Differences in COVID-19 vaccination in the province of Ontario across 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 that during the last three months of 2021, individuals in certain equity-deserving groups (visible minorities) were three times less likely to be vaccinated than White/Caucasian individuals across the province and that in some cases, within these groups individuals in low income brackets had significantly higher odds of vaccination when compared to their peers in high income brackets. Finally, we identified significantly lower odds of vaccination in the West Health Region of Ontario within certain equity-deserving groups. This study shows that there is an ongoing need to better understand and address differences in vaccination uptake across diverse segments of the population of Ontario that have been largely impacted by the pandemic.

Keywords

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

Background

As of May of 2023 there have been 765 million confirmed cases of COVID-19 around the world, including 6.8 million deaths[1]. Although this disease is no longer categorized as a global health emergency by the World Health Organization (WHO)[2], there is ongoing concern due to continued transmission, surges in cases and deaths due to new variants[3], and weaknesses in health systems around the world that could be exploited by a novel virus or another public health emergency in the future[4].

In particular, a major weakness that has received attention during the pandemic has been related to inequalities in vaccine uptake. The rapid development of vaccines against COVID-19 initially brought the hope of a rapid end to the pandemic due to the start of vaccination campaigns in certain parts of the world toward the end of 2020[5–8]) but inequalities in vaccine uptake made these pharmaceutical interventions ultimately unable to replicate the experience of smallpox, where vaccination on a global scale and was crucial to control this disease[9].

This problematic is a multifaceted issue resulting from a combination of factors, among which are failed public health measures[10], inequality in vaccine access between high- and low-income countries[11,12], and vaccine hesitancy[13]. Furthermore, it is well established that this issue has affected in particular individuals in certain equity-deserving groups (e.g., Black, Asian, or Indigenous) as well as individuals with socio-economic disadvantages[14–20].

Reasons given for this inequality have included medical mistrust due to systemic medical racism[16,21], mistrust in vaccines[14], and the influence of conspiracy theories[21–23]. However, it is important to also consider that vaccination uptake can be influenced by geographical (spatial) factors. In this regard, differences in COVID-19 vaccination rates have been associated with varied regional attitudes towards vaccination[24], spatial differences in vaccine access and supply, vaccination location availability, and lack of prioritization of areas where vulnerable groups reside[7,25]. Other studies have also shown heterogeneity in vaccine uptake within small governmental administrative units such as counties[26–29], and that accounting for geographical differences in vaccination can help predict patterns of booster uptake[30].

However, such analyses have been carried mostly in territories outside of Canada, where available studies have been focused in certain cities (such as Toronto[31], or Montreal[32]), or have explored differences at a province-wide level[18]. Therefore, there is a need for studies that explore spatial differences in vaccination within the Canadian territory and that consequently, can help identify disparities that need to be addressed within specific areas in each province.

This need is specially important in the case of Ontario, the most populated province of Canada. Between 2007 and 2019, Ontario managed healthcare access to its inhabitants using 14 intra-provincial divisions called the Local Health Integration Networks (LHINs), which aimed to provide an integrated health system for the province. However, this approach was complex and bureaucratic, and resulted in excessive expenditures, disparities in mortality rates, the deterioration of certain performance indicators such as wait times and hospital readmissions, fragmented electronic health systems, the decline of performance indicators, and inequities in health services access[33–37]. Therefore, with the intent of better organizing and delivering care in late 2019 the provincial government eliminated the LHINs and incorporated the areas covered by them into six larger Health Regions (North East, North West, Central, Toronto, West, and East)[35].

Because the relatively recent adoption of the Health Region model and its alignment with the onset of the COVID-19 pandemic, there is a need to analyze if there are ongoing disparities in health access under this approach that need to be addressed before they are exploited by a new disease or public health threat. In this regard, previous research has highlighted disparities in the level of activity of each Health Region[38]. Therefore, analyzing differences in vaccination uptake within the Health Regions and can help identify which socio-demographic groups are the most vulnerable and what areas of the province deserve special attention by decision-makers.

Therefore, in this study we hypothesized that there were differences in vaccination uptake between the different Health Regions of Ontario between October of 2021 and January of 2022. By including socio-economic factors in our analysis, we aimed at identifying in which groups these differences were significant in order to provide an assessment of the current state of healthcare access in Ontario.

Methods

Data and Methods

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 that was commissioned by the Fields Institute for Research in Mathematical Sciences and the Mathematical Modelling of COVID-19 Task Force under ethical guidance from the University of Toronto, and which ran between September 30th, 2021 and January 17th,2022. The survey collected socio-economic information from participants (Table 1), their location (nearest municipality, as shown in Figure 1), the date of access to the survey, and asked information on vaccination status by using the question "Have you received the first dose of the COVID vaccine?", with possible answers "yes" and "no". The original dataset contained 39,029 observations (where each observation corresponded to a unique respondent).

Preliminary analyses of the data included the removal of outliers (**should we still do this? it's only 19 observations with income >110k and household of 1, but we are not even using such income bracket in the analysis because we re-grouped the data, and the household size variable has 90% missing rate**), of observations where respondents did not provide answers in all the covariates of interest, matching the city of each observations with its corresponding LHIN and Health Region, and removing observations from areas with low representation (107 observations corresponding to the North West and North East Health Regions). After all the preliminary analyses indicated above, the total number of observations used for analysis was 3,549 which included the East, Central, Toronto, and West Health Regions covering the period between October 1st,2021 and December 12th, 2021. The original dataset, clean dataset, and details on the data cleaning process are described in detail in the GitHub repository for this paper.

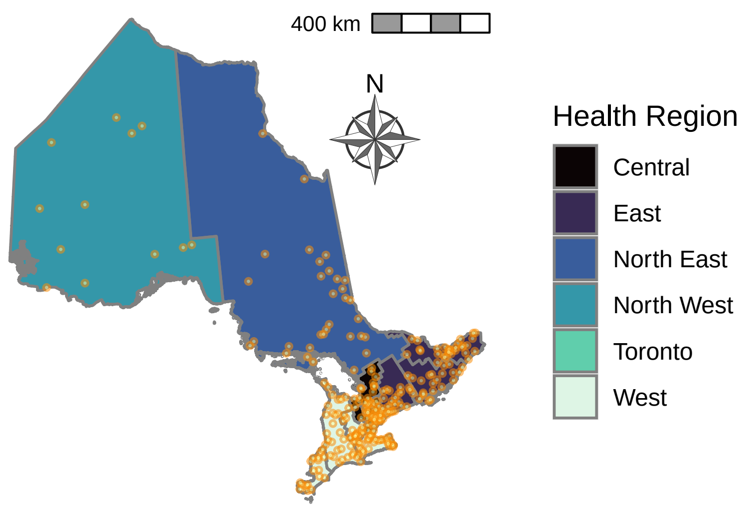

Figure 1: Geographic representation of the data collected by the *Survey of COVID-19 related Behaviours and Attitudes*, collected by the Fields Institute in Ontario. The municipalities (cities) from where survey participants provided answers (in the clean dataset) appear as points. The Health six Regions are color-coded. Internal boundaries within certain Health Regions indicate areas that belonged to the Local Integrated Health Networks (LHINs), the geographic areas for healthcare in Ontario before the adoption of the Health Regions.

Statistical analyses

We used a logistic regression model to examine the impact of the Health Regions in vaccination rates while considering the socio-economic factors and and months covered by the survey

(Table 1) and certain interactions (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[39–41]. Because we identified differences in representativity between the survey data and the estimates from the Census, we used an iterative proportional fitting procedure (*raking*)[42] to correct the data using data from the Census and Health Region population totals; and fitted the regression model to the uncorrected and corrected data. Details regarding the correction can be found in the Appendix. All analyses were conducted in R 4.2.2 using the packages `survey`[43],`tidyverse`[44], `quarto`[45], `modelsummary`[46], and `gtsummary`[47].

Results

Sample Characteristics

Table 1 shows the characteristics of the data from the Fields COVID-19 survey used for analysis. The sample contained **6,236** observations, from which 24.8% (1,547) corresponded to individuals that reported not having received the first dose of the vaccine. Vaccination rates ranged between 71-79% across household income brackets, age groups, Health Regions, and the months considered in the survey. However, the highest vaccination rates in each category were reported by individuals in the highest income bracket (79%), those between 16 and 34 years of age (77%), individuals that lived in the East Health Region (77%), and during January of 2022 (78%). Differences were higher between racial/ethnic groups, where the higher vaccination rate was reported by White/Caucasian individuals (84%), against vaccination rates between 63-66% reported in the case of Arab/Middle Eastern, Black, Indigenous, Latin American individuals, and those that reported belonging to "Other" racial groups, which included Southeast Asian, Filipino, West Asian, and minorities not identified elsewhere.

Table 1: Descriptive Statistics of the Fields COVID-19 Survey (by Vaccination Status)

Variable	**no**, N = 1,547[1]	**yes**, N = 4,689[1]	**p-value**[2]
Income (CAD)			<0.001
60000 and above	542 (21%)	1,996 (79%)	
25000-59999	347 (25%)	1,046 (75%)	
under 25000	658 (29%)	1,647 (71%)	
Age Group			0.002
16-34	645 (23%)	2,117 (77%)	
35-54	411 (24%)	1,305 (76%)	
55 and over	491 (28%)	1,267 (72%)	
Health Region			0.3
Toronto	593 (26%)	1,709 (74%)	
Central	372 (26%)	1,083 (74%)	

East	236 (23%)	783 (77%)	
West	346 (24%)	1,114 (76%)	
Month			<0.001
October	469 (27%)	1,263 (73%)	
November	376 (28%)	980 (72%)	
December	181 (24%)	565 (76%)	
January	521 (22%)	1,881 (78%)	
Race			<0.001
White/Caucasian	354 (16%)	1,871 (84%)	
Arab/Middle Eastern	111 (34%)	220 (66%)	
Black	159 (34%)	303 (66%)	
East Asian/Pacific Islander	94 (19%)	404 (81%)	
Indigenous	112 (37%)	194 (63%)	
Latin American	99 (34%)	195 (66%)	
Mixed	177 (30%)	411 (70%)	
Other[3]	315 (34%)	606 (66%)	
South Asian	126 (21%)	485 (79%)	

[1]n (%)

[2]Pearson's Chi-squared test

[3]Southeast Asian, Filipino, West Asian, and minorities not identified elsewhere according to the Census.

Multivariate Regression

Figure 2 presents the estimates (as odd ratios) from the logistic regression models for vaccination status using the socio-demographic factors collected by the survey, and their interactions. Generally speaking, lower odds of vaccination were identified in both cases in individuals characterized by a low household income, or that identified as part of equity-deserving groups. However, the magnitude of the estimates differed between the uncorrected and corrected models and more importantly, certain estimates were not deemed to be statistically-significant after the correction, in contrast to the estimates from the uncorrected model. Specifically, the corrected model showed no significant differences in vaccination odds between the age groups considered, the East Health Region, Latin American individuals with a household income under CAD 25,000, and Indigenous individuals living in the Central Health Region (Figure 2,B).

However, significantly lower odds of vaccination were identified in the corrected model for those with a household income under CAD 25,000 (OR=0.37, CI=[0.27,0.51]) and those with an income between CAD 25,000 and 59,999 (OR=0.58, CI=[0.42,0.81]). Additionally, individuals who identified as Arab/Middle Eastern, Black, Latin American, of mixed background, or that belonged to other racial groups (a category that included Southeast Asian, Filipino, West Asian, and minorities not identified elsewhere), had significantly lower odds of vaccination

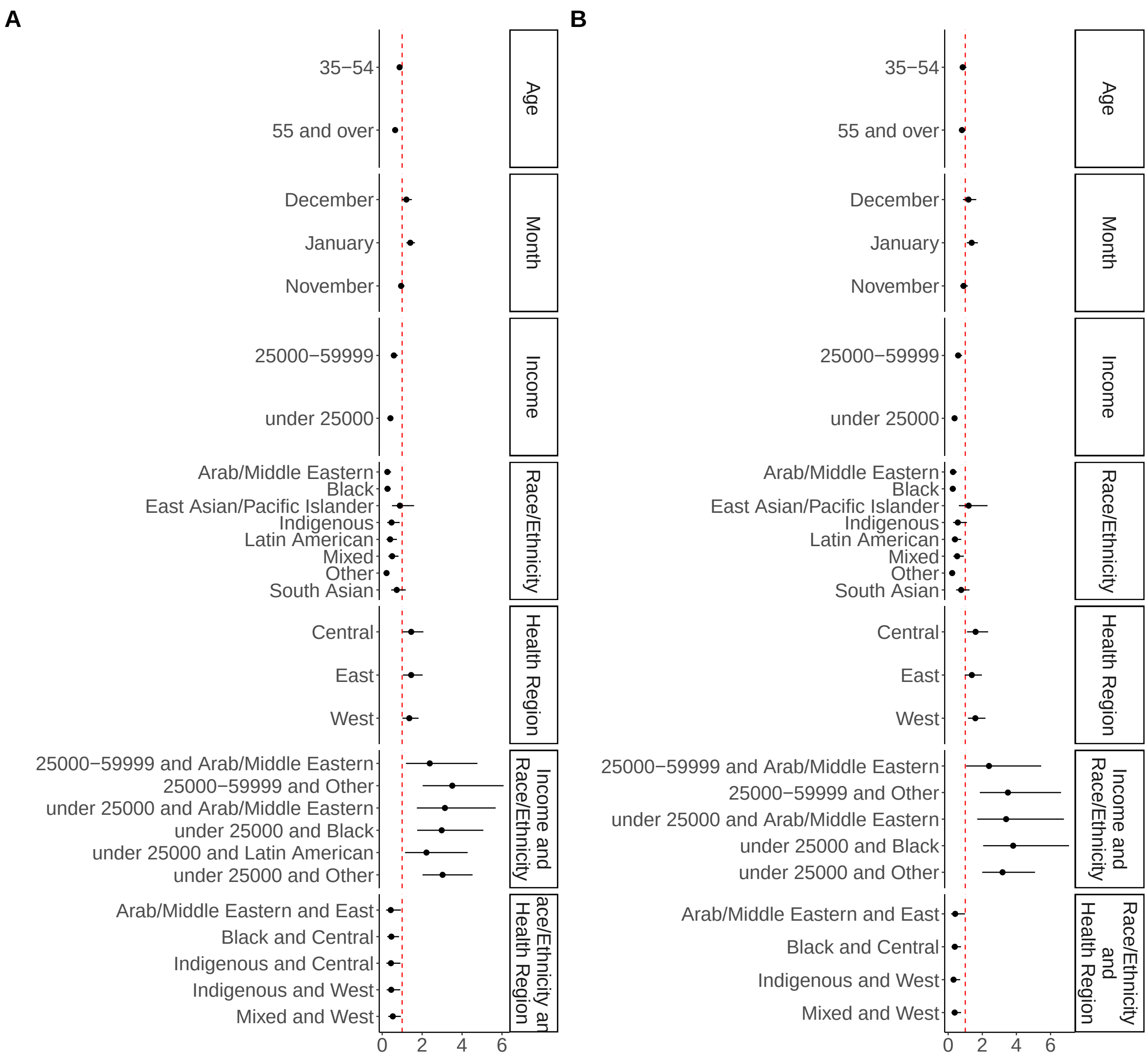

Figure 2: Coefficient estimates and confidence intervals for the uncorrected model. Only statistically significant interaction terms are shown. Full interaction terms can be found in Supplementary Figure A-3.

than those in the White/Caucasian group (ORs and CIs=0.28 [0.16,0.51], 0.27 [0.16,0.45], 0.40 [0.21,0.76], 0.53 [0.30,0.92], 0.23 [0.15,0.36]). Additionally, individuals that reported living in the Central and West Health Regions had higher odds of vaccination than those in the Health Region of Toronto (ORs and CIs=1.61 [1.10,2.34], and 1.59 [1.16,2.19], respectively).

Interestingly, individuals in equity-deserving groups with a household income below CAD 25,000 had higher odds of vaccination (when compared to those with a household income above CAD 60,000). This held true in the case of Arab/Middle Eastern (OR=34, CI=[1.70,6.79]), Black individuals (OR=3.81, CI=[2.05, 7.09]), or those in other racial or ethnic groups (OR=3.19, CI=[2.00,5.09]). Additionally, individuals with an income between CAD 25,000 and 59,999 in the Arab/Middle Eastern and other racial ethnic groups had higher odds of vaccination (ORs and CIs=6.96 [2.67,18.16], and 3.5 [1.85,6.62]).

Finally, significantly lower odds of vaccination were identified (when compared to the Toronto Health Region) for Black individuals in the Central Health Region (OR=0.39, CI=[0.2,0.75]), Arab/Middle Eastern individuals in the East Health Region (OR=0.41 [0.17, 0.98]), and in the Indigenous and mixed groups in the West Health Region (ORs and CIs=[0.31 [0.14, 0.7] and 0.38 [0.19, 0.76], respectively).

Discussion

had significantly higher odds of vaccination than those in the Health Region of Toronto

In this study we hypothesized that differences in COVID-19 vaccination uptake were present between the Health Regions during between late 2021 and early 2022, aiming at determining which socio-demographic groups could be impacted by these disparities in order to provide decision-makers with information that could be used to develop policies focused on reducing or eliminating these differences and ensure that the Health Region model is able to fulfill its missing of improving health access for the inhabitants of Ontario.

Our results show differences in odds of vaccination across Ontario in certain socio-demographic groups. Specifically, those who identified as Arab/Middle Eastern, Black, Latin American, having mixed racial or ethnic background, or that belonged to other groups not explicitly included in the survey (Southeast Asian, Filipino, West Asian, and minority groups not identified elsewhere) had vaccination odds that were between a third and a half of that of individuals that identified as White/Caucasian (Figure 2). These results are consistent with previous studies that have shown lower vaccination rates in individuals with the same socio-demographic characteristics[18–20,48].

Lower vaccine uptake in the socio-demographic groups indicated above may be influenced in part, by vaccine hesitancy and refusal, which have been associated in equity-deserving Canadian individuals to concerns on vaccine safety, effectiveness, and experiences of racial discrimination in health settings[41,49–51]. However, it has been shown that structural barriers also play an important role in vaccination uptake. In the case of equity-deserving individuals, such barriers include complex scheduling systems, language barriers, lack of adequate public transportation, and lack of accessible vaccination sites[52]. In this regard, it is interesting to note that vaccination venues were scarce in low socio-economic areas that had the highest burden of COVID-19 in Toronto and other regions of Ontario around the time covered by the survey[7,53], and that pharmacies in the Peel region (an area identified as a "hotspot" with high numbers of essential workers and multigenerational households) could not keep up with demand[54]. This suggests disparities in vaccine accessibility that affected in particular equity-deserving individuals in Ontario at the time of the survey. However, because to the best of our knowledge there seems to be a very limited amount of literature on this topic in the context of Ontario, there is an ongoing need of future studies that examine the longitudinal impact of vaccine accessibility and structural barriers that affect equity-deserving groups within the province.

Interestingly, whereas overall self-reported vaccination rates were found to be statistically significantly lower in various racial minority groups when compared to White/Caucasian individuals, the change in odds of vaccination within certain racial groups and income strata was actually positive, in contrast to the White/Caucasian group, where vaccination odds decreased in lower income brackets when compared to the CAD 60,000 and over bracket (Supplementary Figure A-5). Specifically, individuals in low income brackets that belonged to Arab/Middle Eastern, Black, or other minority groups had higher odds of vaccination that their peers with an income above 60,000 CAD.

This result is likely reflects in part the fact that individuals in racial minority groups tend to perform occupations that have been deemed as "essential" in the context of the pandemic[55,56], which include grocery store, gas station, warehouse, distribution, and manufacturing workers, all being occupations for which an income within the significant brackets identified in the analysis is to be expected. In Ontario, these workers had priority for COVID-19 vaccination[57]; and there is evidence of interventions by vaccination staff in certain parts of the province to encourage vaccination uptake by these individuals[54]. These facts, combined with evidence of increased trends in vaccination in this group elsewhere[58], suggest that the type of occupation from individuals in equity-deserving groups played an important role in increasing the odds of vaccination in the province.

However, the results also indicate that the place of habitation within the province for certain equity-deserving groups also affected the odds of vaccination (interaction terms of Health Region and Race, Figure 2). Specifically, this held true in the case of individuals identifying as Indigenous or with mixed racial background in the West Health Region, Black individuals in the Central Health Region, and Arab/Middle Eastern individuals in the East Health Region Figure 2. For these individuals, vaccination odds were lower when compared to the Toronto Health Region (Supplementary Figure A-6). Although it is likely that these findings have multiple causes, we indicate next some contributing factors that might help provide context in each case.

First, in the case of Indigenous, mixed, and Arab/Middle Eastern individuals is useful to disaggregate the data by LHINs, because most of the studies in the literature that have analyzed health in Ontario use the LHINs as the base of their analyses. Interestingly, for the first two groups most of the observations in the survey (for West Health Region) came from the Hamilton Niagara Haldimand Brant, South West, and Waterloo Wellington LHINs (**add table in Appendix**), whereas for Arab/Middle Eastern Individuals in the East Health Region the highest number of observations corresponded to the Champlain and Central East LHINs. Previous research has identified health disparities in these (mostly rural) regions, such as unequal distribution of primary care providers, increased mortality, and low pharmacist availability[59–61].

Furthermore, there is an ongoing challenge for the health system of the province with regard to personalized healthcare for marginalized individuals. For example, the West Health Region has only two Aboriginal Health Access Centres in contrast to an Indigenous population of about 100,000 individuals[62]. Lack of access to personalized healthcare affects individuals that may mistrust the traditional healthcare system due to systemic racism or oppression, which is known to be the case for Indigenous and Black individuals in Canada where these rationales have been associated to lower vaccination among these groups[63,64]. Taken together, these aspects indicate ongoing multiple healthcare disparities that continue to affect equity-deserving individuals across the province.

The West Health Region is located in the leftmost southern part of the province, including the regions of Waterloo and Niagara, the counties of Wellington, Essex, and Lambton, and the cities of Hamilton, Haldimand, Brant, and Chatham-Kent. The Central Health Region includes the regions of Peel and Halton, the regional municipality of York, the district of Muskoka, the counties of Dufferin, Simcoe, Grey, and the city of Etobicoke.

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. Moreover, our analysis did not consider the North West and North East Health Regions, due to the low number of entries from these areas in the survey (Figure 1). Although low representation from these areas is based on the fact that these regions only account for 5% of the total population of Ontario, these regions are the home to more than 100,000 individuals that identify as Indigenous[62], a minority group that has historically suffered from reduced access to health care and discrimination[21]. Therefore, there is a need for additional studies that focus on these low-populated Health Regions in Ontario where disparities in vaccination might be significant and understudied.

It is also worth mentioning that province-wide vaccination rates for the period of interest are somewhat different from those of the survey, particularly in the case of those 55 years of age and older, which in the survey had a vaccination rate of 72%, against a rate of 88.4% reported for the closest age bracket (50 years of age and older) reported by Public Health Ontario at the start of the period covered by the data[65]. However, we found good agreement between the estimates from the model and overall vaccination rates reported for Canada, which have been relatively higher when compared to other high income countries[66], and with vaccination uptake rates across different age groups presented in other studies[18,67].

In other words, although vaccination rates obtained from the survey were slightly lower than the provincial estimates, these values still represented a valid approximation to overall trends; this notion is reinforced by the consistency in the proportion of vaccination rates (Table 1) and vaccination odds (**?@fig-model-corr**) across the period covered by the survey, which closely match the vaccination rates from Public Health Ontario and which indicate that due to the relatively high coverage achieved in the population at that point, vaccination rates increased by around 3% across all age groups during the three months covered by the survey[65]. It is also important to mention that to this day, differences in vaccination rates within the province continue. As of March of 2023 some regions still have less than 75% vaccination rate[68], and although data for the period analyzed in this study is not publicly-available, it is likely that differences in vaccination rates were higher at the time, being partially captured by the survey.

The results in this study are based on self-reported data, where bias might be present. However, because in the context of COVID-19 it has been shown that good agreement exists between self-reported and documented vaccination status[69], we believe that our data was able to provide a valid assessment of vaccination in the province. Finally, this study focused on first-dose vaccination status within a relatively short time window, and therefore 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 the collection of robust longitudinal data that can be used to quantify geographical and temporal differences within vulnerable segments of the population, and that can be used to inform the development of adequate 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 during the last quarter of 2021 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, differences in vaccination uptake existed across multiple equity-deserving groups in the province, and that these differences were significant in two of the Health Regions analyzed. It is important that future public health policies in Ontario take into consideration how to adequately reach individuals from equity-deserving groups that might live in areas of the province where access to healthcare might be difficult. Only in this way the goal of the Health Region model, which aims at reducing disparities, will become successful.

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