

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 been 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

17 a COVID-19 vaccine), and different socio-economic and geographical factors. Our results
18 show differences in vaccination due to race/ethnicity, income, Health Regions (geographical
19 areas used for health service access in Ontario), and their interactions. In particular, we show
20 that individuals who identified as Arab/Middle Eastern, Black, or Latin American, had sig-
21 nificantly lower odds of vaccination than White/Caucasian individuals (ORs=0.31, 0.32, 0.28,
22 and $p=0.004$, $p<0.001$ and $p=0.004$, respectively), and that individuals with a household in-
23 come below CAD 25,000 who identified as Arab/Middle Eastern (OR=3.05, $p=0.013$), Black
24 (OR=3.19, $p=0.004$), Latin American (OR=2.80, $p=0.041$), or that belonged to other minority
25 groups (OR=4.59, $p<0.001$) had higher odds of vaccination than individuals from the same
26 racial/ethnic group in higher income brackets. Finally, we also identified lower odds of vacci-
27 nation within different minority groups in West Health Region. This study shows that there
28 is an ongoing need to better understand and address differences in vaccination uptake across
29 diverse segments of the population that have been largely impacted by the pandemic.

30 **Keywords**

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

32 **Background**

33 The COVID-19 pandemic continues around the world with more than 600 million confirmed
34 cases as of November of 2022¹. During the first months of the pandemic in early 2020, non-

35 pharmaceutical interventions such as masking and social distancing were the only methods
36 available to manage the spread of the disease; however, the rapid development of vaccines
37 permitted their approval and use in some countries towards the last month part of 2020. For
38 example, in the US and Canada vaccine campaigns began in mid-December of 2020^{2,3}. Al-
39 though it has been estimated that COVID-19 vaccines have prevented around 14 millions of
40 deaths worldwide⁴, the rollout of COVID-19 vaccines has faced multiple challenges since its
41 inception.

42 Indeed, multiple obstacles that have complicated vaccination efforts against COVID-19 have
43 been identified: inequality in vaccine access, vaccine hesitancy, and differences in vaccination
44 rates across different segments of the population⁵⁻⁷. In the case of Canada, lower vaccine up-
45 take has been associated with socio-economic factors such as younger age, educational level,
46 presence of children in the household, lack of a regular healthcare provider, ethnic origin, and
47 financial instability⁸⁻¹⁰.

48 Additionally, vaccination is influenced by changes in geography. In this regard, it has been
49 shown that there have been spatial differences in COVID-19 vaccination rates due to regional
50 differences in attitudes towards vaccination⁷, geographical differences in vaccine access and
51 supply, vaccination location availability, and lack of prioritization of vulnerable groups^{3,11}.

52 Studies that analyze geographical variations in vaccine uptake are important as they can help
53 inform public health decision-makers to design policies to that consider spatial changes to
54 address vaccination disparities. In this regard, previous geographical (spatial) analyses of
55 vaccination rates have shown that variations in vaccine uptake can occur within small gov-

56 ernmental administrative units (e.g., counties in the case of the US)¹²⁻¹⁵, and that geographical
57 analyses can be predictive of booster uptake patterns¹⁶.

58 In Canada, studies that have used a spatial approach to analyze vaccine uptake have shown
59 disparities in vaccination rates across low and high income neighborhoods in the city of
60 Toronto¹⁷, among adolescents from deprived neighborhoods in the city of Montreal¹⁸, and
61 have also highlighted disparities in vaccination status depending on age, income, and ethnic
62 origin at the provincial level⁸. However, there is limited information on differences in
63 vaccination status inside the provinces. Such analysis is important as it can help identify
64 inequalities that may exist within these geographical areas while providing a granular view
65 of intra-provincial differences that can help understand the barriers for vaccine uptake.

66 In this study, we examined self-reported COVID-19 vaccination status within the province of
67 Ontario using a combination of socio-economic factors(such as ethnic origin, age, and income)
68 and geographical analysis (at the level of the Health Regions) in order to determine intra-
69 provincial differences in vaccine uptake and address the ongoing need of socio-economic in-
70 formation that can provide a rationale for the disparities in vaccination observed within some
71 racial groups¹⁹.

72 **Methods**

73 **Data source: survey overview**

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

80 Briefly, the survey was deployed used random domain intercept technology, where if users
81 clicked on a registered but commercially inactive web link or typed in a web address for a site
82 that was dormant, they had a random chance of that link being temporarily managed by the
83 company that administered the survey and instead of coming across a notification about the
84 status of the site(“this page does not exist”), the survey was deployed to the user²⁰. Users then
85 decided whether to anonymously participate, and those that participated were able to exit the
86 survey at any time. After the survey closed, regardless if it was complete or incomplete, access
87 was denied to any further users with the same internet protocol (IP) address and the domain
88 entry point rotated such that if a user were to attempt to access the survey again, share the link,
89 or enter via the same address using an alternative IP address, the survey would not deploy.
90 This effectively meant that a user could participate only once in the survey.

91 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”.

103 **Data cleaning**

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

111 **Geographical location**

112 For each survey participant certain data was automatically captured, including the nearest
113 municipality (city). This resulted in a total of 578 different municipalities within the clean
114 dataset. Due to our interest in analyzing the differences between Health Regions, we as-
115 signed the city of each entry to its correspondent Health Region following a multi-step pro-
116 cess. Briefly, we used Local Health Integrated Networks (LHINs) to assign a Health Re-
117 gion to each entry in the survey. LHINs were the geographical divisions for health used by
118 Ontario before the adoption of the Health Regions; because of the lack of a publicly avail-
119 able list of all municipalities within each Health Region, we used a dataset of long-term
120 care homes and LHINs to match each city to LHIN, followed by matching each LHIN to a
121 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 status²²⁻²⁴. The model appears in Equation 1,

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

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 $\beta_1 \dots \beta_6$ 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 fol-

182 lows: 16 to 34 years (age group), White Caucasian (Race), Toronto (Health Region), CAD
183 60,000 and over (Income). There were no statistically significant differences in vaccination
184 rates within the age groups from the survey, but significant odds ratios were estimated for
185 other covariates. Within household income brackets, individuals with an income under CAD
186 25,000 or between CAD 25,000-59,999 had significantly lower odds of vaccination than those
187 with an income above CAD 60,000 (ORs=0.37 and 0.59, respectively). Within Race/Ethnicity,
188 individuals who identified as Arab/Middle Eastern, Black, or Latin American, had signifi-
189 cantly lower odds of vaccination than those in the White/Caucasian group (ORs=0.31, 0.32,
190 0.28, and $p=0.004, <0.001$ and 0.004, respectively); additionally, those individuals in the Other
191 Race/Ethnicity group (a group that included Southeast Asian, Filipino, West Asian, and Mi-
192 norities Not Identified Elsewhere) had even lower odds of vaccination than the other minority
193 groups (OR=0.22, $p<0.001$). Regarding Health Regions, individuals that reported living in the
194 West Health Region (which comprises the regions of Waterloo and Niagara, the counties of
195 Wellington, Essex, and Lambton, and the cities of Hamilton, Haldimand, Brant, and Chatham-
196 Kent) had significantly higher odds of vaccination than those in the Health Region of Toronto
197 (OR=1.55, $p=0.029$).

198 Moreover, statistically-significant odd ratios were determined in the case of the interaction
199 of income and race; specifically, for individuals with a household income below CAD 25,000
200 who identified as Arab/Middle Eastern (OR=3.05, $p=0.013$), Black (OR=3.19, $p=0.004$), Latin
201 American (OR=2.80, $p=0.041$), or that belonged to other minority groups (OR=4.59, $p<0.001$).
202 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

210 Discussion

211 The rapid development of COVID-19 vaccines has been considered as a major achievement
212 of modern medicine²⁸. Vaccine availability towards the end of 2020 in certain countries made

213 some believe that they would be a determinant factor in a rapid ending of the pandemic²⁹.
214 However, despite previous successful vaccination campaigns that were crucial to control dis-
215 eases such as smallpox and polio³⁰, vaccination efforts in the case of COVID-19 have faced
216 multiple challenges that have complicated the achievement of global immunity.

217 Among the different challenges faced by COVID-19 vaccination efforts are the development
218 of new variants due to inadequate public health measures³¹ and inequity in vaccine access be-
219 tween low and high income countries³². However, it is also well established that even in the
220 case of high income countries that have had ample access to vaccines since 2020, such as the
221 US, the UK, and Canada, there have been challenges in vaccination efforts due to differences in
222 vaccine uptake among different segments of the population. More specifically, lower vaccine
223 uptake has been associated with socio-economic factors such as race (i.e., identifying as Black,
224 Asian, Indigenous) and household income (typically within lower income brackets)^{33–36}. Rea-
225 sons given for this association have included medical mistrust due to systemic medical racism,
226 mistrust in vaccines, and the influence of conspiracy theories^{33,35,37–39}.

227 In addition, vaccine uptake is influenced by geography, as shown by different studies that
228 have identified intra-regional differences in vaccine uptake^{12,40,41}. However, in the case of
229 Canada, studies that have analyzed spatial differences in vaccination have been focused
230 in country-wide or province-wide estimates^{8,42}. Therefore, we explored spatial and socio-
231 economic determinants of vaccination status in the province of Ontario. This province is of
232 particular interest as it has seen recently major structural health changes with the dissolution
233 of the Local Health Integrated Network (LHIN) system and the incorporation of regions

covered by LHINs into larger Health Regions⁴³. Because the idea behind the change aimed to reduce the inequalities in healthcare that were identified under the LHIN model⁴⁴, 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 countries⁴⁵, 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 survey⁴⁷.

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

255 identified as White/Caucasian (Table 3). These results are consistent with other studies that
256 have shown lower vaccination rates in individuals that identify as part of a racial minority, or
257 that have a low household income^{8–10,48}.

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

274 This result is likely due to the fact that individuals that belong racial minority groups tend to
275 perform occupations that have been deemed as “essential” in the context of the pandemic^{49,50},

276 which include occupations such as grocery store workers, gas station workers, warehouse and
277 distribution workers, and manufacturing workers, all being occupations for which an income
278 within the significant brackets is to be expected. In the case of Ontario, essential workers had
279 priority for COVID-19 vaccination⁵¹, which would explain the higher odds of vaccination for
280 these individuals in certain income brackets, in contrast to the lower odds of vaccination for
281 the same type of individuals with higher household income. In other words, it is possible that
282 the type of occupation played an important role in increasing the odds of vaccination in these
283 racial minority groups.

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

296 According to Ontario Health, 13.2% of the population in the West Health Region identifies as

297 a visible minority, whereas 2.5% identifies as Indigenous⁵². In the case of this analysis, the es-
298 timated lower odds are likely to be explained from a socio-economic perspective. In fact, 50%
299 of the answers from this region in the survey came from the former LHINs of Hamilton Nia-
300 gara Haldimand Brant, and Erie St. Clair, both which are among the regions of Ontario with
301 the highest proportion of their population (more than 20%) in the lowest income quintile⁵³
302 (Supplementary Table A-7). Therefore, this result partly reinforces the well-known existing
303 association between low vaccination rates and income, but it additionally indicates that there
304 were intra-regional differences in vaccination. Interestingly, a disproportionate number of
305 COVID-19 cases and low vaccination rate (under 50%) have been previously reported in the
306 South Asian community of Ontario⁵⁴; in this regard, our result provides additional context
307 by showing that within the South Asian community, there were differences in vaccination
308 uptake across Ontario. Moreover, because significant lower odds of vaccination were also
309 identified other minority groups, this provides a rationale for future studies that explore how
310 vaccination uptake varies across different minority groups within Ontario and other Cana-
311 dian provinces.

312 There are some limitations to the present study. First, the data collection design, which al-
313 lowed respondents to withdraw from the survey at any point, resulted in a high number of
314 unique entries in the survey with multiple missing answers. Because we focused on entries
315 that had complete observations in the covariates of interest for our analysis, it is possible
316 that some information was not considered by excluding observations that had information in
317 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 status⁵⁵, 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 is 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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