Income as a Determinant of the Speed of Transmission: Study of the Fifth Wave of SARS-CoV-2 in Toronto, Ontario

Jason Lam *400201299*
Emily Fletcher *400210334*
Syed Hammad Uddin *400188361*
Jenny Chau *40023317*
Pierce Bourgeois *400220858*

Introduction

Since the first cases in 2019, the COVID-19 outbreak has taken the world by storm. As of writing this (April 2022), there are over five hundred million cases reported worldwide (World Health Organization 2022). With its ability to rapidly spread, the COVID-19 has had profound consequences in every facet of public and private life. Among these include medical, economic, and social spaces (Baena-Díez et al. 2020). Most importantly, these unsettling times have shone a light on pre-existing disparities within national health systems. For many researchers, this does not come as a surprise as socioeconomic factors influencing health outcomes have been noted ubiquitously throughout the world (Khalatbari-Soltani et al. 2020). According to Khalatbari-Soltani et al. (2020), there is even a link between those socio-economically disadvantaged and increased risk of infectious disease.

This research continues in a vein of spatial statistical studies which analyze COVID-19 incidence rates paired with a socio-economic factor. Building upon Khalatabari-Soltani, et al. (2020) and the socio-economic position (SEP) framework, this study seeks to examine the relationship between income levels, population density, and proportion of young adults against COVID-19 incidence rates. More specifically, the overarching objective of this study is to analyze the relationship between the noted socio-economic variables and incidence rates of COVID-19 during the fifth wave in Toronto, Ontario, Canada.

Background

A person's income level affects how they go about their everyday lives. The associated behavioural pattern has been linked to change in health outcomes (Khalatbari-Soltani et al. 2020). Low income, for example, affects housing condition and leads to more tight housing arrangements. Such factors have been associated in the increased risk of infections for pathogens such as tuberculosis (Khalatbari-Soltani et al. 2020).

In Ontario, from January 21 to June 30, 2022, the most attributed workplace was manufacturing (Murti et al. 2021). Manufacturing accounted for 45% of outbreaks which totaled 65% of outbreak cases. Another notable sector was Transport and Warehousing (11% of outbreaks, 8% of outbreak cases). In Toronto, it has been observed the COVID-19 first infiltrate in high income communities before quickly spreading to lower income communities (Mishra et al. 2022). According to Mishra et al. (2022) lower income neighbourhoods were also defined by their higher dwelling densities and greater proportion of occupations that could not make the transition to remote work.

In addition, the susceptibility of adolescents (aged 10-19 years) and youth (aged 15-24 years) to COVID-19 has been a controversial research topic since the pandemic began (Rumain, Schneiderman, and Geliebter 2021). While several studies have concluded that young adults are significantly less susceptible to COVID-19 than older adults, others have found that the prevalence of COVID-19 for adolescents and youth to be significantly greater than that of older adults (Rumain, Schneiderman, and Geliebter 2021). In April 2021, COVID-19 cases were rising rapidly for young Canadians, with cases being highest among those aged 20 to 39 (Aziz 2021). Suggested factors that attribute to higher COVID-19 incidence among younger people include the reopening of high schools, colleges, and universities, larger and more frequent social gatherings and non-compliance with public health guidelines due to perceived low-risk of severe symptoms for the age group, and low income. (Aleta and Moreno 2020). Health-related behaviours of younger adults may also affect their susceptibility to COVID-19 infection (Abbasi 2020). In an online national survey of adolescents and young adults, vaping and the dual use of e-cigarettes and cigarettes heavily increased the chances of COVID-19 diagnosis (Gaiha, Cheng, and Halpern-Felsher 2020).

The first case of COVID-19 in Ontario (and Canada) was reported on January 25, 2020 (Nielsen 2020). As the virus began to spread, Ontario entered its first wave of COVID-19 on February 26, 2020. The first wave of COVID-19 lasted 188 days, ending on August 31, 2020 (Public Health Ontario 2021). As Ontario began loosening restrictions as part of its 3-stage reopening plan, people started getting together again, and observed cases began to rise. Ontario's second wave began September 2020 and ended in February 2021, with cases peaking in January 2021 (Public Health Ontario 2021). The third wave in Ontario was driven by the Alpha (B.1.1.7) variant, which was more transmissible (Detsky and Bogoch 2021). The third wave lasted from March to July 2021, and was the largest wave yet, with the peak number of new cases in a day in Ontario being 5067 (Public Health Ontario 2022). The emergence of the Delta variant (B.1.617.2) caused a smaller and shorter fourth wave in Ontario that lasted from August to October 2021. The largest number of new cases reported in a day in Ontario during the fourth wave was 878.

Table 1: Waves of COVID-19 in Ontario

Wave	Associated Variant	Approx. Start	Approx. End	Peak Cases Per Day	Total Cases
1st	Original Strain	February 2020	August 2020	752	42,486
2nd	Original Strain	September 2020	February 2021	4,168	260,643
3rd	Alpha	March 2021	July 2021	5,067	24,7654
4th	Delta	August 2021	October 2021	878	49,704
5th	Omicron	December 2022	February 2022	19,373	469,955

The fifth wave of the pandemic lasted from the beginning of December 2021 until mid-February 2022. The catalyst for this was the emergence of a new, highly transmissible variant called Omicron. The variant, which was first reported globally in November 2021, has been thoroughly researched due to its scale and rate of infection. This research suggests that the variant is highly transmissible due to several factors. This includes the fact that Omicron is more likely to evade immunity from a previous infection, meaning that there is a high chance that you can get re-infected with COVID-19 (Pulliam et al. 2021). Other research suggests that the variant is up to 3.7% more infectious among vaccinated citizens than its predecessors (Mohsin and Mahmud 2022). During the fifth wave, it became the dominant strain and was responsible for 95% infections globally. In Ontario, the first Omicron cases were reported on November 28, 2021 (Government of Ontario 2021). During the Omicron wave, the highest number of new cases reported for a single day in the province was 19,373 (Public Health Ontario 2022).

Lastly, Toronto has the densest urban core in the province and is one of the most densely populated regions in North America. This has made it susceptible to the ability of COVID-19 to rapidly spread. To date, there have been more than 300,000 reported cases with more than 4000 deaths (City of Toronto 2021). Within the city, there are several pockets that are denser than others, and this density is an important factor to look at. Population density is a measure of spatial distribution of people across space. In the case of Toronto, St James Town is the most densely populated neighbourhood in the city (Canadian Urban Institute 2016). Research around population density and its link to COVID-19 susceptibility is limited. Past literature has not shown a clear relationship between the two, with some noting a positive correlation (Hamidi and Hamidi 2021) while others deducing an insignificant relationship [Carozzi_Provenzano_Roth_2020]. This, as suggested by the entire catalogue of research, is connected to the regional variations connected to density. Some denser areas may have better services to limit their exposure to the virus, while others may be poorer and so may be more susceptible to the virus. It is important to explore this phenomenon in the context of Toronto, to understand the type of relationship found in the city.

Study area

The analysis was conducted at the neighbourhood level for the City of Toronto (See Figure 1). 'Neighbourhood' is a geographic level specifically designed by the City of Toronto. They were created by city to help government and other planning organizations with obtaining socio-economic data (City of Toronto 2017). In total there are 140 unique areas, and their boundaries are based on the Canadian Census Track. Each neighbourhood may contain between two to five of these census tracts. The geography of neighbourhood

was chosen for this study, as opposed to wards or dissemination blocks, not only to showcase acute changes within populations but due to the availability of both COVID-19 and the socio-economic data. The large number neighbourhoods also enable this study to capture diversity across the city.

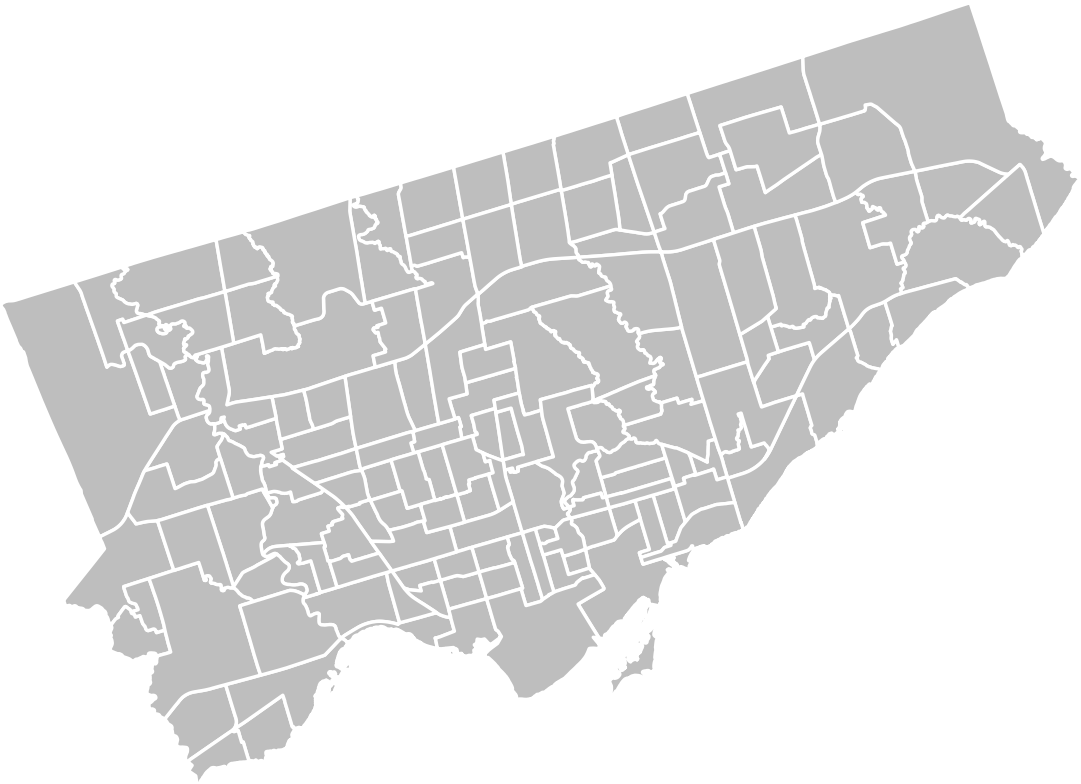

Figure 1: Neighbourhoods in Toronto, Ontario, Canada

Data

The COVID-19 data was retrieved from the City of Toronto Open Data portal (Toronto Public Health 2022). The data was downloaded as a comma-separated values (CSV) file. This data is updated weekly by the city and reports each individual case as a record. The time period of interest was December 2021, corresponding to the fifth wave of the pandemic in Ontario. The cases from the first week of December 2021 (Dec. 1 - Dec. 7) and the last week (Dec. 25 - Dec. 31) were filtered out and aggregated by neighbourhood. The socio-economic data used in this study was also retrieved from Toronto Open Data and comes from a neighbourhood profile dataset (Toronto Social Development, Finance & Administration 2011).

Methods

This study used RStudio to conduct both the data pre-processing, that is cleaning of the original datasets as well as the analysis. The data pre-processing file can be found here: https://github.com/lamj54/4GA3-Project/blob/main/Data%20Pre-Processing.Rmd

The analysis was done using several R packages, including spatstat, tidyverse, ggplot2, dplyr, webshot, gridExtra, patchwork, and spdep.

This document was also written and exported through R-Markdown with minimal adaptation from Steven V. Miller's template for academic manuscripts. See: http://svmiller.com/blog/2016/02/svm-r-markdown-

manuscript/[https://github.com/svmiller/svm-r-markdown-templates/blob/master/svm-latex-ms.tex] and (https://github.com/svmiller/svm-r-markdown-templates/blob/master/svm-latex-ms.tex)

Results

Analysis

Conclusion

This study shows that there is a clear connection between a lower-income status and the incidence rates of the COVID-19. The results show that other socio-economic factors, such as age or population density did not have a clear connection with the data currently available. Socio-economic factors are therefore complex factors that need to be further explored. Identifying these groups from a socio-economic perspective is the first step to establishing that a person's SEP may be as much of an indicator in predicting health outcomes as a pre-existing medical condition. In establishing such similarities, governing healthcare bodies may extend precautionary recommendations to people with specific socio-economic conditions, thus providing a more in-depth and informed disease prevention plan. In a pursuit of identifying groups of the populations who are more susceptible to poorer outcomes when combatting health problems, more research needs to be undertaken.

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