 2 Outcomes from multinomial logistic regression: relative prevalence ratios (RPR) (ref. category=early majority)

	RPR	95% CI		RPR	95% CI		RPR	95% CI	
Variables	**Innovators/early adopters**			**Late majority**			**Late adopters (laggards)**		
Ethnicity (ref. white)									
Non-white	1.05	(0.73 to 1.49)		1.03	(0.78 to 1.37)		1.48	(1.04 to 2.09)	*
Gender (ref. female)									
Male	0.90	(0.68 to 1.20)		0.83	(0.67 to 1.03)		1.01	(0.77 to 1.33)	
Age category (ref. 70+)									
18–39	0.57	(0.32 to 1.03)		0.80	(0.50 to 1.27)		0.74	(0.42 to 1.33)	
40–49	0.65	(0.35 to 1.20)		0.79	(0.49 to 1.29)		0.72	(0.39 to 1.30)	
50–59	0.64	(0.36 to 1.13)		0.83	(0.53 to 1.29)		0.62	(0.35 to 1.09)	
60–69	0.76	(0.48 to 1.19)		1.01	(0.72 to 1.42)		0.79	(0.51 to 1.23)	
Education (ref. some high school/high school diploma)									
Graduate/professional degree	0.75	(0.47 to 1.19)		0.87	(0.60 to 1.26)		0.68	(0.43 to 1.07)	
Technical/trade/ vocational college	0.81	(0.56 to 1.18)		1.13	(0.86 to 1.49)		0.83	(0.60 to 1.17)	
Undergraduate degree	0.83	(0.57 to 1.20)		0.87	(0.65 to 1.16)		0.47	(0.32 to 0.70)	**
Income (ref. less than CAD$50,000)									
More than CAD$50,000	1.35	(0.99 to 1.83)		0.92	(0.72 to 1.17)		0.67	(0.49 to 0.92)	*
Urban/rural (ref. urban)									
Rural	1.09	(0.74 to 1.61)		1.61	(1.21 to 2.14)	**	1.93	(1.37 to 2.74)	**
Citizenship (ref. Canadian citizen)									
Permanent resident/Non-citizen	1.18	(0.70 to 1.97)		1.62	(1.08 to 2.44)	*	1.25	(0.75 to 2.09)	
Currently working (ref. no)									
Retired	0.82	(0.49 to 1.35)		0.74	(0.51 to 1.10)		0.66	(0.42 to 1.09)	
Yes	1.24	(0.82 to 1.87)		0.99	(0.73 to 1.34)		1.02	(0.70 to 1.48)	
How many people do you know in your circle of family, friends, or neighbours who you regularly interact with and who has had a case of COVID-19? (ref. none)									
1 or more people	1.01	(0.76 to 1.36)		0.87	(0.69 to 1.09)		0.73	(0.54 to 0.98)	
Do you believe that you have personally had one or more cases of COVID-19? (ref. no)									
Not sure	0.62	(0.36 to 1.05)		0.94	(0.66 to 1.33)		1.19	(0.77 to 1.83)	
Yes	1.50	(0.95 to 2.37)		0.89	(0.59 to 1.33)		1.56	(1.00 to 2.47)	
How serious of a threat to self (ref. not serious at all/not very serious)									
Somewhat serious	1.37	(0.92 to 2.03)		0.90	(0.68 to 1.20)		0.60	(0.43 to 0.83]	**
Very serious	1.46	(0.98 to 2.20)		0.81	(0.60 to 1.09)		0.45	(0.32 to 0.65)	**
Vaccination location (ref. mass vaccination sites)									
Community centre	1.49	(0.96 to 2.33)		1.30	(0.93 to 1.81)		1.61	(1.05 to 2.48)	*
Pharmacist	1.42	(0.97 to 2.09)		0.94	(0.70 to 1.26)		2.56	(1.84 to 3.58)	**
Other sources	3.9	(2.57 to 5.30)	**	0.63	(0.44 to 0.91)	*	1.65	(1.10 to 2.49)	*

*p<0.05, **p<0.01.

likely to believe COVID-19 was a serious or very serious threat to themselves.

While a diffusion of innovations-based analysis has been the subject of several studies within an international context,[10 22–24 41] within-country COVID-19 vaccine studies are limited with none focusing on Canada after the vaccine roll-out. Two studies found significant differences in attitudes between early adopters and vaccine-hesitant adults.[9 42] These studies, however, had very small populations, only compared early adopters to non-adopters, and were conducted before vaccines were widely available,[9] or did not apply an explicit diffusion of innovations analysis approach.[42] When our survey became available in November 2021, COVID-19 vaccines had been available for all Canadian adults for several months and extraordinary measures, such as the introduction of vaccine mandates, followed.[33] This timing is important because it is likely that all individuals who were planning on receiving a vaccine had done so at this point. In November 2021, 78% of Canadians had received at

least one vaccine; since the survey closed in December 2021, only an additional 4% of Canadians have received at least one vaccine.[43] This demonstrates that when the survey was conducted in late 2021, the vaccine had likely diffused throughout the population to the greatest extent possible.

Understanding the characteristics and beliefs of the different groups can inform future public health strategies, particularly those related to vaccines or other health innovations that require individual uptake and can promote health equity. In this sample, late adopters were significantly more likely to receive their COVID-19 vaccination from a pharmacist, compared with a mass clinic or other locations. While this may in part be a consequence of the time when this population was seeking to be vaccinated (ie, after mass vaccination sites had been dismantled), mass vaccination sites were mostly available in urban settings. Other studies have found pharmacies to be an effective way to reach rural areas, including for rural racialised populations.[44] One strategy, therefore, for reaching late adopters sooner could be to work with rural pharmacies to understand their unique challenges and to provide support to boost their vaccination capacity (eg, increasing supplies, personnel and resources), especially in pharmacy deserts.[45 46] Pharmacy deserts, geographical areas in which residents cannot easily access pharmacies, can affect up to 10% of the population.[45 47 48] Areas categorised as pharmacy deserts also tend to be rural, racialised and have a higher percentage of medically vulnerable persons, with one study reporting that 67% of persons living in pharmacy deserts were high risk for COVID-19.[46–50] While more research on pharmacy deserts has been done in the USA, some studies in Canada have confirmed their existence.[51] Given our results regarding late adopters being more often rural racialised populations, developing strategies to mitigate the potential impacts of pharmacy deserts may be useful in increasing uptake in the late adopters.

Limitations

There are several limitations of this work. One is that healthcare workers and essential workers were prioritised to receive the vaccine, and therefore, were among the innovators and early adopters. Had the analysis considered the date at which all adults were able to get the vaccine in their province, the distribution across the diffusion groups may have been different. However, we attempted to mitigate this by using the early majority as the reference group in the model, which had fewer healthcare workers than the innovators, and by categorising respondents based on the date at which their age group was eligible to receive the vaccine.

Selection bias is present, as the study was gathered by convenience sampling and is likely unrepresentative of the population at large. Self-selection to participate on the platform introduces selection bias, as it excludes those without access to the internet, comprehension of English or French, and wealthier people who would be less motivated to participate in this survey platform to earn rewards. However, surveying representative populations is difficult to achieve, particularly without specifically targeting populations. Another limitation is that this survey took place within the unusual context of vaccine mandates, potentially meaning the late adopter group surveyed by our study may contain those who would not get vaccinated under more typical conditions and thereby weakening external generalisability. Future research should repeat this study following updated COVID-19 vaccination roll-outs to understand which results were unique to the context. Finally, this study is subject to many types of bias, including information bias, recall bias and social desirability bias. The survey platform conducted a pilot study, but these were not provided to the study team. However, as this is not a psychometric scale or inventory, the face validity of the final items in the questionnaire should be sufficient for interpretation. This research relies on self-reported vaccination status rather than health records and is thus subject to recall bias; outcome timing may be misclassified and there is potential for social desirability bias, though the latter was likely mitigated through the anonymity of response. The analyses are observational in nature and subject to residual confounding through a lack of additional, relevant covariates. Unbalanced classes were combined.

CONCLUSION

We found that using a diffusion group-based analysis revealed useful insights. Our learnings included that late adopters were significantly more likely to identify as non-white, live in rural locations and receive COVID-19 vaccinations at pharmacies. A possible application of this insight for vaccination strategy would be to work with rural pharmacies to understand their unique challenges in reaching their populations and to offer additional support where necessary (eg, providing supplies sooner, resources to increase appointments or walk-in hours).

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REFERENCES

1 Beall RF, Moradpour J, Hollis A. The private versus public contribution to the biomedical literature during the COVID-19, Ebola, H1N1, and Zika public health emergencies. *PLoS One* 2021;16:e0258013.
2 Haghani M, Bliemer MCJ. Covid-19 pandemic and the unprecedented mobilisation of scholarly efforts prompted by a health crisis: Scientometric comparisons across SARS, MERS and 2019-nCoV literature. *Scientometrics* 2020;125:2695–726.
3 Polack FP, Thomas SJ, Kitchin N, *et al*. Safety and Efficacy of the BNT162b2 mRNA Covid-19 Vaccine. *N Engl J Med* 2020;383:2603–15.
4 Baden LR, El Sahly HM, Essink B, *et al*. Efficacy and Safety of the mRNA-1273 SARS-CoV-2 Vaccine. *N Engl J Med* 2021;384:403–16.
5 Financial Times. How mrna became a vaccine game-changer. 2021. Available: https://www.ft.com/content/b2978026-4bc2-439c-a561-a1972eeba940
6 Okonkwo NE, Aguwa UT, Jang M, *et al*. COVID-19 and the US response: accelerating health inequities. *BMJ Evid Based Med* 2020;26:176–9.
7 Kondilis E, Gallo V. The inverse care law and COVID-19 vaccination for refugees. *Lancet Healthy Longev* 2023;4:e183–4.
8 Davies AR, Honeyman M, Gann B. Addressing the Digital Inverse Care Law in the Time of COVID-19: Potential for Digital Technology to Exacerbate or Mitigate Health Inequalities. *J Med Internet Res* 2021;23:e21726.
9 Hunter-Mullis K, Macy JT, Greene A, *et al*. Perceived COVID-19 vaccine attributes associated with early adoption among adults in rural Indiana. *Health Educ Res* 2022;37:466–75.
10 Rydland HT, Friedman J, Stringhini S, *et al*. The radically unequal distribution of Covid-19 vaccinations: a predictable yet avoidable symptom of the fundamental causes of inequality. *Humanit Soc Sci Commun* 2022;9:61.
11 Braveman P, Gottlieb L. The social determinants of health: it's time to consider the causes of the causes. *Public Health Rep* 2014;129 Suppl 2:19–31.
12 Lorenc T, Petticrew M, Welch V, *et al*. What types of interventions generate inequalities? Evidence from systematic reviews. *J Epidemiol Community Health* 2013;67:190–3.
13 Mackenbach JP. The persistence of health inequalities in modern welfare states: The explanation of a paradox. *Soc Sci Med* 2012;75:761–9.
14 Marmot M. An inverse care law for our time. *BMJ* 2018;362:k3216.
15 Rogers EM, Singhal A, Quinlan MM. Diffusion of innovations. In: *An integrated approach to communication theory and research*. Routledge, 2014: 432–48.
16 Dearing JW, Cox JG. Diffusion Of Innovations Theory, Principles, And Practice. *Health Aff (Millwood)* 2018;37:183–90.
17 Stewart RE, Beidas RS, Mandell DS. Stop Calling Them Laggards: Strategies for Encouraging Nonadopters to Incorporate Evidence-Based Practices. *Psychiatr Serv* 2019;70:958–60.
18 Victora CG, Vaughan JP, Barros FC, *et al*. Explaining trends in inequities: evidence from Brazilian child health studies. *The Lancet* 2000;356:1093–8.
19 Jandoc R, Mamdani M, Lévesque LE, *et al*. Urban-rural differences in the uptake of new oral bisphosphonate formulations. *Arch Osteoporos* 2016;11:11.
20 Libai B, Mahajan V, Muller E. Can you see the chasm?: Innovation diffusion according to Rogers, Bass, and Moore. *Rev Mark Res Routledge* 2017;38–57.
21 Moore GA. *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream*. Harper Business Essentials, 1991:227.
22 D'Souza GC, Pinto CN, Exten CL, *et al*. Understanding factors associated with COVID-19 vaccination among health care workers using the Diffusion of Innovation Theory. *Am J Infect Control* 2024;52:509–16.
23 Britto MT, Pandzik GM, Meeks CS, *et al*. Combining evidence and diffusion of innovation theory to enhance influenza immunization. *Jt Comm J Qual Patient Saf* 2006;32:426–32.
24 Rosen B, Goodson P. A recommendation to use the diffusion of innovations theory to understand school nurses' role in HPV vaccine uptake. *Int Q Community Health Educ* 2013;34:37–49.
25 Dunn AG, Braithwaite J, Gallego B, *et al*. Nation-scale adoption of new medicines by doctors: an application of the Bass diffusion model. *BMC Health Serv Res* 2012;12:248.
26 Gorbachuk VM, Dunaievskyi MS, Syrku AA, *et al*. Substantiating the Diffusion Model of Innovation Implementation and its Application to Vaccine Propagation. *Cybern Syst Anal* 2022;58:84–94.
27 AskingCanadians. About us. 2022. Available: https://portal.askingcanadiansprojects.com/about-us
28 von Elm E, Altman DG, Egger M, *et al*. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol* 2008;61:344–9.
29 Merkley E, Loewen PJ. The correlates and dynamics of COVID-19 vaccine-specific hesitancy. *Vaccine (Auckl)* 2022;40:2020–7.
30 Clarke PM, Roope LSJ, Loewen PJ, *et al*. Public opinion on global rollout of COVID-19 vaccines. *Nat Med* 2021;27:935–6.
31 Miller CA, Guidry JPD, Dahman B, *et al*. A Tale of Two Diverse Qualtrics Samples: Information for Online Survey Researchers. *Cancer Epidemiol Biomarkers Prev* 2020;29:731–5.
32 Sago. Sago's 5 steps to data quality.
33 Canadian Institutes for Health Information. COVID-19 intervention scan: canadian institutes for health information. 2022. Available: https://www.cihi.ca/en/covid-19-intervention-scan
34 Memedovich A, Farkas B, Hollis A, *et al*. COVID-19 Vaccine's Speed to Market and Vaccine Hesitancy: A Cross-Sectional Survey Study. *Healthc Policy* 2023;19:99–113.
35 Memedovich A, Orr T, Hollis A, *et al*. Social network risk factors and COVID-19 vaccination: A cross-sectional survey study. *Vaccine (Auckl)* 2024;42:891–911.
36 Al-Jayyousi GF, Sherbash MAM, Ali LAM, *et al*. Factors Influencing Public Attitudes towards COVID-19 Vaccination: A Scoping Review Informed by the Socio-Ecological Model. *Vaccines (Basel)* 2021;9:548.
37 Bridgman A, Merkley E, Loewen PJ, *et al*. The causes and consequences of COVID-19 misperceptions: Understanding the role of news and social media. *HKS Misinfo Rev* 2020;1.
38 Sjoberg DD, Whiting K, Curry M, *et al*. Reproducible Summary Tables with the gtsummary Package. *R J* 2021;13:570.
39 Green MJ, Popham F. Interpreting mutual adjustment for multiple indicators of socioeconomic position without committing mutual adjustment fallacies. *BMC Public Health* 2019;19:10.
40 Westreich D, Greenland S. The table 2 fallacy: presenting and interpreting confounder and modifier coefficients. *Am J Epidemiol* 2013;177:292–8.
41 Mo PK-H, Luo S, Wang S, *et al*. Intention to Receive the COVID-19 Vaccination in China: Application of the Diffusion of Innovations Theory and the Moderating Role of Openness to Experience. *Vaccines (Basel)* 2021;9:129.
42 Dzieciolowska S, Hamel D, Gadio S, *et al*. Covid-19 vaccine acceptance, hesitancy, and refusal among Canadian healthcare workers: A multicenter survey. *Am J Infect Control* 2021;49:1152–7.
43 Public Health Agency of Canada. Canadian covid-19 vaccination coverage report. Public Health Agency of Canada; Ottawa, 2024.
44 Olatunji EA, Ogunsola AS, Khodakarami N, *et al*. Who receives influenza vaccinations at the Pharmacy? An analysis of the Texas Behavioral Risk Factor Surveillance System. *Vaccine (Auckl)* 2021;39:2857–66.

45 Qato DM, Daviglus ML, Wilder J, *et al*. 'Pharmacy deserts' are prevalent in Chicago's predominantly minority communities, raising medication access concerns. *Health Aff (Millwood)* 2014;33:1958–65.
46 Grootendorst P. Pharmacy location and medical need: regional evidence from Canada. *BMC Health Serv Res* 2022;22:1309.
47 Rader B, Astley CM, Sewalk K, *et al*. Spatial modeling of vaccine deserts as barriers to controlling SARS-CoV-2. *Commun Med (Lond)* 2022;2:141.
48 Ying X, Kahn P, Mathis WS. Pharmacy deserts: More than where pharmacies are. *J Am Pharm Assoc (2003)* 2022;62:1875–9.
49 Guadamuz JS, Wilder JR, Mouslim MC, *et al*. Fewer Pharmacies In Black And Hispanic/Latino Neighborhoods Compared With White Or Diverse Neighborhoods, 2007–15. *Health Aff (Millwood)* 2021;40:802–11.
50 Wisseh C, Hildreth K, Marshall J, *et al*. Social Determinants of Pharmacy Deserts in Los Angeles County. *J Racial Ethn Health Disparities* 2021;8:1424–34.
51 Houle SKD, Timony P, Waite NM, *et al*. Identifying vaccination deserts: The availability and distribution of pharmacists with authorization to administer injections in Ontario. *Can Pharm J (Ott)* 2022;155:258–66.