COVID-19 vaccination in Ontario: Exploring intra-provincial variations within Health Regions and socio-economic strata

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Abstract

The COVID-19 pandemic continues to be a worldwide public health concern. Although vaccines against this disease were rapidly developed, vaccination uptake has not ben equal across all the segments of the population. In particular, it has been shown that there have been differences in vaccine uptake across different segments of the population. However, there are also differences in vaccination across geographical areas, which might be important to consider in the development of future public health policies against COVID-19. In this study, we examined the relationship between vaccination status (having received the first dose of a COVID-19 vaccine), and different socio-economic and geographical factors. Our results show differences in vaccination due to race/ethnicity, income, Health Regions (geographical areas used for health service access in Ontario), and their interactions. In particular, we show that individuals who identified as Arab/Middle Eastern, Black, or Latin American, had significantly lower odds of vaccination than White/Caucasian individuals (ORs=0.31, 0.32, 0.28, and p=0.004, p<0.001 and p=0.004, respectively), and that individuals with a household income below CAD 25,000 who identified as Arab/Middle Eastern (OR=3.05, p=0.013), Black (OR=3.19, p=0.004), Latin American (OR=2.80, p=0.041), or that belonged to other minority groups (OR=4.59, p<0.001) had higher odds of vaccination than individuals from the same racial/ethnic group in higher income brackets. Finally, we also identified lower odds of vaccination within different minority groups in West Health Region. This study shows that there is an ongoing need to better understand and address differences in vaccination uptake across diverse segments of the population that have been largely impacted by the pandemic.

Keywords

Covid-19, vaccination, survey, socio-economic factors, visible minorities.

Background

The COVID-19 pandemic continues around the world with more than 600 million confirmed cases as of November of 2022[1]. During the first months of the pandemic in early 2020, nonpharmaceutical interventions such as masking and social distancing were the only methods available to manage the spread of the disease; however, the rapid development of vaccines permitted their approval and use in some countries towards the last month part of 2020. For example, in the US and Canada vaccine campaigns began in mid-December of 2020[2,3]. Although it has been estimated that COVID-19 vaccines have prevented around 14 millions of deaths worldwide[4], the rollout of COVID-19 vaccines has faced multiple challenges since its inception.

Indeed, multiple obstacles that have complicated vaccination efforts against COVID-19 have been identified: inequality in vaccine access, vaccine hesitancy, and differences in vaccination rates across different segments of the population[5–7]. In the case of Canada, lower vaccine uptake has been associated with socio-economic factors such as younger age, educational level, presence of children in the household, lack of a regular healthcare provider, ethnic origin, and financial instability[8–10].

Additionally, vaccination is influenced by changes in geography. In this regard, it has been shown that there have been spatial differences in COVID-19 vaccination rates due to regional differences in attitudes towards vaccination[7], geographical differences in vaccine access and supply, vaccination location availability, and lack of prioritization of vulnerable groups[3,11].

Studies that analyze geographical variations in vaccine uptake are important as they can help inform public health decision-makers to design policies to that consider spatial changes to address vaccination disparities. In this regard, previous geographical (spatial) analyses of vaccination rates have shown that variations in vaccine uptake can occur within small governmental administrative units (e.g., counties in the case of the US)[12–15], and that geographical analyses can be predictive of booster uptake patterns[16].

In Canada, studies that have used a spatial approach to analyze vaccine uptake have shown disparities in vaccination rates across low and high income neighborhoods in the city of Toronto[17], among adolescents from deprived neighborhoods in the city of Montreal[18], and have also highlighted disparities in vaccination status depending on age, income, and ethnic origin at the provincial level[8]. However, there is limited information on differences in vaccination status inside the provinces. Such analysis is important as it can help identify inequalities that may exist within these geographical areas while providing a granular view of intra-provincial differences that can help understand the barriers for vaccine uptake.

In this study, we examined self-reported COVID-19 vaccination status within the province of Ontario using a combination of socio-economic factors(such as ethnic origin, age, and income) and geographical analysis (at the level of the Health Regions) in order to determine intra-provincial differences in vaccine uptake and address the ongoing need of socio-economic information that can provide a rationale for the disparities in vaccination observed within some racial groups[19].

Methods

Data source: survey overview

We used data from the *Survey of COVID-19 related Behaviours and Attitudes*, a repeated cross sectional survey focused on the Canadian province of Ontario which ran from Sept 30, 2021 until January 17, 2022 and that was comissioned by the Fields Institute for Research in Mathematical Sciences (henceforth Fields) and the Mathematical Modelling of COVID-19 Task Force. The survey was conducted by a third-party service provider (RIWI Corp.), under ethical guidance from the University of Toronto.

Briefly, the survey was deployed used random domain intercept technology, where if users clicked on a registered but commercially inactive web link or typed in a web address for a site that was dormant, they had a random chance of that link being temporarily managed by the company that administered the survey and instead of coming across a notification about the status of the site("this page does not exist"), the survey was deployed to the user[20]. Users then decided whether to anonymously participate, and those that participated were able to exit the survey at any time. After the survey closed, regardless if it was complete or incomplete, access was denied to any further users with the same internet protocol (IP) address and the domain entry point rotated such that if a user were to attempt to access the survey again, share the link, or enter via the same address using an alternative IP address, the survey would not deploy. This effectively meant that a user could participate only once in the survey.

Additionally, users who indicated they were under the age of 16 were exited from the survey without creating a record, furthermore, these users were unable to navigate back to the "age select" screen. The personal identifier information from each user that participated in the survey was automatically scrubbed and replaced by a unique ID. Respondents were drawn exclusively from the province of Ontario, as per their devices meta-data.

Survey responses

Socio-economic information selected from the survey answers included age group and income brackets, and race/ethnicity. The levels of each socio-economic factor used for analysis appear in Table 1.

Table 1: Selected socio-economic factors from the survey

Variable	Levels
Age group	16-34,35-54,55 and over
Income bracket (CAD)	under 25,000, 25,000-59,999, 60,000 and above
Race/ethnicity	Arab/Middle Eastern, Black, East Asian/Pacific Islander, Indigenous, Latin American, Mixed, South Asian, White Caucasian, Other

Furthermore, the information on vaccination status was provided by survey participants who answered the question "Have you received the first dose of the COVID vaccine?", with possible answers "yes" and "no".

Data cleaning

The original dataset contained 39,029 entries (where each entry corresponded to a set of answers provided by a unique respondent). Following a preliminary analysis, the dataset was cleaned in order to only contain the socio-economic information provided in Table 1 and vaccination status. The cleaning process also included removing outliers that were identified during the preliminary analyses, and processing the geographical information in the survey (city where the survey was responded) in order to match each city to its correspondent Health Region.

Geographical location

For each survey participant certain data was automatically captured, including the nearest municipality (city). This resulted in a total of 578 different municipalities within the clean dataset. Due to our interest in analyzing the differences between Health Regions, we assigned the city of each entry to its correspondent Health Region following a multi-step process. Briefly, we used Local Health Integrated Networks (LHINs) to assign a Health Region to each entry in the survey. LHINs were the geographical divisions for health used by Ontario before the adoption of the Health Regions; because of the lack of a publicly available list of all municipalities within each Health Region, we used a dataset of long-term care homes and LHINs to match each city to LHIN, followed by matching each LHIN to a Health Region following the information provided on the Ontario Health Website, where the list of LHINs and corresponding Health Regions is available. In the case of municipalities that did not appear in the long-term dataset, we manually searched each city in the LHINs websites in order to provide geographical information. The raw dataset, clean dataset, details of the data cleaning process, and the addition of Health Region and LHIN information are described in detail in the GitHub repository for this paper, which can be found at https://github.com/aimundo/Fields_COVID-19/.

Following an assessment of the number of entries corresponding to each Health Region in the final dataset, only 107 observations (4.3% of the total) corresponded to cities located in the North West and North East Health Regions. Due to the low number of entries, we omitted these Health Regions from further analyses. Therefore, the total number of unique entries used for analysis was 3,551 which included the East, Central, Toronto, and West Health Regions.

Corrections

We identified differences between the proportions of all the socio-economic factors included in the analysis (Table 1) and the 2016 Canada Census data for Ontario. Additionally, because the Census divisions do not match the exact boundaries of the Health Regions, we also obtained population estimates for each Health Region from the Ontario Health website in order to correct for the population totals. We used an iterative proportional fitting procedure (*raking*)[21] to correct for socio-economic factors and Health Region populations using the R `survey` package. Details about the correction can be found in the Appendix.

Statistical analyses

We used a logistic regression model to estimate the probability of vaccination depending on the socio-economic factors described in Section , the Health Regions from Section , and the interactions between Race and Health Region, and Race and income as previous studies have shown that socio-economic factors and their interactions are significant predictors of intent of vaccination and vaccination status[22–24]. The model appears in Equation 1,

$$\log\left(\frac{p(\text{vac})}{1-p(\text{vac})}\right) = \beta_0 + \beta_1(\text{Age group}) + \beta_2\ \text{Race} + \beta_3\ \text{Health Region} + \beta_4\ \text{Income} + \beta_5(\text{Health Region} \times \text{Race}) + \beta_6\ (\text{Income} \times \text{Race}) \tag{1}$$

Where $p(\text{vac})$ indicates the probability of having received the first dose of a COVID-19 vaccine, β_0 indicates the population intercept, and $\beta_1 \ldots \beta_6$ indicate the coefficients for each term. The the model was fitted using the function `svyglm` from the `survey` R package in order to incorporate the correction in sampling probability obtained from raking.

All analyses were conducted in RStudio (2022.12.0 Build 353), using R 4.2.2 and the packages `survey`[25],`tidyverse`[26], and `quarto`[27].

Results

Survey Results

Table 2 shows the descriptive statistics (uncorrected) from the Fields COVID-19 survey data for vaccination status and each of the covariates analyzed. The total number of entries from the survey in the dataset after cleaning was 3,551. Overall, 26.9% of survey respondents (958) reported not having received the first dose of the vaccine, whereas 73.1% (2,593) reported having received it. Within each socio-economic factor, respondents who reported living in a household with an income under CAD 25,000 represented 37% of the total number of entries, those within the CAD 25,000-59,999 income bracket represented 25% of the total sample, and those with an income above CAD 60,000 represented 38 % of the sample; across all income brackets, the percentage of individuals that reported having received a first dose of the vaccine was consistent, above 69%.

Within the age groups of survey respondents, the age group between 16-34 years had the highest representation in the survey responses (1,521, 42.8% of all responses). Within this age bracket, 73% of respondents indicated having received the vaccine, whereas the lowest vaccination rate was in the bracket of those 55 years of age and above, with a total of 72%. The Health Region with highest representation in the survey was Toronto, accounting for 1,324 entries (37.2%), with a vaccination rate of 72%. Regarding race/ethnicity, individuals that identified as White/Caucasian represented 1313 (37%) of all entries and had the highest vaccination uptake with 82% of them indicating to have received the COVID-19 vaccine. On

Table 2: Descriptive Statistics of the Fields COVID-19 Survey (by Vaccination Status)

Variable	**no**, N = 958	**yes**, N = 2,593
Income		
60000_and_above	305 (23%)	1,049 (77%)
25000_59999	253 (28%)	636 (72%)
under_25000	400 (31%)	908 (69%)
Age Group		
16_34	409 (27%)	1,112 (73%)
35_54	252 (26%)	712 (74%)
55_and_over	297 (28%)	769 (72%)
Health Region		
Toronto	371 (28%)	953 (72%)
Central	224 (28%)	581 (72%)
East	135 (23%)	448 (77%)
West	228 (27%)	611 (73%)
Race		
white_caucasian	233 (18%)	1,080 (82%)
arab_middle_eastern	76 (36%)	138 (64%)
black	114 (38%)	184 (62%)
east_asian_pacific_islander	69 (23%)	234 (77%)
indigenous	76 (40%)	115 (60%)
latin_american	69 (38%)	111 (62%)
mixed	105 (34%)	205 (66%)
other	128 (35%)	239 (65%)
south_asian	88 (23%)	287 (77%)

[1] n (%)

the other hand, the ethnic group with the lowest number of entries in the survey was Latin American, with a total of 180, or 5% of all entries. Vaccination rates across all minority groups were below the value reported by White/Caucasians, with the lowest vaccination rate (60%) being reported by individuals that identified as Indigenous.

Multivariate Regression

Table 3 shows the results of the logistic regression on vaccination status using socio-economic factors (age group, income, race), geographical areas (Health Regions) and the interactions between income and race and Health Region and race. The reference groups were set as follows: 16 to 34 years (age group), White Caucasian (Race), Toronto (Health Region), CAD 60,000 and over (Income). There were no statistically significant differences in vaccination rates within the age groups from the survey, but significant odds ratios were estimated for other covariates. Within household income brackets, individuals with an income under CAD 25,000 or between CAD 25,000-59,999 had significantly lower odds of vaccination than those with an income above CAD 60,000 (ORs=0.37 and 0.59, respectively). Within Race/Ethnicity, individuals who identified as Arab/Middle Eastern, Black, or Latin American, had significantly lower odds of vaccination than those in the White/Caucasian group (ORs=0.31, 0.32, 0.28, and p=0.004,<0.001 and 0.004, respectively); additionally, those individuals in the Other Race/Ethnicity group (a group that included Southeast Asian, Filipino, West Asian, and Minorities Not Identified Elsewhere) had even lower odds of vaccination than the other minority groups (OR=0.22, p<0.001). Regarding Health Regions, individuals that reported living in the West Health Region (which comprises the regions of Waterloo and Niagara, the counties of Wellington, Essex, and Lambton, and the cities of Hamilton, Haldimand, Brant, and Chatham-Kent) had significantly higher odds of vaccination than those in the Health Region of Toronto (OR=1.55, p=0.029).

Moreover, statistically-significant odd ratios were determined in the case of the interaction of income and race; specifically, for individuals with a household income below CAD 25,000 who identified as Arab/Middle Eastern (OR=3.05, p=0.013), Black (OR=3.19, p=0.004), Latin American (OR=2.80, p=0.041), or that belonged to other minority groups (OR=4.59, p<0.001). Within the CAD 25,000-59,999 income bracket, individuals who identified as belonging to other racial minority groups had significantly higher odds of vaccination (OR=6.93, p<0.001).

For the interaction of Health Region and race, significant odds of vaccination were identified for Black individuals in the Central Health Region, which comprises the region of York, counties of Dufferin and Simcoe and the district of Muskoka (OR=0.44, p=0.046), and in individuals that identified as part of other racial minorities or South Asian that lived in the West Health Region (ORs=0.41, p=0.032 and p=0.037, respectively).

Table 3: Multiple Regression Analysis-Predictors of Vaccination Status

Characteristic	**OR**	**95% CI**	**p-value**
Age Group			
16_34	—	—	
35_54	0.90	0.67, 1.21	0.5
55_and_over	0.99	0.74, 1.32	>0.9
Income			
60000_and_above	—	—	
25000_59999	0.59	0.39, 0.89	0.011
under_25000	0.37	0.25, 0.56	<0.001
Race			
white_caucasian	—	—	
arab_middle_eastern	0.31	0.14, 0.69	0.004
black	0.32	0.17, 0.60	<0.001
east_asian_pacific_islander	1.15	0.50, 2.66	0.7
indigenous	0.44	0.19, 1.02	0.056
latin_american	0.28	0.11, 0.67	0.004
mixed	0.64	0.25, 1.65	0.4
other	0.22	0.12, 0.41	<0.001
south_asian	0.91	0.49, 1.69	0.8
Health Region			
Toronto	—	—	
Central	1.47	0.92, 2.35	0.11
East	1.42	0.90, 2.23	0.13
West	1.55	1.05, 2.30	0.029
Income * Race			
25000_59999 * arab_middle_eastern	1.79	0.67, 4.83	0.2
under_25000 * arab_middle_eastern	3.05	1.26, 7.39	0.013
25000_59999 * black	1.34	0.59, 3.05	0.5
under_25000 * black	3.19	1.45, 6.99	0.004
25000_59999 * east_asian_pacific_islander	0.42	0.17, 1.05	0.062
under_25000 * east_asian_pacific_islander	1.16	0.47, 2.86	0.8
25000_59999 * indigenous	1.36	0.48, 3.89	0.6

(continued)

Characteristic	**OR**	**95% CI**	**p-value**
under_25000 * indigenous	1.45	0.55, 3.80	0.5
25000_59999 * latin_american	1.24	0.45, 3.43	0.7
under_25000 * latin_american	2.80	1.04, 7.51	0.041
25000_59999 * mixed	0.85	0.32, 2.26	0.7
under_25000 * mixed	1.10	0.37, 3.27	0.9
25000_59999 * other	6.93	2.65, 18.1	<0.001
under_25000 * other	4.59	2.33, 9.05	<0.001
25000_59999 * south_asian	1.20	0.51, 2.85	0.7
under_25000 * south_asian	2.00	0.93, 4.30	0.077
Race * Health Region			
arab_middle_eastern * Central	0.66	0.26, 1.70	0.4
black * Central	0.44	0.19, 0.98	0.046
east_asian_pacific_islander * Central	0.98	0.38, 2.53	>0.9
indigenous * Central	0.63	0.22, 1.79	0.4
latin_american * Central	0.67	0.23, 1.96	0.5
mixed * Central	0.73	0.24, 2.22	0.6
other * Central	0.80	0.36, 1.78	0.6
south_asian * Central	0.54	0.25, 1.20	0.13
arab_middle_eastern * East	0.43	0.13, 1.45	0.2
black * East	0.83	0.34, 2.04	0.7
east_asian_pacific_islander * East	0.86	0.29, 2.56	0.8
indigenous * East	0.69	0.23, 2.08	0.5
latin_american * East	1.03	0.32, 3.34	>0.9
mixed * East	0.91	0.28, 3.03	0.9
other * East	1.05	0.39, 2.83	>0.9
south_asian * East	0.52	0.19, 1.45	0.2
arab_middle_eastern * West	1.00	0.37, 2.73	>0.9
black * West	0.76	0.32, 1.80	0.5
east_asian_pacific_islander * West	0.52	0.20, 1.34	0.2
indigenous * West	0.39	0.14, 1.09	0.073
latin_american * West	0.94	0.32, 2.72	>0.9
mixed * West	0.37	0.12, 1.16	0.089
other * West	0.41	0.18, 0.93	0.032
south_asian * West	0.41	0.18, 0.95	0.037

[1] OR = Odds Ratio, CI = Confidence Interval

Discussion

The rapid development of COVID-19 vaccines has been considered as a major achievement of modern medicine[28]. Vaccine availability towards the end of 2020 in certain countries made some believe that they would be a determinant factor in a rapid ending of the pandemic[29]. However, despite previous successful vaccination campaigns that were crucial to control diseases such as smallpox and polio[30], vaccination efforts in the case of COVID-19 have faced multiple challenges that have complicated the achievement of global immunity.

Among the different challenges faced by COVID-19 vaccination efforts are the development of new variants due to inadequate public health measures[31] and inequity in vaccine access between low and high income countries[32]. However, it is also well established that even in the case of high income countries that have had ample access to vaccines since 2020, such as the US, the UK, and Canada, there have been challenges in vaccination efforts due to differences in vaccine uptake among different segments of the population. More specifically, lower vaccine uptake has been associated with socio-economic factors such as race (i.e., identifying as Black, Asian, Indigenous) and household income (typically within lower income brackets)[33–36]. Reasons given for this association have included medical mistrust due to systemic medical racism, mistrust in vaccines, and the influence of conspiracy theories[33,35,37–39].

In addition, vaccine uptake is influenced by geography, as shown by different studies that have identified intra-regional differences in vaccine uptake[12,40,41]. However, in the case of Canada, studies that have analyzed spatial differences in vaccination have been focused in country-wide or province-wide estimates[8,42]. Therefore, we explored spatial and socio-economic determinants of vaccination status in the province of Ontario. This province is of particular interest as it has seen recently major structural health changes with the dissolution of the Local Health Integrated Network (LHIN) system and the incorporation of regions covered by LHINs into larger Health Regions[43]. Because the idea behind the change aimed to reduce the inequalities in healthcare that were identified under the LHIN model[44], examining differences in vaccination between the Health Regions can provide decision-makers with insight regarding intra-provincial health disparities that may need to be addressed in future vaccination or public health campaigns.

Our results indicate that across the most densely populated Health Regions of Ontario, almost three quarters of the surveyed individuals reported having received the first dose of the COVID-19 vaccine (Table 2), and that there were no significant differences in vaccination odds among the age groups considered in the survey. This result is consistent with overall vaccination rates reported for Canada, which have been relatively higher when compared to other high income countries[45], with vaccination uptake rates across different age groups presented in other studies[8,46], and with the vaccination information provided by Public Health Ontario, which shows that for the period where the Fields survey ran (Sept 30, 2021-Jan 17, 2022) there was a minimum of 80% of first dose vaccination coverage among all the age groups considered in the survey[47].

However, we identified intra-provincial differences in vaccination based on socio-economic and geographical factors. First, our results show significant differences in vaccination odds in individuals with a household income below CAD 60,000 and in individuals belonging to visible minority groups. Those who identified as Black, Latin American, or belonging to a minority group not included in the survey (Southeast Asian, Filipino, West Asian, and Minority not identified elsewhere) had vaccination odds below 33% when compared to individuals that identified as White/Caucasian (Table 3). These results are consistent with other studies that have shown lower vaccination rates in individuals that identify as part of a racial minority, or that have a low household income[8–10,48].

In this study, we also decided to explore the interactions between income and race and race and Health Region, as it is known that many individuals within racial minority groups perform tend to occupy certain types of occupations that fall within income brackets that have been shown to be associated with differences in vaccination uptake. In other words, we decided to explore if there were differences in vaccination within racial groups in certain income brackets and in certain the Health Regions. In this regard, it is interesting to note that although overall self-reported vaccination rates were found to be statistically significantly lower in various racial minority groups when compared to White/Caucasian individuals (Table 3), the change in odds of vaccination within certain racial groups and income strata was actually positive, in contrast to the White/Caucasian group, for which vaccination odds decreased in lower income brackets (when compared to the CAD 60,000 and over bracket, Supplementary Figure A-3). More specifically, the change in odds of vaccination increased in individuals who identified as Arab/Middle Eastern, Black, Latin American, or belonging to other minority groups with a household income below CAD 25,000, which was also true for individuals in other racial minority groups with an income between CAD 25,000-59,999 (Table 3, Supplementary Figure A-3).

This result is likely due to the fact that individuals that belong racial minority groups tend to perform occupations that have been deemed as “essential” in the context of the pandemic[49,50], which include occupations such as grocery store workers, gas station workers, warehouse and distribution workers, and manufacturing workers, all being occupations for which an income within the significant brackets is to be expected. In the case of Ontario, essential workers had priority for COVID-19 vaccination[51], which would explain the higher odds of vaccination for these individuals in certain income brackets, in contrast to the lower odds of vaccination for the same type of individuals with higher household income. In other words, it is possible that the type of occupation played an important role in increasing the odds of vaccination in these racial minority groups.

Additionally, significant higher vaccination odds were identified in the West Health Region when compared to the Health Region of Toronto (Table 3). The West Health Region comprises the regions of Waterloo and Niagara, the counties of Wellington, Essex and Lambton, and the cities of Hamilton, Haldimand, Brant, and Chatham-Kent. In this case, a possible rationale for the results is the fact that in the survey, about 47% of the entries for this Health Region corresponded to White/Caucasian individuals, who reported an overall 83% vaccination rate (Supplementary Table A-6). However, the interaction effect of Health Region and race was also significant in the case of individuals identifying as South Asian or other minorities not included in the survey Table 3. In this case, the results of the interaction term in the model indicate that the odds of vaccination for those within the South Asian and Other minority groups in the West Region decreased when compared to the other Health Regions (Supplementary Figure A-4).

According to Ontario Health, 13.2% of the population in the West Health Region identifies as a visible minority, whereas 2.5% identifies as Indigenous[52]. In the case of this analysis, the estimated lower odds are likely to be explained from a socio-economic perspective. In fact, 50% of the answers from this region in the survey came from the former LHINs of Hamilton Niagara Haldimand Brant, and Erie St. Clair, both which are among the regions of Ontario with the highest proportion of their population (more than 20%) in the lowest income quintile[53] (Supplementary Table A-7). Therefore, this result partly reinforces the well-known existing association between low vaccination rates and income, but it additionally indicates that there were intra-regional differences in vaccination. Interestingly, a disproportionate number of COVID-19 cases and low vaccination rate (under 50%) have been previously reported in the South Asian community of Ontario[54]; in this regard, our result provides additional context by showing that within the South Asian community, there were differences in vaccination uptake across Ontario. Moreover, because significant lower odds of vaccination were also identified other minority groups, this provides a rationale for future studies that explore how vaccination uptake varies across different minority groups within Ontario and other Canadian provinces.

There are some limitations to the present study. First, the data collection design, which allowed respondents to withdraw from the survey at any point, resulted in a high number of unique entries in the survey with multiple missing answers. Because we focused on entries that had complete observations in the covariates of interest for our analysis, it is possible that some information was not considered by excluding observations that had information in other variables (such as work from home, or number of persons in the household). However, we attempted to minimize this possibility by correcting the dataset using information from the Census. More granular corrections, which for example could be based on demographic information by municipality, could be used in the future to obtain a more accurate approximation to the population totals of the province. Additionally, the results in this study are based on self-reported data, where the risk of bias exist. Despite this, because in the context of COVID-19 it has been shown that good agreement exists between self-reported and documented vaccination status[55], the effect of self-reported bias is likely to not be significant in this case.

Finally, it is likely that there have been differences in vaccination across the province as more doses of the vaccine were administered and as successive variants emerged. Because this study focused only on vaccination status regarding the first dose of the vaccine within a relatively short time window, it can only provide a snapshot of the societal dynamics behind the pandemic. Nonetheless, the results presented here can serve as a starting point to motivate future longitudinal research that aims to quantify geographical differences within vulnerable segments of the population, and that can be used to inform the development of public health policies within the province of Ontario or across other provinces that aim to minimize disparities in health access.

Conclusion

This study explored differences in COVID-19 vaccination across the province of Ontario between late 2021 and early 2022 by taking into consideration socio-economic factors, such as income and race, their interactions, and the Health Regions within the province. Our results show that, during the period analyzed, significant differences in vaccination existed across different visible minority groups, income brackets, and Health Regions, showing intra-provincial disparities in vaccine uptake. As the COVID-19 continues around the world, it important that future public policies take into consideration how to adequately reach individuals within minority groups that live across geographical areas where less probabilities of being vaccinated are likely. At the moment, this is an ongoing issue that needs to be addressed to ensure a more homogeneous outcome from the pandemic.

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