Public Health Unit Funding Per Capita and Seasonal Influenza Vaccination among Youth and Adults in Ontario, Canada in 2013/14 and 2018/19

by

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Abstract

Background

Previous studies have indicated that public health funding was associated with beneficial health outcomes at the population-level. Some individuals may be less likely to vaccinate against influenza for a variety of reasons, including the presence of health inequities as a barrier. For example, individuals from a lower SES background, who are younger, and who are male may be less likely to get the flu vaccine. Few studies have focused on the potential impact of public health funding per capita on influenza vaccine uptake and inequities related to influenza vaccination at the individual level. The objectives of this study are to: 1) estimate the association between public health unit (PHU) funding per capita and influenza vaccine uptake among individuals aged 12 and older in Ontario, Canada in 2013/14 and 2018/19; and 2) determine whether any observed associations were heterogeneous across household income groups, gender, and age categories.

Methods

Cross-sectional studies were conducted using the 2013/14 and 2018/19 cycles of the Canadian Community Health Survey (CCHS), a population-representative survey, by Statistics Canada that collects annual health data from individuals residing in local Ontario PHU service areas. PHU funding per capita was measured using the approved provincial funding for mandatory programs and the Canadian Census Population Estimates. Influenza vaccination in the past 12 months was measured by self-report in the CCHS. Multilevel logistic regression modelling was used to estimate the association between PHU funding per capita and self-reported influenza vaccine uptake, adjusting for gender, age, presence of chronic medication conditions, education, household income, presence of a regular medical doctor, urbanicity, self-perceived health, immigration status, and material deprivation. Cross-level interaction between PHU funding per capita and household income, and gender, and age were tested.

Results

A case-complete weighted dataset of 10,780,494 and 10,653,927 CCHS respondents in 2013/14 and 2018/19, respectively were included in this study. The proportion of respondents who were vaccinated against influenza were 33.2% in 2013/14 and 35.5% in 2018/19. Across both years, among those who reported vaccination in the previous year, a higher proportion were female (54.8% for 2013/14; 55.8% for 2018/19), aged 20 to 49 years (30.7% for 2013/14; 33.0% for 2018/19), and from the highest household income group (50.4% for 2013/14; 66.5% for 2018/19). In 2013/14, an increase of one standard deviation (SD) in PHU funding was associated with having the influenza vaccine (OR: 1.08; 95% CI: 1.01, 1.15; SD: 14.1), which was not observed in 2018/19 (OR: 1.00; 95% CI: 0.93, 1.08; SD: 14.4). A cross-level interaction between PHU funding per capita and household income further revealed that public health funding is protective among those from the lowest household income group and those between the ages of 50 and 64 years in 2013/14. Specifically, for every SD increase in PHU funding per capita, there is an increased likelihood of being vaccinated against influenza among individuals who belong to the lowest household income group (OR: 1.29; 95% CI: 1.10, 1.50) and those who are between the ages of 50 and 64 years (OR: 1.13; 95% CI: 1.03, 1.23) while adjusting for confounders. No heterogeneous associations were observed in 2018/19.

Conclusion

PHU funding per capita was found to improve influenza vaccination uptake among individuals from low-income households and those who are between the ages of 50 and 64 years in 2013/14.

Through funding, PHUs would be able to work towards their goal of preventing diseases, promoting health, and reducing health inequities among the population.

Preface

This thesis is an original work by Jo Lin Chew under the supervision of Dr. Roman Pabayo and thesis committee members: Dr. Ambikaipakan Senthilselvan, Dr. Brendan Smith, and Dr. Sarah Buchan. As part of a CIHR grant to understand the impact of funding on public health systems, Dr. R. Pabayo came up with the research topic to examine the association between public health unit funding and influenza vaccine uptake. Public health funding data used in this study was obtained from the Ontario Public Health Information Database (OPHID), which was assembled in alignment with the purpose of the CIHR grant. This research has received research ethics approval from the University of Alberta (study ID:Pro00099672) (Appendix A.1).

To support this research idea, J. Chew was involved in the collection of the OPHID data, data cleaning, statistical analysis, data interpretation, and writing of this thesis. Dr. R. Pabayo made substantial contributions to the development of this research topic, study design, interpretation of the data, and countless revisions of this thesis. Dr. A. Senthilselvan contributed by providing guidance on the analytical methods, variables to be examined, the interpretation of the findings, and a critical review of this paper. Dr. B. Smith contributed to the methodology, acquisition of the OPHID data, interpretation of the findings, and critical review of this thesis. Dr. S. Buchan contributed to the methodology, understanding of the findings, and a critical review of this thesis.

Currently, this thesis has not been published in any research journals. Nevertheless, future plans have been made to submit this thesis to the Canadian Journal of Public Health, as evident by the creation of a manuscript in Chapter 4.

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Glossary of Terms

ASP	Annual Service Plan and Budget Submission
BOH	Boards of Health
CCHS	Canadian Community Health Survey
CI	Confidence Intervals
CMC	Chronic Medical Conditions
FS	Financial Statements
MOHLTC	Ministry of Health and Long-Term Care
OPHID	Ontario Public Health Information Database
OR	Odds Ratio
PHU	Public Health Unit
SD	Standard Deviation
SDOH	Social Determinants of Health
UIIP	Universal Influenza Immunization Program

1. Introduction

1.1 Burden of Influenza

Seasonal influenza (flu), an infectious respiratory disease caused primarily by influenza A and B viruses, presents a significant threat to public health.[1] During peak influenza season, which commonly occurs during winter months, these viruses can spread easily and quickly from one person to another directly via cough or sneeze droplets or indirectly via contaminated objects.[1] As a result, infected individuals may experience a wide spectrum of symptoms, ranging from mild cold-like symptoms that recovers quickly to severe medical complications that may lead to hospitalization, long-term adverse health effects or even death.[1] People who are pregnant, 65 years of age and older, have chronic medical conditions, and who are between the ages of 6 and 59 months are especially susceptible to influenza-related complications or hospitalization.[2]

Globally, up until the COVID-19 pandemic in March 2020, it is estimated that each year, up to 20% of the population were infected by influenza.[2] This includes approximately 1 billion infections, 3 to 5 million severe cases, and up to 650,000 deaths annually.[2] In Canada, the burden of influenza is also very much present. In fact, seasonal influenza was rated as one of the top ten leading causes of death alongside pneumonia in 2019.[3] According to the Public Health Agency of Canada (PHAC)[1], approximately 12,200 hospitalizations and 3,500 deaths were recorded annually before the COVID-19 pandemic. During the 2018 to 2019 influenza season, Canada also observed a wave of influenza activity and hospitalization rates that were longer and higher than the previous five seasons.[4] Consequently, this places a heavy economic burden and pressure on the Canadian healthcare system, where an average cost per case of acute hospital care for influenza/ acute upper respiratory infection was about $2,145.[5] This cost was found to be 2.5 times higher among individuals who are at risk.[6] Additionally, seasonal influenza also affects overall economic costs through workplace absenteeism, where about 20 working days per 100 full time employees were lost.[7]

Similarly, in Ontario, the most populous province in Canada, influenza was rated as one of the top ten most burdensome infectious disease in Ontario during the 2005 to 2007 season.[8] Annually, during the peak of the season up until the COVID-19 pandemic, over 1000 confirmed influenza cases, an estimated 621,151 serious infections requiring medical attention, and approximately 272 deaths were reported.[8,9] Similar to the longer than usual seasonal influenza activity observed nationally in 2018 to 2019, Ontario recorded an estimated 133.8 infection rates per 100,000 population due to influenza in 2018.[9]

On a positive note, influenza vaccines are available and can help prevent the disease. Among the public health measures implemented to prevent and reduce the burden of seasonal influenza epidemics, vaccination is the most effective prevention and control method.[1] Vaccines are also safe, low-cost, and effective in reducing severe complications from influenza.[1] As one of public health's greatest achievements, the introduction and implementation of vaccines over the years have contributed to a significant decrease in the morbidity and mortality rates of many infectious diseases.[10] Due to frequent changes of the influenza virus antigens, influenza vaccines are updated annually to ensure that people are protected against the strain of influenza viruses circulating that year.[2] Therefore, annual uptake of the influenza vaccine is highly recommended by the National Advisory Committee on Immunization (NACI) to individuals aged 6 months and older who do not have any contraindications to the vaccine and especially those who are at risk for influenza-related complications and/or hospitalization.[1] To support this recommendation, many provinces and territories offered free influenza vaccines over the years to either the whole population or to at-risk populations.[11] By 2023, all provinces and territories have incorporated a universal vaccination program to offer free influenza vaccines to individuals 6 months and older.[12] In Ontario, free influenza vaccines are provided through the Universal Influenza Immunization Program (UIIP).[13]

Despite the burden of influenza among the population and recommendations to get vaccinated, vaccination coverage was observed to decline from 2006 to 2014, especially among the high-risk groups, including older adults aged 65 and older and those with chronic medical conditions.[14] In 2019, only 34% of adults between the ages of 18 and 64 and 70% of older adults were vaccinated against seasonal influenza.[4] This, unfortunately, still falls short of the national influenza vaccination coverage goal of 80% for high-risk groups.[15] Several factors have been demonstrated to influence the uptake of influenza vaccine. This includes sociodemographic characteristics, psychological barriers, and contextual factors, which will be described in further detail in Chapter 2. Additionally, vaccine uptake can also be influenced by macro-level factors, such as policies, regional health promotional programs, and public health systems.[16]

In Canada, annual recommendations, policies, and administration of the seasonal influenza vaccine are led by several federal agencies, such as PHAC, NACI, and the Canadian Immunization Committee (CIC).[17] At the provincial and territorial level, the implementation of vaccine policies and programs in accordance with the national recommendation and regional community needs are performed by public health systems.[17] The structure of public health systems differ across provinces and territories.[18] Currently, only the province of Ontario maintained a decentralized public health system structure while the other provinces have moved on to a centralized/ regionalized structure.[19] This means that a large portion of power and responsibility falls on the local public health units (PHUs) to implement and deliver health promotion programs in accordance with the provincial guidelines, as well as the needs and preferences of their respective local population.[19]

1.2 History, Structure, and Role of Ontario Public Health Units

Public health can be defined as the science and art of protecting and improving the health and well-being of people.[20] This involves taking on a population approach to protect and promote the health and well-being of all, prevent injury and illnesses, and reduce health inequities via upstream interventions.[20] In Ontario, PHUs are responsible for upholding these principles, as well as organizing and delivering these services at the local level. Since passing the Public Health Act in 1873 and Health Protection and Promotion Act (HPPA) in 1983, a gradual increase of PHUs were established across the province to promote and protect the well-being of Ontarians.[21] Over the years, as the Ontario government underwent several restructurings and regrouping of regions and cities, the PHUs that were a part of these areas also merged.[21] Consequently, the number of PHUs decreased from 42 to 37 in 1998, 37 to 36 in 2005, 36 to 35 in 2018, and 35 to 34 in 2020 (**Figure 1.1.**).[20,21] This brings the total number of PHUs to 34 across seven Ontario health regions as of 2023 (**Figure 1.2.**).[21,22] Due to the availability of the funding data (exposure variable) collected for this study, it is important to note that a total of 36 and 35 PHUs were present in 2013 and 2018 respectively.

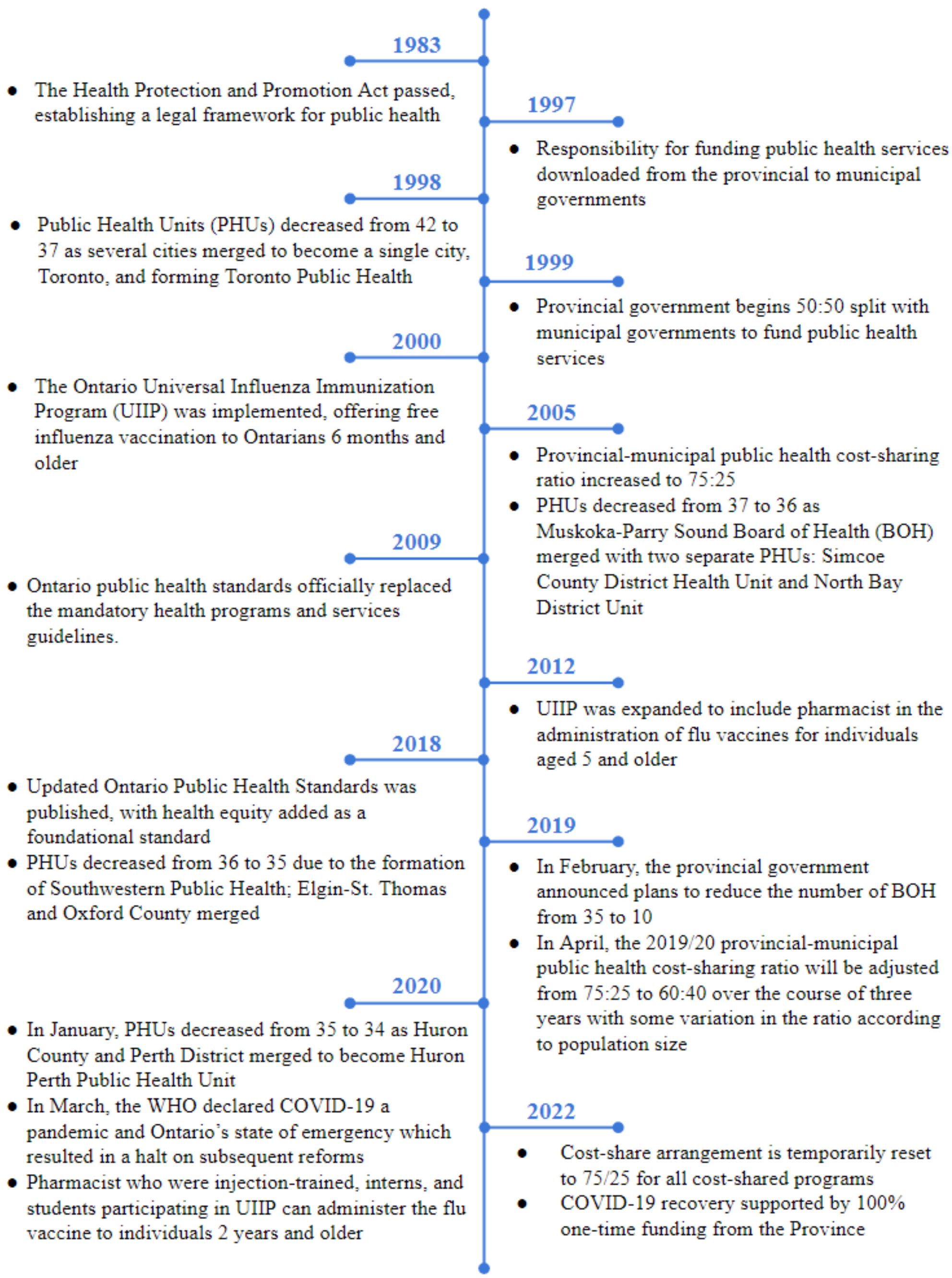

Figure 1.1. Timeline of proposed and enacted reforms influencing the implementation of the Universal Influenza Immunization Program (UIIP), number of public health units, and provincial funding structure for public health units from 1983 to 2022. (Figure adapted from Smith et al[21]; Sources: Smith et al[21], Association of Local Public Health Agencies (alPHa)[22,23], and Ontario Pharmacists Association[24].)

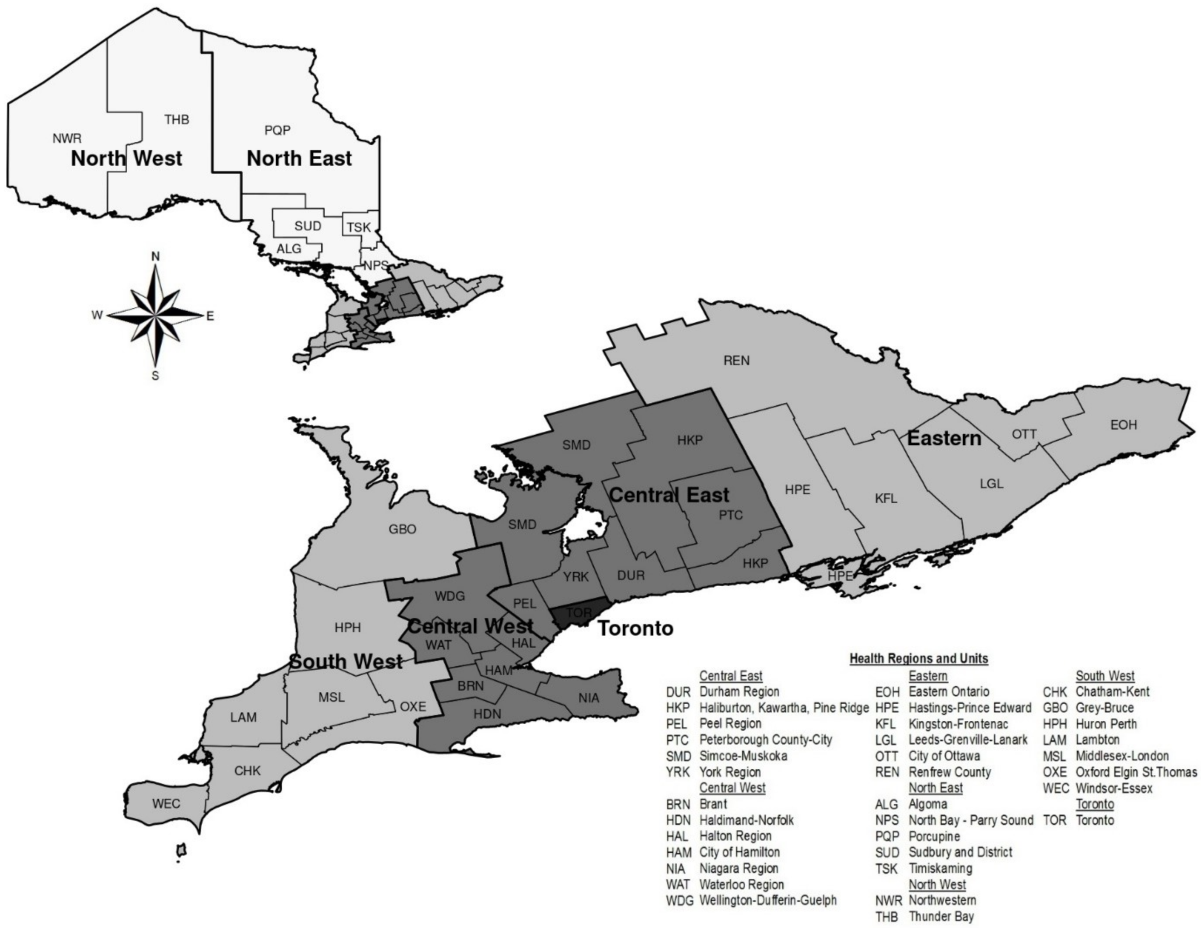

Figure 1.2. Map of Ontario presenting 34 Public Health Units across seven health regions in 2023. (Map created using Easy Maps Tool from Public Health Ontario[25] and adapted from alPHa[26]).

Depending on the region, the organizational structure of PHUs vary. Out of the 34 PHUs, 24 PHUs operate autonomously, six operate as part of the regional administration of municipalities, and four under municipal administrations.[21] As such, these PHUs have different governing bodies and organizational structures. Despite that, each PHU has their own head of operations, including Medical Officers of Health (MOH), Chief Executive Officer (CEO), Chief

Administrative Officer (CAO), commissioner, or general manger who oversees and manages the public health programs and services (**Figure A.3.**).[21] These head of operations then report directly to the Board of Health (BOH), whose responsibility is to govern PHUs by monitoring and ensuring that all programs and services are operating smoothly and are delivered in accordance with the Ontario Public Health Standards (OPHS).[20,21] Created by the Ministry of Health and Long-Term Care, [19] the OPHS describes the requirements and implementations of public health programs and services via foundational and program standards. In 2018, the OPHS's goal of improving and protecting the health and well-being of Ontarians was updated and complemented by reducing health inequities.[27] This was followed by the establishment of health equity as a foundational standard and the release of a companion document, the "Health Equity Guideline, 2018" to fully support and ensure that PHUs take on a health equity lens in the planning and delivery of their programs and services.[28] As described in the OPHS document, health equity refers to the ability for all people to reach their full potential for health without being disadvantaged by their sociodemographic background or other socially determined circumstances.[27,28] PHUs enable equitable opportunities for the health of their people by conducting population health assessments; identifying and engaging with priority populations; collaborating with different sectors to increase the reach of health promotional programs and services; and supporting healthy public policies.[28] Through the OPHS, PHUs are also required to fulfill three other foundational standards and nine program standards, of which includes "immunization".[20] The full list of foundational and program standards is listed in the appendix (**Figure A.4.**).

PHU as an organization consists of a wide range of public health service providers and program support staff in addition to the head of operations and BOH to keep the system running.

This includes PH nurses, dietitians, PH inspectors, health promoters, epidemiologists, policy advisors, and more.[29] Together, these public health professionals deliver public health programs and services in accordance with the OPHS. In terms of immunization, PHUs are responsible for managing vaccine inventories; conducting population health assessment to identify priority populations; ensuring that childhood immunizations are up to date by partnering with school and licensed child care facilities; monitoring trends of vaccine-preventable diseases; detect and manage potential outbreaks; and advocating for the importance and benefits of vaccines. [20] When it comes to influenza, PHUs promote influenza vaccine uptake and health equity by organizing influenza clinics to increase reach and access to priority populations; creating influenza campaigns and education resources to mitigate vaccine hesitancy; and working with the government to support and optimize the reach of the Universal Influenza Immunization Program (UIIP).[20,29]

1.3 PHUs, UIIP, and Pharmacists

The UIIP was initiated in 2000 as an effort to improve influenza vaccination coverage in Ontario; the first program of its kind in Canada.[30] Individuals aged six months and older can access free influenza vaccine via PHU clinics, health care providers, pharmacies, community health centres, and long-term care homes.[31] Since the implementation of this program, influenza vaccine coverage have been observed to increase from 18% to 36% among Ontarians aged 12 and older between 1996/97 and 2000/01.[11] The effectiveness of this program was further demonstrated by Polisena et al [32] and Sander et al.[32,33] According to their findings, when compared to other provinces, Ontario was associated with a higher likelihood of having the influenza vaccine and a decline in influenza-related mortality and health care utilization.[32,33] To support the UIIP, PHUs were primarily responsible for providing community clinics; promoting influenza vaccine uptake through campaigns; communicating with local health care providers about vaccine availability, eligibility, and UIIP requirements; and developing and implementing a vaccine distribution plan.[31,34] In 2012, the UIIP was expanded to include pharmacists in the administration of influenza vaccines to individuals aged 5 and older (**Figure 1.1.**).[24] In 2020, the government of Ontario further permitted injection-trained pharmacist, pharmacist interns, and pharmacist students to vaccinate individuals aged 2 and older.[24] As described by Alsabbagh et al[34] and Buchan et al[35], the addition of pharmacists in the administration of UIIP was beneficial as it improved overall accessibility through increased availability in service hours and proximity to pharmacies. More importantly, influenza vaccination coverage among Ontarians increased by about 448,000 from 2011/2012 to 2013/2014.[35] While this increase in coverage has led to an increased expenditure of $6.3 million by the Ontario government, it also saved $0.7 million in health care costs and $7.9 million in productivity costs.[35] Other provinces that have a universal funding policy in conjunction with a pharmacist-administered vaccination policy also observed an increase in influenza vaccine coverage.[36] At the time of study conducted by Buchan et al[36], Quebec and all three territories did not have a pharmacist-administered vaccination policy.

1.4 Funding Structure of PHUs

According to a systematic review that looked at public health systems as a potential factor in influencing population health, the author found that financial resources were critical to maintain an effective public health system.[37] Through funding, public health systems can expand their work capacity, improve their internal performance, and enable timely and efficient delivery of health promotion programs and services.[37] Similarly, in a recent survey examining components of public health system performance and health equity work in Ontario, the majority of the BOHs described having sufficient financial resources as an enabler to support capacity building, workforce development, and to advance their work in health equity.[38] In Ontario, to ensure that all the public health professionals, programs, and services were supported and carried out, PHUs receive funding from several sources. This includes funding from the federal government, the Ministry, municipalities, one-time funding applications, and other revenue.[21] For this study, due to the availability of the exposure data, only provincial funding (i.e., funding from the Ministry) for mandatory programs will be examined. Currently, the ministry provides ongoing funding to PHUs for the delivery of mandatory programs – which "refers to the public health programs and services that public health units must provide to their local communities in accordance with the HPPA, OPHS, and Organizational Standards."[39] This includes funding for the immunization standard, of which UIIP and all other influenza-related programs and services are a part of. Funding to PHUs for mandatory and related programs are based on a calendar year.[39] After the BOHs submit their operating budget in March, the Ministry will review the budget submission and provide PHUs with the necessary resources to operate and deliver their programs and services.[39] In 1999, the Ministry began a 50:50 split with municipal governments to provide funding for the mandatory programs (**Figure 1.1.**).[21] This cost-sharing ratio was then increased to 75:25 in 2005 as the Ministry decided to increase their contribution to strengthen the resource base of public health.[21] By April, 2019, this cost-sharing ratio would again change as the Ministry announced their decision to reduce the cost-sharing ratio from 75:25 to 60:40 over the course of three years from 2019/2020 to 2022/2023.[21] While the reason for this decision was not clear, it may be related to the discussion in February, 2019 by the Ministry around the possibility of reducing the number of PHUs from 35 to 10.[21] However, due to the sudden declaration of the COVID-19 pandemic in 2020, the motion to decrease the mandatory programs funding was temporarily paused to provide PHUs with sufficient funds to mitigate the pandemic.[21] The 75:25 funding split between the Ministry and municipal governments for PHU mandatory programs thus remains throughout the study period of this thesis.

1.5 Research Question, Study Objectives, and Hypothesis

To support and sustain the work of PHUs in preventing infectious diseases, promoting health, and reducing health inequities, funding is therefore essential. Previous studies have demonstrated the protective effect of public health funding on population health outcomes. For example, in the United States, a 10% increase in public health funding is associated with a 20% reduction in black and white maternal mortality gap, a decrease of all-cause mortality deaths by 9.1 deaths per 100,000, and a decrease in infant mortality by 0.9%.[40–42] However, few if any have looked at public health funding per capita and its relationship with influenza vaccine uptake in Canada. To understand the impact of public health funding on influenza vaccination, this thesis attempts to answer the research question: Is PHU funding per capita associated with the uptake of influenza vaccine among individuals aged 12 and older who are living in Ontario? Therefore, the objectives of this thesis is to 1) estimate the association between PHU funding per capita and influenza vaccine uptake among individuals aged 12 and older in Ontario, Canada in 2013/14 and 2018/19; and 2) determine whether PHU funding per capita decreases vaccine uptake inequity by examining whether any observed associations were heterogeneous across household income groups, gender, and age categories in 2013/14 and in 2018/19. Based on the results of the preliminary literature review which demonstrated the protective effect of public health funding, the study hypotheses include: 1) PHUs that have a higher funding per capita are more likely to have a higher number of individuals who are vaccinated against influenza compared to PHUs that have a lower funding per capita; and 2) PHU funding per capita will decrease health inequities that are associated with the uptake of the influenza vaccine.

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2. Background

The second chapter of this thesis provides an overview of risk factors associated with influenza vaccine uptake at the individual- and area-level. In conjunction with the influence of the social determinants of health, health inequities related to vaccines will also be discussed. Lastly, this chapter will describe the definition of public health funding and its role in reducing vaccine inequities.

2.1 Determinants of Seasonal Influenza Vaccine Uptake

The determinants of influenza vaccination have been well examined. These studies covered a wide range of individual- and structural-level determinants across different influenza vaccination outcomes (e.g. non-vaccination, vaccination uptake, vaccination coverage, and vaccination behaviour, such as acceptance, hesitancy, confidence, and intention) and population groups (e.g. general public, adults, older adults, adolescents, high-risk groups, health care providers, hard-to-reach populations, and across different ethnicities). Moreover, due to the recent influenza pandemic (H1N1) in 2009, some of these studies have also focused on H1N1 as the influenza of interest, while others continued to look at seasonal influenza, and some chose to examine a combination of both. To match the study population and objective of this thesis, this section will only discuss literature covering seasonal influenza vaccination outcomes among individuals aged 12 and older.

It is well known that health is more than just the absence or presence of diseases. Health is complex and can be influenced by multiple factors. To properly evaluate and understand the risk factors of influenza vaccine uptake or hesitancy, many researchers utilized different theoretical models and frameworks, among which are the social determinants of health (SDOH) and health belief model. According to the SDOH, health is primarily shaped by our social, cultural, economic, and environmental conditions.[1] For example, SDOH, such as gender, race, age, income, education, housing, and health services may positively or negatively influence a person's susceptibility to influenza, as well as their behaviour and intention to vaccinate.[1] On the other hand, the health belief model theorizes that an individual's health behaviour can be examined through their understanding and beliefs about their health and diseases/illnesses.[43] This includes perceived susceptibility, perceived severity, perceived benefits, cues to action, and self-efficacy.[2] To help explain these concepts better, the social ecological model will be used. This model incorporates both the SDOH and health belief model, and organizes them into different levels of individual, interpersonal, organizational, community, and public policy. To ensure that the risk factors identified in the literature were appropriately assigned to the levels of the social ecological model, the study by Kumar et al[3] on "The social ecological model as a framework for influenza vaccine acceptance" will be used as a guide.

2.1.1 Individual Level

Starting at the inner-most level of the social ecological model, the individual-level looks at an individual's sociodemographic characteristics, as well as their knowledge, perception, and attitude towards influenza as a disease and influenza vaccination.[3]

Sociodemographic Characteristics

Some of the most studied sociodemographic characteristics that were also a part of the social determinants of health, include age, gender, ethnic origin/ immigration status, household income, marital status/ living arrangements, and education.[3] Among these determinants, age was shown to have a mostly consistent and strong association with influenza vaccine uptake.[4-9] For example, in a systematic review conducted by Yeung et al[4], several studies have demonstrated that increasing age was associated with an increased uptake of seasonal influenza vaccine among

European and Asian adult populations. Similarly, two Canadian studies that looked at age in groups of 18 to 44, 45 to 64, and 65 and older, found that within each of the three age groups, the youngest people were less likely to get the seasonal influenza vaccine in comparison to the older people.[6,7] A possible reason for these observations were that younger individuals were more likely to have a good perception of their own health and thus do not feel the need to be vaccinated against influenza.[7]

Gender is another risk factor that was often examined across studies. However, research on gender revealed mixed results. For example, according to a systematic review by Schmid et al[5], females compared to males were less likely to vaccinate against influenza in some studies, more likely to vaccinate in some studies, and were inconclusive in other studies. The same findings were noted in another systematic review by Yeung et al[4] who focused on seasonal influenza vaccine uptake. That said, across several Canadian studies, females were reported to be more likely to vaccinate compared to males due to the more frequent visits to preventative health services.[6,10,11]

Socioeconomic status (SES), commonly measured by an individual's income, education, and occupation is another key predictor for influenza and influenza vaccination.[1,12] According to Zipfel et al[13] and Roy et al[6], individuals with low SES tend to disproportionately bear the burden of the influenza infection due to lower access to social and healthcare support, as well as lesser intentions to participate in preventative measures. As revealed by a systematic review, more than 50% of the literature examined demonstrated an association between higher levels of SES and higher levels of influenza vaccination.[12] However, the authors also stated that the SES measures used were different across studies, thus making it difficult to formally conclude the relationship between SES and influenza vaccination.[12] Among the components of SES, household income and education respectively were also widely studied as risk factors of influenza vaccine uptake. Higher levels of household income, for example, were found to be associated with increased likelihood of vaccination in a study with Canadians aged 12 and older, as well as a systematic review focusing on older adults.[8,10] This pattern was also observed with education, where higher levels of education were often associated with increased likelihood of getting the influenza vaccine.[3,7,8,10] Although, the relationship between education and influenza vaccine uptake was also reported to be inconsistent in a systematic review looking at adults and seasonal influenza vaccination.[4]

Studies examining ethnic origins or immigration status as predictors were less consistent. While some studies demonstrated that White people were more likely to be vaccinated against influenza, others found that ethnic groups (e.g. Southeast Asian and Filipinos living in Canada and Hispanics and Blacks in the US) were more likely to receive the influenza vaccine compared to White individuals.[3,5,14] Further, in Canada, studies have shown that individuals who were born outside of Canada were less likely to be vaccinated.[6,7]

Intrapersonal Characteristics

Attitudes and perceptions towards influenza and influenza vaccine are also common risk factors. Drawing from the health belief model, an individual's level of knowledge about influenza and the vaccine, perceived susceptibility towards acquiring influenza, and perception of vaccine efficacy, vaccine safety, and adverse events were some of the intrapersonal characteristics commonly studied. In terms of level of knowledge, both Yeung et al[4] and Schmid et al[5] reported that increased levels of knowledge about the vaccine was associated with increased likelihood of getting vaccinated in their systematic reviews. That being said, when levels of knowledge were compared with an individual's perception on vaccine efficacy/ safety/

adverse events, it was less influential toward vaccination behaviour.[4] Individuals who have not experienced previous adverse events from influenza vaccines do not view vaccines as a concern, while those who do not believe in the effectiveness of vaccines were less likely to be vaccinated.[4,5] It was also found that perceived health impact or susceptibility towards influenza were associated with an increased intention to get the vaccine.[4,5] Unfavourable view towards these perceptions were also found to be commonly described as one of the reasons for not getting the influenza vaccine.[7]

Psychological and Physical Characteristics

According to a systematic review, many studies that looked at health perception found that perceiving one's health as good was associated with a decreased likelihood of vaccination.[5,10] This finding is similar to a more recent study in Canada where individuals aged 65 and older without chronic medical conditions (CMC) and individuals aged 18 to 64 with CMC who perceived their health as excellent were less likely to be vaccinated.[6] The CMC is another predictor of vaccination as it increases the risk of severe complications from influenza.[15] Based on several Canadian studies, CMC often included the presence of asthma, chronic obstructive pulmonary disease (COPD), heart disease, stroke, diabetes, or cancer.[8,10,15] According to several studies, the presence of at least one CMC was consistently associated with an increased likelihood of vaccination compared to individuals with no CMC.[4,6,8,10]

2.1.2 Interpersonal Level

The interpersonal level looks at how an individual's relationships with their family, friends, and surrounding social network or norm can influence their health.[3] Studies examining this relationship were mostly consistent wherein individuals who were advised by their close friends or relatives were associated with an increased acceptance of the influenza vaccine.[4,5]

2.1.3 Organizational Level

Organizations, such as schools, hospitals, workplaces, and public health clinics can also play a role in influenza vaccine uptake.[3] This can happen in the form of direct influence via a doctor's recommendation or through posters/pamphlets present in these organizations with information about influenza and vaccines; or in the form of indirect influence through the presence of a regular health care provider/ family doctor or access to a healthcare system.[3] Based on the literature, doctor's advice was often found to be consistently associated with an increased uptake of the influenza vaccine.[3-5] Similarly, individuals who reported a recent visit to a medical doctor or having a regular health care provider were associated with a higher likelihood of vaccinating against influenza.[6,7,8,10] Individuals who interacted less frequently with the healthcare systems (e.g. fewer doctor visits or hospitalization) had a lower likelihood of vaccination.[5,8,10]

2.1.4 Community Level

In terms of vaccination, Kumar et al[3] describes the community level as the social context of risk perception, such as the presence of a disease in a community. An example of this would be seasonal epidemics of influenza during winter months or a global scale outbreak, such as the pandemic (H1N1) influenza in 2009, which resulted in severe mortalities and morbidities.[16] Interestingly, post-pandemic influenza vaccination rates were low in many of the studies that examined the impact of post-pandemic influenza on vaccine coverage.[4,7]

2.1.5 Public Policy Level

At the public policy level, influenza vaccine uptake may be influenced by governmental policies and plans related to the cost, access, and distribution of the vaccine. An example of this is the presence of a universal immunization program that offers free vaccination to either the whole population or to a certain subgroup. To date, all Canadian provinces and territories provide free influenza vaccines to individuals aged 6 months and older under a universal immunization program.[17] The implementation of a universal publicly funded vaccines program have been found to be associated with an increased uptake of the vaccine.[18,19] When pharmacist-administration policies were added to universal immunization plan to improve access to influenza vaccines, the likelihood of getting vaccinated and vaccine coverage were reported to increase.[20]

Material deprivation is another risk factor that influences influenza vaccine uptake. As described by Matheson et al[21], material deprivation "refers to the inability for individuals and communities to access and attain basic material needs". This involves measuring neighbourhood level SES, housing quality, and family structures.[44] According to Schmid et al[5], three articles demonstrating this relationship revealed that people living in the most socioeconomically deprived areas were associated with a decreased likelihood of getting the vaccine compared to people living in wealthier neighbourhoods. This relationship was also observed in a Canadian study where neighbourhoods with higher percentages of material deprivation were associated with a 7% decrease in the odds of neighbourhood vaccination.[11]

Additionally, individuals who reside in rural areas were also significantly associated with non-vaccination among adults with no chronic medical conditions and individuals 65+ years.[6] This is due to lower numbers of health services present, which makes it difficult for people to access the influenza vaccine.[6]

2.2 Public Health Funding and Vaccine Inequity

The combination of certain risk factors listed above may also present as a barrier to influenza vaccine uptake in the form of vaccine inequity. According to the World Health Organization (WHO), health inequity can be described as the "systematic differences in the health status of different population groups"[22] that are unfair and avoidable, "arising from the social conditions in which people are born, grow, live, work, and age."[23] In the context of vaccination, this means that inequity in vaccination refers to the unfair and "avoidable differences in vaccine coverage between population groups that arise due to barriers to vaccination among disadvantaged groups that are not addressed through policies, structures, governance, or program implementation."[24] Unfortunately, many studies have demonstrated the existence of vaccine inequity, where disparities in influenza vaccine uptake were often associated with the social determinants of health. In other words, those who were less educated, had low income, marginalized, immigrants, lived in a rural area, and/or have reduced access to health care facilities have a lower influenza vaccine coverage.[5,7,25-28]

According to Solar & Irwin[29], addressing the unequal distribution of the social determinants of health that contributed to health inequities is one step towards achieving social justice and health equity. Based on the WHO's Commission on Social Determinants of Health (CSDH) conceptual framework, public health systems can be viewed as a structural determinant or a "social determinant of health inequities".[29] This means that public health can play a role in addressing and reducing inequities in vaccination.[24] Public health systems can do so by monitoring and collecting health equity data related to influenza vaccine coverage, implement vaccination outreach programs that are equity-focused, and ensure fair and inclusive infrastructures, policies, and resources for all.[24] Such as the case of UIIP, public health systems play a crucial role in turning a written policy into action by implementing the program, managing vaccine inventory, and developing a vaccine distribution plan.

As briefly mentioned in Chapter 1, the Ontario Ministry released a "Health Equity Guideline, 2018" as a companion document to the Ontario Public Health Standards (OPHS).[30]

The purpose of this document was to guide Boards of Health (BOH) in their implementation of health equity systematically across all programs and services at every level of intervention, including upstream, midstream, and downstream interventions.[30] According to the guidebook, BOHs can do so by assessing and reporting on population health, modifying and orienting public health interventions, engaging in multi-sectoral collaboration, and advancing healthy public policies.[30] Under the immunization standard, PHUs also aim to reduce or eliminate the burden of vaccine preventable diseases by improving the uptake of provincially funded vaccines among Ontarians.[31] To achieve this, PHUs were encouraged to improve access to undeserved and priority populations, as well as increase and improve public confidence and knowledge in immunization by engaging with community partners.[30,31]

To support the role of public health in reducing vaccine inequities and enable the delivery of upstream interventions, funding for public health is therefore crucial.[24,32] In Canada, the definition of public health spending refers to government expenditures on disease prevention, health promotion activities, and the social determinants of health.[33,34] Based on this definition, numerous studies in the United States and United Kingdom have explored and demonstrated the protective effect of public health funding on population health outcomes, such as all-cause mortality, infant mortality rates, and vaccine preventable diseases.[35-39] For example, a 10% increase in public health funding in the United States was associated with a 20% reduction in black and white maternal mortality gap, a decrease of all-cause mortality deaths by 9.1 deaths per 100,000, and a decrease in infant mortality by 0.9%.[37,40,41] On the contrary, a divestment in public health limits the capacity of public health system to function properly, thus, resulting in the reduction of public health programs that target a wider determinants of health, which may lead to an increase in health inequities.[32]

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3. Literature Review of the Relationship between Public Health Funding and Vaccination

This chapter covers the search for peer-reviewed literature examining the association between public health funding and population health outcomes, including vaccination uptake. During the development of this thesis topic, a preliminary literature review on public health funding and influenza vaccine uptake was performed. However, due to the lack of articles, the search terms were broadened to include vaccination uptake for all types of vaccine-preventable diseases. Additionally, the relationship between public health funding and all forms of population health conditions as the health outcome was also examined to further understand the impact of public health funding. Based on the articles selected, the overall findings, study characteristics, statistical methods used, and limitations/gaps were presented and discussed.

3.1 Search Strategy

Four databases, including PubMed, PsycINFO, Medline, and Google Scholar were used. In these databases, to identify articles on public health funding and population health outcomes, search terms, such as (*"public health", government*, health authorit*, state, federal*) and (*expenditure*, spending, fund*, investment*, divestment*, budget*)* and (*population health, community health, health outcome*) were applied. Next, to capture studies on public health funding and vaccination uptake, similar search terms for the exposure (public health funding) were used while search terms for the outcome were modified to include (*vaccin*, immunization**) and (*uptake, coverage, rate*). Additionally, articles listed in the reference list of relevant articles and articles that cited or were related to the relevant articles were manually screened. During a preliminary literature search of this topic, a systematic review on public health spending and population health outcomes by Singh,[1] which covered papers from 1998 to

2012 was found. While Singh's paper will be included as one of the articles identified, this literature search will focus on articles that were published in 2013 and onward. Further criteria were also applied to select for relevant articles:

Inclusion Criteria

- Articles published between the year 2013 and 2023
- Peer-reviewed articles
- Articles written in English
- Articles that have public health funding or related terminologies as the main exposure of interest
- The definition of "public health funding" examined in the articles must include funding received by or spent by a public health system, whose goal is to prevent diseases, develop health promotion activities, and address the social determinants of health at the population level[2,3]
- The outcomes assessed in the articles must be related to health of the individual or population
- Articles from Canada or countries similar to Canada (i.e., OECD countries)

Exclusion Criteria

- Studies that focus on the evaluation, cost-effectiveness, and return-of-investment of programs
- Studies that focus on funding or expenditure of health care services or social services

3.2 Study Characteristics

Based on the selection criteria, a total of 21 studies were extracted and presented in two separate summary tables: **Table 3.1.,** which includes articles on the relationship between public health funding and vaccination uptake; and, **Table 3.2.,** which focuses on public health funding and all forms of population health outcomes. These tables include information, such as the author, year of publication, location of the study, timeline of the study data examined, sample size, unit of analysis, study design, statistical methods, main exposure, health outcomes, individual- and area-level covariates, and key findings.

Of the 21 studies identified, the majority of studies (n=15)[1,4-17] were set in the United States of America (US) while others were conducted in Italy (n=1)[18] and in England (n=3)[19-21]. Two studies covered multiple countries from the United Kingdom (UK) (n=1)[22] and from the European Union (n=1)[23]. In terms of the study design used, all but one study[5] were ecological. Due to this ecological study design, the sample size and unit of analysis ranged from county-level local health departments (LHD) (n=14)[4,6-13,15,19-22] to state-level public health departments (n=6)[5,14,16-18,23]. As for the one cross-sectional study design, the sample population of this study consisted of adults 18 years and older living in the US between the year 2009 to 2010.[5]

Regarding the exposure of interest, the majority of the studies looked at per capita or total expenditure by public health departments (n=13)[5,9-16,18,19,22,23]. Some articles were more specific and examined targeted per capita or total spending on specific departments or programs within the public health departments (n=6)[4,6,8,17,20,21]. For example, per capita expenditure of the LHD's food safety and sanitation department[6] or county-level public health spending on pregnancy-related programs[8]. One article looked at both total public health spending and targeted spending.[7] Additionally, there were two articles that also looked at the spillover effects of public health spending in neighbouring counties as an exposure of interest.[11,12] As for the health outcome measured, only 3 of the 21 articles focused on vaccine uptake.[4,5,18] These measures include toddler immunization completeness,[4] mumps, pertussis, and rubella (MMR) vaccine coverage,[18] and the intent to receive the H1N1 (swine flu) vaccine[5]. Among the non-vaccine-related studies, the population health outcomes examined include chronic and infectious disease prevalence and rates, mortality and morbidity measures, case detection rates, and the ability to reduce outbreaks.[6-17,19-23]

3.2 Study results

Relationship between Public Health Funding and Vaccination Uptake

Among the three articles that examined the association between public health funding and vaccine uptake, two studies found that per capita public health spending was associated with an increased odds for vaccine uptake.[5,18] Specifically, Zhao and Bishai[5] who conducted a cross-sectional study in the US, found that an increase in state-level per capita public health spending was associated with an increase in the intent to receive the H1N1 vaccine among adults. Similarly, a repeated cross-sectional study conducted in Italy found that a 1% reduction of regional-level per capita public health spending was associated with 0.5% decrease in MMR coverage while adjusting for the year.[18] The remaining study by Bekemeier et al[4], who looked at targeted county-level per capita LHD expenditure on immunization reported that there was no association between higher per capita expenditure and toddler vaccination completeness in the US.

Relationship between Public Health Funding and Other Population Health Outcomes

Similar to the findings described above, studies that investigated the association between public health funding and non-vaccine-related population health outcomes were mostly positive, however, some revealed mix results. Nonetheless, a vast majority of these studies (n=12)[6-9,11,12,14,16,17,21-23] demonstrated that public health funding was beneficial to population health. Among studies that looked at targeted public health spending, 5 out of 6 of these studies found that increased targeted county/ local level public health funding was associated with improved health outcomes, such as a reduction in the incidence of some enteric diseases, infant mortality rates, maternal mortality rates among Black mothers, under-18 conception rates, and rate of some sexually transmitted diseases.[6-8,17,21] Liu et al[20] was the only study that found no association between targeted public health funding and childhood obesity in England. Besides that, a total of 8 articles looked at aggregate local public health department per capita.[9-13,15,19,22] Among these articles, a large portion (n=5) found that aggregated public health spending was associated with improved population health outcomes.[9,11,12,15,22] Two studies, on the other hand, found no association.[10,19] For example, Elliot et al[10] found that public health spending had no effect on decreasing obesity prevalence, diabetes prevalence, and sexually transmitted infections in the US. Acharya et al[19] also found no association between local public health spending and decreasing the speed of COVID-19 outbreaks in England. Interestingly, the one remaining longitudinal study conducted across Georgia counties in the US looked at local per capita funding and found results that were unlike any of the previous studies discussed.[13] Findings from this study showed that increased county level public health spending was associated with increased mortality due to early death and heart disease, suggesting a more complex relationship with public health funding and population health outcomes may be at play.[13] Lastly, 4 studies looked at the relationship between per capita public health spending and population health outcomes at the state-level.[14,16,18,23] All 4 studies showed that an increase in government expenditure on public health services were associated with a decreased state-level infant, neonatal, and post-neonatal mortality rates; a decline in state-level mumps and rubella incidence; a decreased rate of state-level gonorrhea and chlamydia; and a decline in Tuberculosis case detection rates as government expenditure on public health services declined.[14,16,18,23]

3.3 Discussion

Overall, despite the lack of literature examining the relationship of public health funding and population health outcomes (as well as vaccination), public health funding was found to largely benefit population health. That said, there were also several articles that found no association between public health spending and population health outcomes; and one article found an inverse association of public health spending and population health.[13] Several explanations were discussed in these papers to determine the presence of these mixed results. This includes the different methodologies that were employed across studies, such as the unit of analysis measured (local, state, and individual level); research designs (ecological, longitudinal, cross-sectional); location and time of study; and using different statistical methods (time series, panel design, fixed effect) to account for the lag effect between public health spending and the health outcome.[7,10,13,15] Furthermore, there also exists factors that may be difficult to adjust for. This includes the source of funding data; low data accuracy and reliability; the lack of available and comparable public health funding across the years; the presence of reverse caution – where poor health outcomes may lead to higher public health spending; the presence of potential sources of endogeneity of public health spending; the utilization of aggregated funding data; and trends associated with certain time periods.[4,7,10,13,14,16,18] Other limitations that were reported include selection bias due to the low response rate of the surveys[5] and the nature of public health interventions which can take a long time before its effects can be seen.[7,13,15]

Based on the overall findings of this literature review, the majority of the studies were conducted in the US, European Union, and United Kingdom, with none conducted in the context of Canada. The majority of these studies also only examined health outcomes at an ecological level. Additionally, no studies on public health funding and influenza vaccine uptake were found. The paper by Zhao et al[5] was the closest but focused on the pandemic H1N1 influenza rather than seasonal influenza; and examined the intention to get vaccinated against the H1N1 influenza rather than the action of getting vaccinated. This thesis therefore aims to address this gap in the literature by examining the impact of local public health funding per capita and influenza vaccine uptake at the individual level in the province of Ontario, Canada.

Table 3.1. Summary of key findings from the literature review on the relationship between public health funding and vaccination (n=3).

First Author (Year)	Location, Sample, Timeline, Study design	Statistical Method	Unit of Analysis/ Relevant Funding Level	Health Outcome	Covariates	Key Findings
Bekemeir et al. (2017)[4]	USA 159 local jurisdictions across Florida, New York, and Washington (2000-2010) Ecological (2011) & longitudinal (2000-2010)	Multivariate regression; stratified by poverty level	County-level Annual per capita local health departments immunization-related expenditures	Jurisdiction-level rate of toddler immunization completeness (ecological) Annual jurisdiction-level pertussis incidence rates (longitudinal) Infant deaths per 1000 live births, deaths per 100,000 population from influenza, cancer, heart disease, diabetes, and total deaths per 100,000 population	**Area-level:**: Total population size, rurality, % black residents, % Hispanics residents, % residents <5 yrs and >65 yrs, social disadvantage index **LHD-level:** Led by clinician, presence of other childhood immunization services, LHD's approach to service delivery	No association between LHD immunization expenditures and toddler immunization completeness and pertussis incidence rates
Toffolutti et al. (2018)[18]	Italy 20 regions (2000-2014) Ecological	Multivariate & fixed effects model	Regional-level Annual per capita public health expenditure	Regional-level mumps, pertussis, and rubella (MMR) vaccine coverage rates at 24 months	Controlled for year and region	1% reduction in per capita public health expenditure was associated with a decrease of 0.5% points (95% CI: 0.36-0.65) in MMR coverage, adjusting for time and regional-specific time trends

Table 3.1. Continued

First author (year)	Location, Sample, Timeline, Study design	Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Zhao et al. (2022)[5]	USA 56,656 adults (18+) across all 50 states and DC (2009-2010) Cross-sectional	Logistic regression; Mediation analysis: Doctor's recommendation, concern about H1N1	State-level Per capita public health spending	Intent to receive H1N1 vaccine	**Area-level:** state's political orientation, H1N1 case rate, death rate **Individual-level:** Age, education, household income, healthcare worker, chronic condition, close contact with child	Positive association between public health spending and intent to vaccinate

Table 3.2. Summary of key findings from the literature review examining the relationship between public health funding and population health outcomes (n=18).

First author (year)	Location, Sample, Timeline, Study design	Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Acharya et al. (2021)[19]	England 136 public health departments at upper tier local areas (UTLAs) (2019 and March-July 2020) Ecological	Survival models and ordinary least squares	Local-level Public health expenditure per capita in 2019	Number of days between a UTLA's 10th case of COVID-19 and the day when new cases per 100,000 peaked and began to decline	**Area-level:** Median household income, % population experiencing fuel poverty, % of unemployment, rate of housing cost to income, population density, % under 18 population, % over 65 population, and % feeling or experiencing social isolation among adult caregivers or care receivers	There is no statistically significant association between local public health expenditure and the speed of control of COVID-19. However, overall public expenditure allocated to improve local areas helped reduce time to reach peak
Bekemeier et al. (2015)[6]	USA 778 LHDs in Washington and New York (2000-2010) Ecological	Multivariate panel time-series	County-level Local health departments' food safety and sanitation per capita expenditure	Enteric disease rates (7 most commonly notifiable in NYC and WA)	**Area-level:** High social disadvantage, % of foreign-born residents, % of children aged 0-4 years, number of per capita food and drink establishments, county area classification, high social disadvantage index, consumer price index	Higher LHD expenditures on food safety and sanitation were associated with a significant reduction in the incidence of salmonellosis in Washington and a lower incidence of cryptosporidiosis in New York, while controlling for other factors

Table 3.2. Continued

First author (year)	Location, Sample, Timeline, Study design	Study Design, Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Bernet et al. (2018)[7]	USA 67 Florida counties (2001-2014) Ecological, longitudinal	Ordinary Least Squares (OLS) and Generalized Method of Moments (GMM)	County-level Total public health spending and targeted spending on infant-related programs	Infant mortality per 1000 live births	**Area-level:** % population at child-bearing age 15-44, % non-white population, % Hispanic population, % population age 65 and older, unemployment rate, poverty rate, per capita income, access to healthcare services, availability of physicians and hospital beds	A 10% increase in targeted public health spending per infant is associated with a 2.07% decrease in infant mortality rates and a 4% reduction of infant mortality among blacks
Bernet et al. (2020)[8]	USA 67 Florida counties (2001-2014) Ecological, longitudinal	Ordinary Least Squares (OLS) and Generalized Method of Moments (GMM)	County-level Public health spending on pregnancy-related programs	Maternal mortality rates (MMR): maternal deaths per 100,000 live births	**Area-level:** % of non-white population, % Hispanic population, % population at child-bearing age 15 to 44, % population age 65 and older, unemployment rate, personal income per capita, % of births covered by Medicaid, number of physicians, and hospital beds per 100,000 people	A 10% increase in program spending is associated with a 13.5% decrease in MMR among black mothers and a 20.0% reduction in black-white disparities, while adjusted for income, unemployment, and access to care

Table 3.2. Continued

First author (year)	Location, Sample, Timeline, Study design	Study Design, Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Brown (2014)[9]	USA 56 California counties (2001-2008) Ecological	Dynamic panel models; Koyck distributed lag model and Lewbel Instrumental variables	County-level Public health expenditures	Crude all-cause mortality rates per 100,000	**Area-level:** Price of medical care, income, racial/ethnic structure, age, unemployment rate, population density, crime rate, and education level	An additional 10% public health expenditure per capita reduces all-cause mortality by 9.1 deaths per 100,000. In the long run, annual number of lives saved by the presence of county departments of public health in California is estimated to be approximately 27,000 (26,937 lives, 95% CI: 11,963, 41,911)
Elliott et al. (2023)[10]	USA Local Health Departments (2010, 2013, 2016, and 2019) Ecological	Multivariate linear regression, pooled ordinary least squares, panel data with fixed effects	County-level Per capita LHD expenditures	Obesity prevalence, sexually transmitted infections, diabetes prevalence, and HIV prevalence	**Area-level:** % of uninsured adults, primary care physicians per 100,000 residents, preventable hospital stays per 100,000 population, % of high school graduation, % unemployment, % children in poverty, population size, % age, % race, % ethnicity, and median household income	Increased LHD expenditures per capita were not associated with any of the population health outcomes. Results from the 1- and 2-year lag structure revealed the same results

Table 3.2. Continued

First author (year)	Location, Sample, Timeline, Study design	Study Design, Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Gallet (2017)[11]	USA California counties (2003-2012) Ecological	Multivariate regression; Ordinary least square	County-level Per capita own-county public health spending and spillover effects of public health spending in nearby counties	Rates of gonorrhea and syphilis	**Area-level:** Number of physicians per 1000 population, county unemployment rate, % of Black, Asian, and Hispanic population, % young population (ages15-19 and 20-24), % older population (age 65 and older), presence of campus in county, county cancer mortality rate, heart disease mortality rate, county foreclosure rate, and % voters registered democrat	A $1 increase in per capita public health spending is associated with a 0.30% decrease in gonorrhea rate and 0.60% decrease in syphilis rate; spillover effects were also associated with own-county public health spending, where increases in public health spending in neighboring counties reduces a county's STD rate

Table 3.2. Continued

First author (year)	Location, Sample, Timeline, Study design	Study Design, Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Gallet et al. (2016)[12]	USA 37 California counties (1991-2012) Ecological	Multiple linear regression	County-level Per capita own-county public health spending and the average of per capita public health spending of neighboring counties	Infant and under-five mortality rate	**Area-level:** Unemployment rate, number of physicians per 1000 population, population density, % of non-white population, 1-year lagged mortality rate	A 10% increase in own-county public health spending decreases infant (under 5) mortality by 0.90 (0.50) %. If both own- and neighbour-county public health spending increases by 10%, in the short-run, infant mortality (under 5) will decrease by 1.80 (1.30) %. In the long run, spending elasticity associated with own-county and neighbour-county PH spending is -0.24 for infant mortality

Table 3.2. Continued

First author (year)	Location, Sample, Timeline, Study design	Study Design, Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Liu et al. (2019)[20]	England 150 upper tier and single tier local authorities (2013/14 and 2016/17) Ecological	Random effects negative binomial	Local-level 2013/14 Local authority per capita actual net current expenditure on childhood obesity, physical activity, and children 5-9 years public health program	Proportion of children in each of the school years who were overweight or obese in 2016/17	**Area-level:** Gender, rurality, deprivation, ethnicity, access to fast-food outlets, and type of local authority	Level of spending in 2013/14 was not significantly associated with lower levels of obesity in children aged 4-5 and aged 10-11 in 2016/17

Table 3.2. Continued

First author (year)	Location, Sample, Timeline, Study design	Study Design, Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Martin et al. (2020)[22]	UK 150 unitary and upper tier local authorities (2013-2014) Cross-sectional	Instrumental variable regression	Local-level Health care and public health expenditure	Quality-adjusted life years (QALY)	**Area-level:** Age index, input price index, distance from target index, % of owner-occupied households, % of foreign-born residence, % of white population, % of population providing unpaid care, % of population aged 16-74 with no qualifications, % of households that are owner occupied, % of households without a care, % of households that are one pensioner households, % of lone parent households with dependent children, % of population aged 16-74 that are permanently sick, % of those aged 16-74 that are long-term unemployed, % of those aged 16-74 working in agriculture, % of those aged 16-74 in managerial and professional occupations, and multiple deprivation index	A 1% increase in public health expenditure in 2013/14 is associated with 0.115% decline in the number of life years lost. An additional £1billion spent on public health will generate 206,398 QALYs and an additional £1 billion spent on healthcare will generate 67,060 QALYs

Table 3.2. Continued

First author (year)	Location, Sample, Timeline, Study design	Study Design, Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Marton et al. (2015)[13]	USA 159 Georgia counties (2000-2011) Ecological study	Koyck distributed lag model, standard 2-stage least squares (2SLSs)	County-level Allocation of general grant-in-aid (GGIA) funds to Georgia counties	Mortality (number of infant deaths, early deaths, and heart disease deaths per 1000 residents) and morbidity (number of cancer, heart disease, asthma, and diabetes cases per 1000 residents) outcomes per capita	**Area-level:** Per capita income, county unemployment rate, number of physicians per capita, county age distribution, county racial/ ethnic distribution	Increases in public health spending is associated with an increase in mortality by several different causes (early deaths and heart disease deaths). No difference was observed when comparing the short-run and long-run impact of PH spending
McLaughlin et al. (2018)[14]	USA 50 states (2004-2013) Ecological	Fixed effects regression model	State-level Dollar amount of federal transfers received per capita	Infant, neonatal, and post neonatal mortality rates	**Area-level:** Race and ethnicity, economic conditions, education (the average freshman graduation rate), and the overall amount of state expenditures	An increase in per capita federal transfer is significantly associated with a decrease in state-level infant, neonatal and post neonatal mortality rates. A $200 increase in the amount of federal transfers per capita would save one child's life for every 10,000 live births while controlling for all other factors. The impact is particularly robust for black infants

Table 3.2. Continued

First author (year)	Location, Sample, Timeline, Study design	Study Design, Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Mays et al. (2011)[15]	USA National county-level (1993-2005) Ecological	Multivariate regression	County-level Per capita local public health spending	Age-adjusted mortality rates for heart disease, cancer, diabetes, and influenza	**Area-level:** Population size, population per square mile, community located within metropolitan area, % of non-white, % of 65+, % with college degree, % of unemployed, % below federal poverty level, % non-English speaking, % of uninsured, active physicians, and hospital beds	For every 10% increase in spending, infant mortality rates, cardiovascular disease mortality rate, diabetes mortality rate, and cancer mortality rate decreases by 6.9%, 3.2%, 1.4%, and 1.1%. Influenza mortality and total mortality changed in the expected direction but was not statistically significant
Paton et al. (2017)[21]	England 149 local authorities (2009-2014) Ecological	Fixed effects panel data regression model, instrumental variable regression	Local-level Annual local authority expenditure on teenage (aged 13-17) pregnancy services	Under 18 conception, abortion, and birth rates among residents in each local authority	**Area-level:** Education, ethnicity, alcohol consumption, % of final year pupils at state-funded secondary schools who are classified as non-white, rate of under 18 who were admitted to the hospital with alcohol-specific conditions per 100,000 of the resident population, levels of deprivation, unemployment rate, and level of family breakdown	A 10% reduction in expenditure is associated with a 0.25% decrease in under-18 conception rate, 0.19% decrease in abortion rate, and 0.32% decrease in birth rate

Table 3.2. Continued

First author (year)	Location, Sample, Timeline, Study design	Study Design, Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Reeves et al. (2015)[23]	Europe 21 European union member states (1991-2012) Ecological	Multivariate regression	State-level Government expenditure on public health services	Tuberculosis case detection rates	-	A $100 decline in spending on public health is associated with a decline of 3.11% in Tuberculosis case detection rate
Singh (2014)[1]	USA Studies that examine the effectiveness of public health spending between 1985 and 2012 Systematic Review	N/A	State-, local-, and county-level Public health department spending	Population-level mortality and morbidity rates and health disparities	N/A	9 studies found that an increase in public health spending is associated with improved population health. 2 studies found limited evidence that increased public health spending can contribute to meaningful reductions in health disparities

Table 3.2. Continued

First author (year)	Location, Sample, Timeline, Study design	Study Design, Statistical method	Unit of analysis/ Relevant Funding Level	Health Outcome	Covariates	Direction of Relationship / Key Findings
Verma et al. (2017)[16]	USA State-level Ecological	Fixed effects model	State-level Total state expenditure and total non-hospital related public health expenditure	Annual state-level mumps, pertussis, and rubella (MMR) incidence	**Area-level:** Birth count by race, yearly mean population, year	A 1% increase in public health spending was significantly associated with a 11.5% and 6% decrease in mumps and rubella incidence respectively. Lagged analysis showed the benefits of public health spending increase in magnitude in future years
Williams et al. (2019)[17]	USA All 50 states (1975-2016) Ecological	Ordinary least squares and lag regression model	State-level Annual STI prevention funding allocations by state from 1975 to 2016	Rates of gonorrhea (1981-2016) and chlamydia (2000-2016)	**Area-level:** State-level poverty, violent crime rates, race/ethnicity, age, state, and year	A 1% increase in annual funding cumulatively decreases chlamydia rates by 0.17% ($p<0.10$) and gonorrhea rates by 0.33% ($p<0.05$). Results were similar when stratified by sex. Reported STI rate found to depend more on prevention funding in previous years than on prevention funding in the given year

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4. Manuscript

Public Health Unit Funding Per Capita and Seasonal Influenza Vaccination among Youth and Adults in Ontario, Canada in 2013/14 and 2018/19

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4.1 Abstract

Background

Previous studies have indicated that public health funding was associated with beneficial health outcomes at the population-level. Some individuals may be less likely to vaccinate against influenza for a variety of reasons, including the presence of health inequities as a barrier. For example, individuals from a lower SES background, who are younger, and who are male may be less likely to get the flu vaccine. Few studies have focused on the potential impact of public health funding per capita on influenza vaccine uptake and inequities related to influenza vaccination at the individual level. The objectives of this study are to: 1) estimate the association between public health unit (PHU) funding per capita and influenza vaccine uptake among individuals aged 12 and older in Ontario, Canada in 2013/14 and 2018/19; and 2) determine whether any observed associations were heterogeneous across household income groups, gender, and age categories.

Methods

Cross-sectional studies were conducted using the 2013/14 and 2018/19 cycles of the Canadian Community Health Survey (CCHS), a population-representative survey, by Statistics Canada that collects annual health data from individuals residing in local Ontario PHU service areas. PHU funding per capita was measured using the approved provincial funding for mandatory programs and the Canadian Census Population Estimates. Influenza vaccination in the past 12 months was measured by self-report in the CCHS. Multilevel logistic regression modelling was used to estimate the association between PHU funding per capita and self-reported influenza vaccine uptake, adjusting for gender, age, presence of chronic medication conditions, education, household income, presence of a regular medical doctor, urbanicity, self-perceived health,

immigration status, and material deprivation. Cross-level interaction between PHU funding per capita and household income, and gender, and age were tested.

Results

A case-complete weighted dataset of 10,780,494 and 10,653,927 CCHS respondents in 2013/14 and 2018/19, respectively were included in this study. The proportion of respondents who were vaccinated against influenza were 33.2% in 2013/14 and 35.5% in 2018/19. Across both years, among those who reported vaccination in the previous year, a higher proportion were female (54.8% for 2013/14; 55.8% for 2018/19), aged 20 to 49 years (30.7% for 2013/14; 33.0% for 2018/19), and from the highest household income group (50.4% for 2013/14; 66.5% for 2018/19). In 2013/14, an increase of one standard deviation (SD) in PHU funding was associated with having the influenza vaccine (OR: 1.08; 95% CI: 1.01, 1.15; SD: 14.1), which was not observed in 2018/19 (OR: 1.00; 95% CI: 0.93, 1.08; SD:14.4). A cross-level interaction between PHU funding per capita and household income further revealed that public health funding is protective among those from the lowest household income group and those between the ages of 50 and 64 years in 2013/14. Specifically, for every SD increase in PHU funding per capita, there is an increased likelihood of being vaccinated against influenza among individuals who belong to the lowest household income group (OR: 1.29; 95% CI: 1.10, 1.50) and those who are between the ages of 50 and 64 years (OR: 1.13; 95% CI: 1.03, 1.23) while adjusting for confounders. No heterogeneous associations were observed in 2018/19.

Conclusion

PHU funding per capita was found to improve influenza vaccination uptake among individuals from low-income households and those who are between the ages of 50 and 64 years in 2013/14.

Through funding, PHUs would be able to work towards their goal of preventing diseases, promoting health, and reducing health inequities among the population.

4.2 Introduction

As one of the top ten leading causes of death in 2019, influenza presents a significant public health threat in Canada.[1,2] Known commonly as the “flu”, influenza is an infectious respiratory disease caused primarily by influenza A and B viruses.[2] These viruses can spread easily from one person to another directly via cough or sneeze droplets or indirectly via infected objects.[2] Infected individuals may experience a wide variety of symptoms, ranging from mild cold-like symptoms that recovers quickly to severe medical complications that may lead to hospitalization, long-term adverse health effects or even death.[2] Annually, it is estimated that seasonal influenza epidemics are responsible for an average of 12,200 hospitalizations and up to 3,500 deaths in Canada.[2] This places a substantial economic burden and pressure on the Canadian healthcare system, where an average cost per case of acute hospital care for influenza/ acute upper respiratory infection was estimated to be $2,145 (CIHI, 2008).[3] This cost was found to be 2.5 times higher among individuals who are at risk, including young children, pregnant women, people with chronic illnesses, and older adults.[4] Additionally, seasonal influenza also affects overall economic costs through workplace absenteeism, where about 20 working days per 100 full time employees were lost.[5]

Among the public health measures implemented to prevent and reduce the burden of seasonal influenza epidemics, vaccination is the most effective prevention and control method.[2] However, vaccination coverage in Canada was reported to decline from 2006 to 2014, especially among high-risk groups.[6] In 2019, only about 34% of adults aged 18 to 64 years and 70% of older adults were vaccinated against influenza.[7] This unfortunately still falls short of the national influenza vaccination coverage goal of 80% for high-risk groups.[8]

Several factors have been found to influence influenza vaccine uptake; notably, the social determinants of health (SDOH).[9,10] SDOH are the conditions in which people are born, grow, work, live, and age.[11] SDOH, such as age, gender, immigration status, education, and household income can influence an individual's behaviour to get vaccinated.[10,11] For example, individuals who were older, female, had a postsecondary education, were not an immigrant, and came from a higher household income were found to be associated with an increased likelihood of being vaccinated against influenza.[12-16] In contrast, individuals who were less educated, had low income, marginalized, immigrants, and/or have reduced access to health care facilities have a lower influenza vaccine coverage.[9,13,14,17-19] This shows how the SDOH may also contribute to health inequities, which is the unfair and avoidable difference in health status.[20] In the case of vaccine uptake, SDOH can influence a person's understanding of vaccines due to education and language barriers, access to vaccines due to contextual factors, vaccine hesitancy, and the ability to make informed decisions about vaccines.[9] In addition to the SDOH, these health inequities may also be influenced by the structural determinants of health at the macro level.[21] According to Solar & Irwin[21], the structural determinants of health at the macro level are the socioeconomic and political context that surrounds us. An example of a structural determinant of health includes public health systems. Functioning at the macro-level, public health systems have the ability to mitigate health issues at a population-level, contribute to the development of health policies, address health inequities, and deliver upstream preventions.[10,21]

In Canada, public health systems at the provincial and territorial level oversee the implementation of vaccine policies and programs.[22] The structure of public health systems differ across provinces and territories.[22,23] In Ontario, for example, the public health system is decentralized.[24] As part of the decentralized system, there are a total of 34 public health units

(PHUs) that operate autonomously at the regional or municipal level to promote healthy living and prevent/control the spread of diseases.[24] As of 2018, a commitment towards health equity was also established as one of the four foundational standards and overall goals of the Ontario public health system.[25] This ensures that all PHUs take on a health equity lens when performing population health assessments, implementing interventions, and developing policies.[25,26] When it comes to vaccination, Ontario PHUs play an essential role in managing vaccine-related services, programs, surveillance, and administration that are in alignment with the Ontario Public Health Program Standards and Health Equity Guidelines.[20] Most notably, PHUs promote influenza vaccine uptake and health equity by organizing influenza clinics to increase reach and access to priority populations; creating influenza campaigns and education resources; and working with the government to support and optimize the reach of the universal influenza immunization program (UIIP), which provides free influenza vaccines to Ontarians 6 months and older.[27-29] Through the UIIP, free influenza vaccines can be obtained via health care providers, PHU clinics, community health centres, and long-term care homes.[30] Pharmacies were later added to this list as UIIP was expanded in 2012 to include pharmacists in the administration of influenza vaccines for individuals aged 5 and older.[31] The addition of pharmacists was beneficial as it improved overall accessibility through increased availability in service hours and proximity to pharmacies.[32,33] More importantly, influenza vaccination coverage among Ontarians was shown to increased by about 448,000 from 2011/2012 to 2013/2014.[34]

To support the role of public health in the delivery of these programs and reducing vaccine inequities, funding for public health systems is therefore crucial. Through financial support, public health systems are better able to improve work capacity, engage in workforce training and development, advance their work in reducing health inequities, and enable timely and efficient delivery of health promotion programs and services.[35,36] Besides that, previous studies have also demonstrated the protective effect of public health funding on population health outcomes. For example, in the United States, a 10% increase in public health funding was associated with a 20% reduction in black and white maternal mortality gap, a decrease of all-cause mortality deaths by 9.1 deaths per 100,000, and a decrease in infant mortality by 0.9%.[37-39] In terms of vaccines, two studies, respectively, showed that an increase in public health spending per capita was associated with an increase in an individual's intent to vaccinate against the H1N1 influenza in the United States[40] and was associated with better state-level vaccine coverage for measles, mumps, and rubella in Italy.[41] That said, few have looked at public health funding per capita and its association with influenza vaccine uptake in Canada at the individual level.

To understand the impact of public health funding in Canada, the presence of a decentralized public health system in Ontario, with varying amounts of funding received across regional PHUs, thus presents an opportunity to evaluate the association between PHU funding and influenza vaccination. Therefore, the objectives of this study are to: 1) estimate the association between PHU funding per capita and influenza vaccine uptake among individuals aged 12 and older in Ontario, Canada in 2013/14 and 2018/19; and 2) determine whether PHU funding per capita decreases inequities in vaccine uptake by examining whether any observed associations were heterogeneous across household income groups, gender, and age categories in 2013/14 and in 2018/19.

4.3 Methods

4.3.1 Study Design and Population

A cross-sectional study design was utilized to examine the association between PHU funding per capita and influenza vaccine uptake in 2013/14 and 2018/19. The population of interest for this study includes individuals aged 12 and older living in Ontario who responded to the 2013/14 and 2018/19 Canadian Community Health Survey (CCHS).

4.3.2 Data Access and Collection

CCHS data used in this study were administered by Statistics Canada and accessed via the Research Data Centre (RDC) at the University of Alberta. PHU funding data was obtained from two separate sources: (1) the 2013 Public Health Funding Model for Mandatory Program report[42]; and (2) the Ontario Public Health Information Database (OPHID). OPHID was assembled in 2020 to collect information on funding, expenditures, programs, and services across PHUs from the year 2018 and onwards. Additional data involving Ontario population estimates and marginalization index were accessed online and are described in further detail below.

4.3.3 Data Sources

Canadian Community Health Survey (CCHS) - Annual Component

Conducted by Statistics Canada, CCHS is an annual cross-sectional population-representative survey that collects health information from individuals aged 12 and older across provinces and territories in Canada.[43] This collection involves a multi-stage stratified cluster sampling method where randomly selected individuals were interviewed in-person or through a telephone using a computer-assisted system.[43] Overall, less than 3% of the target population, including individuals living on reserves and other Aboriginal settlements, full-time members of the Canadian Forces, the institutionalized population, and persons living in the Quebec health regions of Région du Nunavik and Région des Terres-Cries-de-la-Baie-James were excluded from the survey.[43] In 2015, however, the sampling methodology, sampling frame, and survey content of CCHS were revised and redesigned.[43] Therefore, for this study, comparing data variables from the cycles before and after 2015 were done with caution. To match the availability of the exposure data, specific CCHS cycles were selected for this study. In other words, the readily available two-year CCHS data file from 2013 to 2014 was used for the 2013 PHU funding dataset. As for the 2018 PHU funding dataset, due to the lack of a two-year CCHS data file from 2018 to 2019, the 2018 and 2019 CCHS annual components were manually appended to create a combined 2018/19 CCHS dataset. Through these cycles, the outcome and sociodemographic data of interest were extracted for this study.

2013 Public Health Funding Model for Mandatory Programs

In 2013, there were a total of 36 PHUs.[44] Two PHUs would later merge in 2018 to become one unit, thus resulting in a total of 35 PHUs in 2018.[44] For 2013, a complete list of PHU funding per capita across 36 PHUs was accessed online via a paper written by the Funding Review Working Group.[42] This Funding Review Working Group was assembled to review and provide advice to the Ontario Ministry regarding the implementation of a public health funding model.[42] In this report, PHU funding per capita "was calculated using the 2013 mandatory programs funding approved for public health units (provincial share) and the most recent Statistics Canada Population Estimates (2011)."[42]

2018 Annual Service Plan and Budget Submission (ASP)

In 2018, annual reporting of the Annual Service Plan and Budget Submission (ASP) was initiated.[45] The ASP is a document that allows the Boards of Health from each PHU to share their program and service plans, assessments, funding sources, and allocation of budgeted expenditures in accordance with the Ontario Public Health Standards, local population needs, and tentative funding for a given year.[28,45] These documents are submitted by Boards of Health in March, where the Ministry of Health and Long-Term Care (MOHLTC) will then review and respond to the funding requests.[28,45] In 2020, initial requests of the 2018 to 2020 ASPs were sent out to all of the PHUs by the OPHID research team. As of May 1st, 2023, a total of 29 out of 35 (82.9%) ASPs from the year 2018 were received. From these documents, data on provincial share funding for mandatory programs (cost-shared) were extracted to calculate PHU funding per capita.

2018 PHU-level Audited Financial Statements

In addition to the ASPs, the provincial share funding for mandatory programs were also extracted from the 2018 PHU-level audited financial statements. This additional step was performed to fill in the gaps of funding data due to the incomplete collection of ASPs received in 2018. Completed yearly by chartered professional accountants that are independent of PHUs, these publicly available reports contain budgeted and actual revenue and expenditure that were spent on public health-related programs and services. Financial statements completed at the end of the year (i.e. financial statements for the year ended December 31st, 20XX) were collected by the OPHID team. As of May 1st, 2023, a total of 27 (77.1%) FS from the year 2018 were collected. To ensure consistency, the ASPs were prioritized over the FS. Therefore, of the 27 FS collected, only 2 were used to fill in the PHUs with missing ASPs. Combined with the ASPs, the total funding data collected in 2018 were 31 out of 35 PHUs (88.6%). The remaining four PHUs with no funding data available were removed from the 2018/19 portion of the study.

2011 and 2016 Ontario Marginalization Index (ON-Marg) and Population Estimates

To measure health inequities at the PHU level, the 2011 and 2016 ON-Marg were obtained from Public Health Ontario, an agency of the Government of Ontario. The ON-Marg contains the 2011 and 2016 marginalization scores for four different dimensions: residential instability, material deprivation, dependency, and ethnic concentration.[46] These scores were calculated using principal component factor analysis across different geographic areas using multiple data sources, including the Canadian Census.[46] Detailed information about the methods and data sources have been previously published.[46] For this study, PHU-level material deprivation across 36 and 31 PHU for 2013 and 2018, respectively, was the dimension of interest. According to Matheson et al[46], material deprivation score at the PHU-level was derived from dissemination area factor scores. For the 2011 version, it is important to note that due to the replacement of the mandatory long-form census with a voluntary survey in 2011, the majority of the indicators used to calculate material deprivation have been substituted or removed, thus, affecting the comparability of the data in 2011 and 2016.[45] However, a recent study has shown that the use of alternative data sources in 2011 did not affect the overall consistency of the data at the Dissemination Area level.[46] In addition to the marginalization score, the total estimated population count for each PHU area in 2011 and 2016 was also provided in the ON-Marg dataset. This estimated population count was extracted from the 2011 and 2016 Canadian Census Population Estimates, which were made available by Statistics Canada. This estimated population count was also used to calculate PHU funding per capita in 2013 and 2018.

4.3.4 Study Variables

Outcome Measure

The outcome of interest was self-reported influenza vaccination status in the past 12 months. This is derived through a two-fold question, where the first question asked, “Have you ever had a seasonal influenza shot?”, followed by a second question asking, “When did you last have your seasonal flu shot” (**Table A.1.**). Participants who answered “yes” to ever having the flu shot and “less than 1 year ago” to when they last had the flu shot were labeled as vaccinated. Participants who answered “no” to ever having the flu shot” or “1 year to less than 2 years” or “2 years ago or more” when asked when their last flu shot was were categorized as unvaccinated. Participants who answered, “don’t know”, “refuse to answer”, or “not stated” were excluded from the study.

Exposure of Interest

PHU funding per capita was calculated using the 2013 and 2018 approved mandatory programs funding for each PHU, also known as provincial share, and the most recent Statistics Canada Population Estimates (see formula). The calculated per capita was then z-transformed to allow for easier interpretation.

$$PHU\ Funding\ Per\ Capita = \frac{Provincial\ Share\ Funding\ for\ Mandatory\ Programs\ (Cost-shared)}{Most\ Recent\ Statistics\ Canada\ Population\ Estimate}$$

Individual-level Covariates

Gender (male, female), age (12-19, 20-49, 50-64, 65-74, 75+ years), respondent’s education level (less than high school, high school, university), household income level (lowest, lower-middle, upper-middle, highest), presence of chronic medical conditions (CMC) (no CMC, have at least one CMC), presence of regular medical doctor (yes, no), urbanicity (urban, rural), self-perceived health (poor-fair, good-very good, excellent), and immigration status (Canadian born, immigrant) derived from the CCHS dataset were included in this study as individual-level covariates. The age groups listed above were categorized based on previous studies that examined influenza vaccination in Canada.[14,47] Of the variables listed, the presence of CMC, respondent's education, household income group, and presence of regular medical doctor were specially derived using a combination of existing variables from the CCHS dataset (**Table A.1.**). For example, the CMC variable was determined by categorizing participants into those who do not have any CMC and those who have at least one CMC, including asthma, chronic obstructive pulmonary disease (COPD), heart disease, stroke, diabetes, or cancer. This was done to identify high-risk individuals who were highly recommended by the National Advisory Committee on Immunization (NACI) to get vaccinated.[2] Household income group, on the other hand, was divided into quartiles and derived based on the number of people living in a household and the total household income from all sources in the last 12 months, as defined by Kwong et al[49] (**Table A.1.**). Due to the revision of survey contents in 2015, the variables involving respondents' education and presence of regular medical doctor in 2013/14 differed from the same variables in the 2018/19 CCHS datasets. These 2018/19 variables were therefore recategorized using the formula provided in the 2013/14 CCHS dataset to ensure that the 2013/14 and 2018/19 variables matched as closely as possible (**Table A.1.**).

Area-level Covariates

Material deprivation index at the PHU level from the ON-Marg dataset was included as the area-level covariate. The material deprivation index was closely connected to poverty and health equity through indicators that demonstrated the ability to attain basic material needs, such as income, unemployment, housing quality, educational attainment, and family structure.[46] The PHU level material deprivation index was z-transformed to allow for easier interpretation.

4.3.5 Statistical Analysis

A two-level multilevel logistic model (MLM) was used to examine the association between PHU funding per capita and self-reported influenza vaccination. This was performed in consideration of the clustering of the CCHS respondents within different PHUs, as well as the binary measure of the outcome variable. Level-1 of the model consisted of CCHS respondents and the individual-level covariates, while level-2 included PHU funding per capita and the material deprivation index at the PHU level. These two levels were then linked via an identification number that is unique to each PHU. Next, participants who refused, answered "don't know", or did not state their answer to any of the variables of interest were excluded from the study. This resulted in the exclusion of less than 0.1% of the sample population in both the 2013/14 and 2018/19 datasets. PHUs with missing funding data were also excluded, resulting in the loss of four PHUs in 2018/19. Using a step-up approach, the analysis first began with an intercept-only model. This allowed for the calculation of the Intraclass Correlation Coefficient (ICC) to understand the proportion of variance for receiving the influenza vaccine at the individual- and area-level. Next, PHU funding per capita was added to the model to identify the crude relationship with the outcome. This is followed by the addition of the individual- and area-level covariates to understand the association between PHU funding per capita and influenza vaccination while controlling for potential confounders. Lastly, cross-level interactions between PHU funding per capita and three different individual-level variables across three separate models while controlling for all other confounders were examined: (1) household income; (2)

gender; and (3) age groups. A final model containing all of the significant cross-level interactions was also fitted.

In both the descriptive analysis and multilevel models, sampling weights designed by Statistics Canada to estimate findings that were representative of the Ontario population were applied to level 1 of the model; level 2 weights were set to one. However, to account for the multilevel nature of the data, sampling weights from the CCHS datasets were scaled using the method by Carle[50] so that the new weights sum to the cluster sample size.[50] This method was performed to reduce the bias of variance component estimates and standard errors which may occur when sampling weights were designed without considering the clustered nature of the data.[50,51] Additionally, the sampling weights for 2018 and 2019 CCHS cycles were also combined using the pooled approach described by Thomas and Wannell[52]. Overall, a p-value of less than 0.05 was the level of significance considered for this study. All analyses were fitted using the *melogit* command and were performed using Stata/MP 17.

4.4 Results

Descriptive Analysis

A case-complete weighted dataset of 10,780,494 CCHS respondents across 36 PHUs in 2013/14 and 10,653,927 CCHS respondents across 31 PHUs in 2018/19 were included in this study (**Table 4.1.)**. Across both years, the proportion of vaccinated respondents (33.2% for 2013/14; 35.1% for 2018/19) were smaller compared to the proportion of unvaccinated respondents (66.8% for 2013/14; 64.9% for 2018/19) (**Table 4.1.**). That being said, the proportion of vaccinated individuals was observed to increase slightly from 33.2% to 35.1% across 5 years. Across both years, among those who reported vaccination, the majority were female (54.8% for 2013/14; 55.8% for 2018/19), 20 to 49 years old (30.7% for 2013/14; 33.0%

for 2018/19), did not have any CMC (69.3% for 2013/14; 72.1% for 2018/19), had at least a university degree (56.7% for 2013/14; 64.9% for 2018/19), were from the highest household income group (50.4% for 2013/14; 66.5% for 2018/19), had a regular medical doctor (96.6% for 2013/14; 83.3% for 2018/19), lived in a urban area (84.3% for 2013/14; 86.6% for 2018/19), perceived their health as good to very good (65.4% for 2013/14; 62.2% for 2018/19), and were Canadian-born (66.4% for 2013/14; 66.0% for 2018/19) (**Table 4.1.**).

At the PHU level, a total of 36 (100%) and 31 (88.6%) PHU funding data in 2013/14 and 2018/19 respectively were obtained and included in the study. In 2013/14, PHU funding per capita across 36 PHUs ranged from $29.8 to $84.0 CAD (**Table 4.1.**). This range widened by a dollar across 31 PHUs in 2018/19, with the lowest and highest PHU funding per capita also increasing to $34.0 and $89.2, respectively. As such, the average PHU funding per capita over a five-year period increased by about $3.50 CAD from $48.7 (SD= 14.1) in 2013/14 to $52.2 (SD= 14.4) in 2018/19. As for material deprivation, 2018/19 was observed to have a higher average marginalization score of 0.03 (SD=0.24) compared to -0.06 (SD=0.25) in 2013/14.

Table 4.1. Weighted descriptive statistics by influenza vaccination status in 2013/14 and 2018/19.

Variables	2013/14 CCHS (n=10,780,494)			2018/19 CCHS (n=10,653,927)		
	Not Vaccinated n=7,200,634 (66.8%)	**Vaccinated** n=3,579,860 (33.2%)	**p**	**Not Vaccinated** n=6,910,850 (64.9%)	**Vaccinated** n=3,743,077 (35.1%)	**p**
	%	**%**		**%**	**%**	
Individual-level variables						
Gender						
Male	50.5	45.2	<0.001	50.9	44.2	<0.001
Female	49.5	54.8		49.1	55.8	
Age						
12-19 years	12.3	8.1	<0.001	10.3	8.2	<0.001
20-49 years	57.7	30.7		55.8	33.0	
50-64 years	22.7	27.7		24.4	24.8	
65-74 years	5.2	19.4		6.7	19.6	
75+ years	2.2	14.2		2.9	14.5	
Presence of CMC*						
No CMC	86.0	69.3	<0.001	85.2	72.1	<0.001
At least one CMC	14.0	30.7		14.8	27.9	
Education						
Less than high school	17.7	20.8	<0.001	13.7	15.5	<0.001
High school	26.3	22.6		24.2	19.6	
University	56.0	56.7		62.0	64.9	
Household Income Group						
Lowest	5.9	5.2	0.101	4.4	2.9	0.018
Lower-middle	13.8	16.3		9.2	8.9	
Upper-middle	27.0	28.1		21.8	21.6	
Highest	53.3	50.4		64.6	66.5	
Presence of regular medical doctor						
Has regular medical doctor	89.5	96.6	<0.001	85.3	93.3	<0.001
No regular medical doctor	10.5	3.5		14.7	6.7	
Urbanicity						
Urban	84.1	84.3	0.766	86.4	86.6	0.671
Rural	15.9	15.7		13.6	13.4	
Self-perceived health						
Poor to fair	8.8	15.1	<0.001	8.8	12.4	<0.001
Good to very good	68.9	65.4		66.4	64.2	
Excellent	22.3	19.6		24.8	23.4	
Immigration status						
Canadian-born	68.2	66.4	0.122	63.9	66.0	0.245
Immigrant	31.8	33.6		36.1	34.0	

Area-level variables	Mean (SD) (n=36)	Mean (SD) (n=31)
Public health unit funding per capita	48.7 (14.1) range: 29.8 – 84.0	52.2 (14.4) range: 34.0 – 89.2
Material deprivation index	-0.06 (0.25) range: -0.56 – 0.63	0.03 (0.24) range: -0.47 – 0.49

* Chronic Medical Conditions

To better understand the distribution of individual- and area-level characteristics across PHUs, PHUs were also categorized into low, moderate, and high funding based on the tercile calculation of PHU funding per capita **(Table 4.2. and 4.3.)**. In both 2013/14 and 2018/19, PHUs with low funding per capita (n=12) had the largest sample population size, comprising about half of the sample population, while the PHUs with high funding per capita (n=12) represented about 10% of the sample population. Across all three levels of PHU funding per capita, PHUs with high funding per capita had the highest proportion of vaccinated individuals (37.5% for 2013/14; 36.7% for 2018/19) compared to PHUs with low- (31.9% for 2013/14; 34.9% for 2018/19) and moderate- (33.8% for 2013/14; 35.0% for 2018/19) funding per capita. In 2013/14, PHUs with high funding per capita also had a higher proportion of individuals who were older (65+ years) (12.9%), had at least one CMC (24.2%), had no regular medical doctor (89.2%), lived in a rural area (39.8%), and were Canadian-born (92.6%) compared to the other PHU funding per capita categories. This pattern was also observed in 2018/19, with the exception of the presence of a regular medical doctor, where PHUs with high and moderate funding per capita had similar proportions. In terms of material deprivation, PHUs with moderate funding per capita had the highest average of -0.02 in 2013/14. In contrast, the 2018/19 data showed that PHUs with high funding per capita had the highest material deprivation average of 0.11 while PHUs with low funding per capita had the lowest material deprivation average of -0.10.

Table 4.2. Comparison of the characteristics of 2013/14 CCHS respondents across low, moderate, and high public health unit funding per capita (n=10,780,494).

Variables	2013 Public Health Unit Funding Per Capita			
	Low n=5,583,611 (51.8%)	**Moderate** n=4,118,094 (38.2%)	**High** n=1,078,789 (10.0%)	**P-value**
Influenza vaccination in the last 12 months				
Not vaccinated	68.1	66.2	62.5	0.076
Vaccinated	31.9	33.8	37.5	
Individual-level variables				
Gender				
Male	49.0	48.4	49.0	0.046
Female	51.0	51.6	51.0	
Age				
12-19 years	11.7	10.0	10.1	0.003
20-49 years	50.0	49.2	40.4	
50-64 years	23.6	24.1	28.9	
65-74 years	9.2	10.0	12.9	
75+ years	5.5	6.7	7.8	
Presence of chronic medical conditions (CMC)				
No CMC	80.8	81.2	75.8	0.036
Have at least one CMC	19.2	18.8	24.2	
Education				
Less than high school	17.4	19.2	23.8	0.095
High school	25.9	24.1	24.7	
University	56.7	56.8	51.5	
Household income group				
Lowest	4.4	7.4	6.1	0.003
Lower-middle	13.3	16.3	15.1	
Upper-middle	25.6	28.9	31.1	
Highest	56.8	47.4	47.8	
Presence of regular medical doctor				
Has regular medical doctor	92.7	91.3	89.2	0.248
No regular medical doctor	7.3	8.7	10.8	
Urbanicity				
Urban	86.7	87.0	60.2	0.091
Rural area	13.3	13.0	39.8	
Self-perceived health				
Poor to fair	10.0	11.4	13.4	<0.001
Good to very good	68.7	66.1	68.7	
Excellent	21.3	22.5	17.9	
Immigration status				
Canadian-born	66.2	63.0	92.6	0.136
Immigrant	33.8	37.0	7.4	
Area-level characteristic	**Mean (SD)** (n=12)	**Mean (SD)** (n=12)	**Mean (SD)** (n=12)	
PHU funding per capita	35.8 (4.12) Range: 29.8 – 40.7	45.5 (2.91) Range: 41.3 – 50.8	64.9 (11.2) Range: 51.5 – 84.0	
Material deprivation index	-0.10 (0.22) Range: -0.56 – 0.26	-0.02 (0.29) Range: -0.37 – 0.63	-0.06 (0.26) Range: -0.53 – 0.23	

Table 4.3. Comparison of the characteristics of 2018/19 CCHS respondents across low, moderate, and high public health unit funding per capita (n=10,653,927).

Variables	**2018 Public Health Unit Funding Per Capita**			
	Low n= 5,445,394 (51.1%)	**Moderate** n= 4,064,119 (38.2%)	**High** n= 1,144,414 (10.7%)	**P-value**
Influenza vaccination in the last 12 months				
Not vaccinated	65.1	65.0	63.3	0.710
Vaccinated	34.9	35.0	36.7	
Individual-level variables				
Gender				
Male	48.8	48.3	48.3	0.526
Female	51.2	51.7	51.7	
Age				
12-19 years	10.5	8.6	8.8	0.007
20-49 years	47.9	49.3	42.0	
50-64 years	24.7	23.6	26.7	
65-74 years	10.5	11.4	13.6	
75+ years	6.5	7.0	9.0	
Presence of chronic medical conditions (CMC)				
No CMC	81.5	80.6	76.2	0.019
Have at least one CMC	18.5	19.4	23.8	
Education				
Less than high school	13.9	14.1	17.5	0.225
High school	22.8	21.7	24.9	
University	63.3	64.2	57.6	
Household income group				
Lowest	3.3	4.9	3.0	<0.001
Lower-middle	7.7	11.3	8.2	
Upper-middle	19.9	23.9	22.5	
Highest	69.1	59.9	66.2	
Presence of regular medical doctor				
Has regular medical doctor	89.5	86.5	86.7	0.034
No regular medical doctor	10.5	13.5	13.3	
Urbanicity				
Urban	88.5	90.1	63.9	0.066
Rural area	11.5	9.9	36.1	
Self-perceived health				
Poor to fair	8.8	11.4	11.8	0.017
Good to very good	66.5	64.3	66.2	
Excellent	24.7	24.3	22.0	
Immigration status				
Canadian-born	63.7	59.1	88.4	0.155
Immigrant	36.3	40.9	11.6	
Area-level characteristic	**Mean (SD)** (n=11)	**Mean (SD)** (n=10)	**Mean (SD)** (n=10)	
Public health unit funding per capita	40.1 (3.4) Range: 34.0 – 44.9	48.9 (2.9) Range: 45.1 – 53.3	68.8 (13.1) Range: 53.5 – 89.2	
Material deprivation index	-0.10 (0.19) Range: -0.47 – 0.23	0.09 (0.14) Range: -0.13 – 0.26	0.11 (0.30) Range: -0.41 – 0.49	

Multilevel Analysis

Results from the multilevel analysis between PHU funding per capita and influenza vaccination status for 2013/14 and 2018/19 are presented in **Table 4.4.** and **Table 4.5.,** respectively. Model 1, an intercept-only model presented an intraclass-correlation (ICC) of 0.0069 (95% CI: 0.0039, 0.012) for 2013/14 and 0.0056 (95% CI: 0.0024, 0.013) for 2018/19 (**Table A.5., A.6.)**. This indicates that only a small variation in having the influenza vaccine was explained at the PHU level. Instead, most of the variation in having the influenza vaccine was explained by the individual-level characteristics across both years (ICC= 99.4% for 2013/14; ICC= 99.1% for 2018/19). Next, the crude model (M2), containing only the exposure variable and the outcome variable, demonstrated that in 2013/14, a standard deviation increase (SD= 14.1) in PHU funding per capita was associated with a 1.07 (95% CI: 1.01, 1.13) times increase in the odds of vaccination. In 2018/19, no association was observed between PHU funding per capita and influenza vaccination (OR: 1.02; 95% CI: 0.96, 1.08). In 2013/14, when individual-level (M3) and later area-level (M4) variables were added to the model, the association between PHU funding per capita and having the influenza vaccine remained the same (OR: 1.08; 95% CI: 1.00, 1.11). Results from the 2018/19 analysis also remain the same, where no association was observed when individual- and area-level factors were adjusted for (OR: 0.99; 95% CI: 0.92, 1.07 for M3; OR: 1.00; 95% CI: 0.93, 1.08 for M4).

Overall, in both 2013/14 and 2018/19, the fully adjusted models (M4) demonstrated that females had a higher likelihood of being vaccinated against influenza compared to males (OR: 1.27; 95% CI 1.16, 1.40 for 2013/14; OR: 1.33; 95% CI: 1.25, 1.42 for 2018/19), after adjusting for all other factors. Among the different age categories, individuals aged 75 years and older had the highest likelihood of having the influenza vaccine compared to individuals between the ages of 20 and 49 (OR: 10.71; 95% CI: 9.25, 12.40 for 2013/14; OR: 8.72; 95% CI: 7.37, 10.33 for 2018/19). Individuals with at least one CMC were also more likely to have been vaccinated compared to those without any CMC in both 2013/14 and 2018/19. On the other hand, individuals with less than a post-secondary degree, lived in rural areas, and do not have a regular medical doctor had a lower likelihood of receiving the influenza vaccine across both years. While a similar direction of association were observed across many of the covariates in both the 2013/14 and 2018/19 data, there were also some covariates with different direction of association presented in the different years. This includes household income group, self-perceived health, and immigration status. In 2013/14, those belonging to the lowest household income group (OR: 0.80; 95% CI: 0.64, 0.99) had the lowest odds of vaccination, whereas in 2018/19, individuals from the lower-middle income group (OR: 0.76, 95% CI: 0.67, 0.87) had the lowest odds of receiving the influenza. As for those who perceived their health as poor to fair, the results in 2013/14 showed that they were significantly more likely to be vaccinated, while in 2018/19, they were found to be less likely to be vaccinated against influenza, although this result was not statistically significant. The same pattern was observed among immigrants but this time, statistical significance was only observed in 2018/19. As for the area-level factor, no significance was observed among material deprivation throughout all models in both 2013/14 and 2018/19.

Cross-level Interactions

In 2013/14, a cross-level interaction between PHU funding per capita and household income (M5) revealed that public health funding was associated with vaccination against influenza but only among the lowest household income group. Using a linear combination estimate (*lincom*) in Stata revealed that compared to other household income levels, individuals from the lowest household income had a 29% (OR: 1.29; 95% CI: 1.10, 1.50) increased odds of having the vaccine for every standard deviation (SD = 14.1) increase in PHU funding per capita in 2013/14. An illustration of this interaction is included in **Figure 4.1a**. Despite not having any statistical significance, the other household income groups, with the exception of the lower-middle income group, showed an increased probability of vaccination as PHU funding per capita increases (**Figure 4.1a**). Although the cross-level interaction with gender (M6) in 2013/14 did not yield any significance, the predicted probability of receiving the influenza vaccine was observed to increase with increasing PHU funding per capita among both males and females (**Figure 4.1b**).

Furthermore, in 2013/14, results from M7 showed a heterogeneous association between PHU funding per capita and age group (**Figure 4.1c**). Specifically, individuals aged 50 to 64 years had a 13% (OR: 1.13; 95% CI: 1.03, 1.23) increased likelihood of vaccination with every standard deviation (SD = 14.1) increase in PHU funding per capita. Similarly, a higher odds of influenza vaccination was reported among individuals belonging to the 20 to 49 age group and 65 to 74 age group as PHU funding per capita increases, however, statistically significance was not observed. On the other hand, although the results were not significant, individuals belonging to the age group of 12 to 19 and 75 and older were observed to have an inverse relationship with PHU funding per capita. Based on these results, a final model was created where all of the significant interactions were fitted into a single model (M7).

In 2018/19, a cross-level interaction with age (M7) showed unusual results. Among the age groups, the interaction term with the 75 and older age group was statistically significant (OR: 0.83; 95%: 0.72, 0.97). However, upon using *lincom* to interpret the relationship between the age groups and PHU funding per capita, the overall significance for the age groups were found to be insignificant. This may be attributed to the selection of reference group across all variables for this analysis. In 2018/19, cross-level interactions with gender and household income groups also showed no heterogeneous association. That said, the direction of association between many of these interactions were unexpected. Other than individuals from the highest household income group, between the ages of 20 and 49 years, and females, all other household income groups, age groups, and gender showed an inverse relationship with PHU funding per capita (**Figure 4.2a-c**). Since none of the interactions in 2018/19 were significant, the main effects model with both individual- and area-level covariates would be the final model (M4).

Table 4.4. Unadjusted and adjusted multilevel logistic models estimating the association between z-transformed public health unit funding per capita (zFunding per capita) and having the influenza vaccine using data from CCHS 2013/14 (weighted n=10,780,494).

Vaccinated	**(M1)** Null OR (95%CI)	**(M2)** Crude OR(95%CI)	**(M3)** Individual OR (95% CI)	**(M4)** Main effects OR (95% CI)	**(M5)** Int- income OR (95% CI)	**(M6)** Int- gender OR (95% CI)	**(M7)** Int- age OR (95% CI)	**(M8)** Final model OR (95% CI)
zFunding per capita		**1.07 (1.01, 1.13)**	**1.08 (1.00, 1.15)**	**1.08 (1.01, 1.15)**	1.10 (0.99, 1.23)	1.06 (0.99, 1.15)	1.09 (1.00, 1.20)	1.11 (0.98, 1.25)
Interaction between PHU funding per capita and household income								
*lowest					1.17 (0.98, 1.39)			1.18 (0.99, 1.40)
*lower-middle					0.89 (0.75, 1.05)			0.92 (0.77, 1.09)
*upper-middle					0.93 (0.84, 1.04)			0.94 (0.84, 1.06)
Interaction between PHU funding per capita and gender								
*female						1.02 (0.91, 1.15)		
Interaction between PHU funding per capita and age								
*12-19 years							**0.89 (0.81, 0.99)**	**0.90 (0.81, 1.00)**
*50-64 years							1.03 (0.93, 1.15)	1.03 (0.93, 1.15)
*65-74 years							0.98 (0.87, 1.12)	1.01 (0.89, 1.15)
*75+ years							**0.80 (0.69, 0.94)**	**0.83 (0.70, 0.97)**
Area-Level								
Material deprivation (z-transformed)				1.03 (0.98, 1.09)	1.03 (0.98, 1.09)	1.03 (0.98, 1.09)	1.03 (0.98, 1.09)	1.03 (0.98, 1.09)
Individual-Level								
Gender (ref: male)								
Female			**1.27 (1.16, 1.40)**	**1.27 (1.16, 1.40)**	**1.27 (1.16, 1.40)**	**1.28 (1.16, 1.41)**	**1.27 (1.16, 1.40)**	**1.27 (1.16, 1.40)**
Age (ref: 20 - 49 years)								
12 - 19 years			**1.36**	**1.36**	**1.36**	**1.36**	**1.32**	**1.32**

			(1.22, 1.52)	**(1.22, 1.52)**	**(1.22, 1.52)**	**(1.22, 1.52)**	**(1.17, 1.48)**	**(1.18, 1.49)**
50 - 64 years			**2.18**	**2.18**	**2.18**	**2.18**	**2.19**	**2.19**
			(2.00, 2.38)	**(2.00, 2.38)**	**(2.00, 2.38)**	**(2.00, 2.38)**	**(1.99, 2.40)**	**(1.99, 2.41)**
65 - 74 years			**6.50**	**6.50**	**6.54**	**6.50**	**6.47**	**6.53**
			(5.38, 7.25)	**(5.38, 7.25)**	**(5.87, 7.28)**	**(5.38, 7.25)**	**(5.74, 7.29)**	**(5.80, 7.35)**
75+ years			**10.70**	**10.71**	**10.77**	**10.71**	**10.41**	**10.51**
			(9.24, 12.38)	**(9.25, 12.40)**	**(9.32, 12.45)**	**(9.25, 12.40)**	**(9.04, 11.99)**	**(9.15, 12.08)**
Presence of CMC (ref: no CMC)								
Have at least one CMC			**1.78**	**1.78**	**1.78**	**1.78**	**1.79**	**1.79**
			(1.63, 1.95)	**(1.63, 1.95)**	**(1.63, 1.95)**	**(1.63, 1.95)**	**(1.64, 1.95)**	**(1.64, 1.95)**
Respondent's Education (ref: university)								
Less than high school			**0.80**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**
			(0.73, 0.87)	**(0.73, 0.87)**	**(0.73, 0.87)**	**(0.73, 0.87)**	**(0.74, 0.87)**	**(0.74, 0.87)**
High school			**0.79**	**0.79**	**0.79**	**0.79**	**0.79**	**0.79**
			(0.73, 0.85)	**(0.73, 0.85)**	**(0.73, 0.85)**	**(0.73, 0.85)**	**(0.72, 0.85)**	**(0.73, 0.85)**
Household Income Group (ref: highest)								
Lowest			**0.80**	**0.79**	**0.80**	**0.79**	**0.79**	**0.80**
			(0.64, 0.99)	**(0.64, 0.99)**	**(0.65, 0.99)**	**(0.64, 0.99)**	**(0.64, 0.99)**	**(0.65, 0.99)**
Lower-middle			**0.83**	**0.83**	**0.81**	**0.83**	**0.83**	**0.82**
			(0.71, 0.98)	**(0.70, 0.98)**	**(0.70, 0.95)**	**(0.70, 0.98)**	**(0.71, 0.98)**	**(0.70, 0.95)**
Upper-middle			**0.85**	**0.85**	**0.83**	**0.85**	**0.85**	**0.84**
			(0.77, 0.93)	**(0.77, 0.93)**	**(0.76, 0.91)**	**(0.77, 0.93)**	**(0.77, 0.93)**	**(0.76, 0.91)**
Presence of Regular Medical Doctor (ref: has regular doctor)								
No regular medical doctor			**0.39**	**0.39**	**0.39**	**0.39**	**0.39**	**0.39**
			(0.34, 0.46)	**(0.34, 0.46)**	**(0.34, 0.46)**	**(0.34, 0.46)**	**(0.34, 0.46)**	**(0.34, 0.46)**
Urbanicity (ref: urban)								
Rural			**0.79**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**
			(0.72, 0.88)	**(0.72, 0.88)**	**(0.72, 0.88)**	**(0.72, 0.88)**	**(0.72, 0.88)**	**(0.72, 0.88)**
Self-Perceived Health (ref: excellent)								
Poor to fair			**1.29**	**1.29**	**1.29**	**1.29**	**1.29**	**1.29**
			(1.06, 1.57)	**(1.06, 1.57)**	**(1.06, 1.57)**	**(1.06, 1.57)**	**(1.06, 1.57)**	**(1.06, 1.57)**
Good to very good			1.04	1.04	1.04	1.04	1.04	1.04
			(0.94, 1.16)	(0.94, 1.16)	(0.94, 1.16)	(0.94, 1.16)	(0.94, 1.16)	(0.94, 1.16)
Immigration Status (ref: Canadian-born)								
Immigrant			1.03	1.03	1.03	1.03	1.03	1.03
			(0.92, 1.16)	(0.92, 1.15)	(0.92, 1.14)	(0.92, 1.15)	(0.93, 1.15)	(0.93, 1.15)
Intercept	**0.55**	**0.55**	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**
	(0.51, 0.58)	**(0.52, 0.58)**	**(0.24, 0.33)**	**(0.24, 0.33)**	**(0.24, 0.33)**	**(0.24, 0.33)**	**(0.24, 0.33)**	**(0.24, 0.33)**

Bolded values indicate a statistically significant p-value ($p < 0.05$).

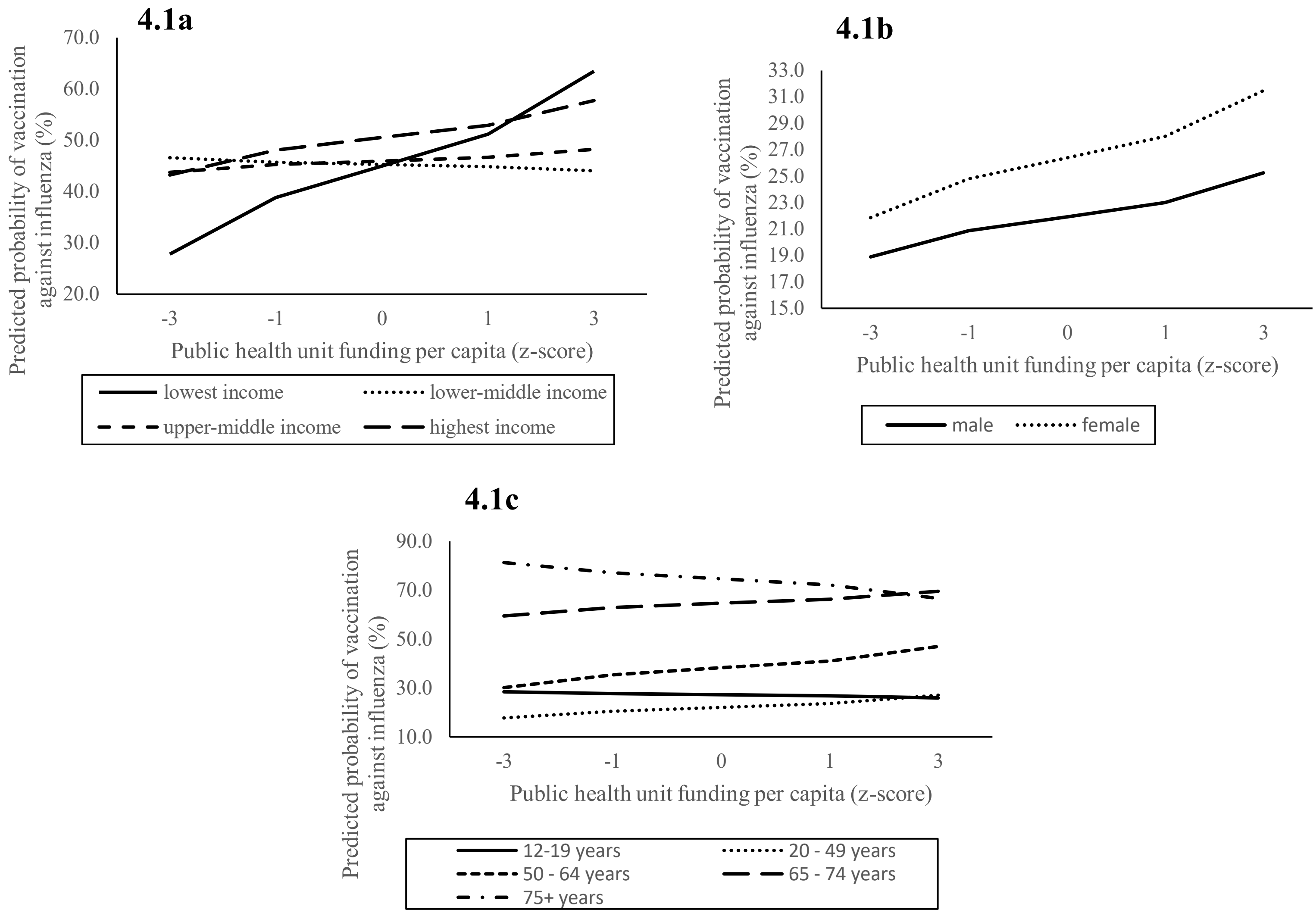

Figure 4.1. Predicted probability of having the influenza vaccine and the interaction between z-transformed public health unit funding per capita and **(a)** household income, **(b)** gender, and **(c)** age categories in 2013/14.

Table 4.5. Unadjusted and adjusted multilevel logistic models examining the association between z-transformed public health unit funding per capita (zFunding per capita) and influenza vaccine uptake using data from CCHS 2018/19 (weighted n=10,653,927).

Vaccinated	**(M1)** Null OR (95% CI)	**(M2)** Crude OR (95% CI)	**(M3)** Individual OR (95% CI)	**(M4)** Main effects OR (95% CI)	**(M5)** Int- income OR (95% CI)	**(M6)** Int- gender OR (95% CI)	**(M7)** Int- age OR (95% CI)
zFunding per capita		1.02 (0.96, 1.08)	0.99 (0.92, 1.07)	1.00 (0.93, 1.08)	1.02 (0.92, 1.12)	0.98 (0.91, 1.06)	1.07 (0.95, 1.20)
Interaction between PHU funding per capita and household income							
*lowest					0.95 (0.72, 1.24)		
*lower-middle					0.93 (0.84, 1.05)		
*upper-middle					0.97 (0.87, 1.08)		
Interaction between PHU funding per capita and gender							
*female						1.04 (0.95, 1.13)	
Interaction between PHU funding per capita and age							
*12-19 years							0.88 (0.73, 1.06)
*50-64 years							0.92 (0.83, 1.03)
*65-74 years							0.92 (0.81, 1.05)
*75+ years							**0.83 (0.72, 0.97)**
Area-Level							
Material deprivation (z-transformed)				0.98 (0.91, 1.05)	0.98 (0.91, 1.05)	0.98 (0.91, 1.05)	0.98 (0.91, 1.05)
Individual-Level							
Gender (ref: male)							
Female			**1.33 (1.25, 1.42)**	**1.33 (1.25, 1.42)**	**1.33 (1.25, 1.42)**	**1.34 (1.25, 1.44)**	**1.33 (1.25, 1.42)**
Age (ref: 20 - 49 years)							
12 - 19 years			**1.46**	**1.45**	**1.45**	**1.46**	**1.41**

			(1.19 1.78)	**(1.19 1.78)**	**(1.19 1.78)**	**(1.19 1.78)**	**(1.15 1.72)**
50 - 64 years			**1.68**	**1.68**	**1.68**	**1.68**	**1.65**
			(1.51, 1.87)	**(1.51, 1.87)**	**(1.51, 1.87)**	**(1.51, 1.87)**	**(1.48, 1.84)**
65 - 74 years			**4.98**	**4.98**	**4.99**	**4.98**	**4.90**
			(4.36, 5.70)	**(4.36, 5.70)**	**(4.36, 5.70)**	**(4.36, 5.70)**	**(4.30, 5.58)**
75+ years			**8.72**	**8.72**	**8.75**	**8.73**	**8.50**
			(7.37, 10.33)	**(7.37, 10.33)**	**(7.39, 10.36)**	**(7.37, 10.33)**	**(7.24, 9.98)**
Presence of CMC (ref: no CMC)							
Have at least one CMC			**1.53**	**1.53**	**1.53**	**1.53**	**1.53**
			(1.39, 1.68)	**(1.39, 1.68)**	**(1.39, 1.68)**	**(1.39, 1.68)**	**(1.39, 1.68)**
Respondent's Education (ref: university)							
Less than high school			**0.78**	**0.78**	**0.78**	**0.78**	**0.78**
			(0.69, 0.89)	**(0.69, 0.89)**	**(0.69, 0.89)**	**(0.69, 0.89)**	**(0.69, 0.89)**
High school			**0.73**	**0.73**	**0.73**	**0.73**	**0.73**
			(0.63, 0.84)	**(0.63, 0.84)**	**(0.63, 0.84)**	**(0.63, 0.84)**	**(0.63, 0.84)**
Household Income Group (ref: highest)							
Lowest			0.85	0.85	0.84	0.85	0.85
			(0.70, 1.03)	(0.70, 1.03)	(0.68, 1.05)	(0.70, 1.03)	(0.70, 1.03)
Lower-middle			**0.76**	**0.76**	**0.75**	**0.76**	**0.77**
			(0.67, 0.86)	**(0.67, 0.87)**	**(0.67, 0.84)**	**(0.67, 0.87)**	**(0.68, 0.87)**
Upper-middle			**0.84**	**0.84**	**0.83**	**0.84**	**0.84**
			(0.76, 0.92)	**(0.76, 0.92)**	**(0.75, 0.92)**	**(0.76, 0.92)**	**(0.77, 0.93)**
Presence of Regular Medical Doctor (ref: has regular doctor)							
No regular medical doctor			**0.58**	**0.58**	**0.58**	**0.58**	**0.58**
			(0.50, 0.68)	**(0.50, 0.68)**	**(0.50, 0.67)**	**(0.50, 0.68)**	**(0.50, 0.68)**
Urbanicity (ref: urban)							
Rural			**0.82**	**0.82**	**0.82**	**0.82**	**0.82**
			(0.73, 0.91)	**(0.73, 0.91)**	**(0.73, 0.91)**	**(0.73, 0.91)**	**(0.73, 0.91)**
Self-Perceived Health (ref: excellent)							
Poor to fair			0.98	0.98	0.98	0.98	0.98
			(0.85, 1.14)	(0.85, 1.14)	(0.85, 1.14)	(0.85, 1.14)	(0.85, 1.14)
Good to very good			0.91	0.91	0.91	0.91	0.91
			(0.83, 1.00)	(0.83, 1.00)	(0.83, 1.00)	(0.83, 1.00)	(0.83, 1.00)
Immigration Status (ref: Canadian-born)							
Immigrant			**0.85**	**0.85**	**0.85**	**0.85**	**0.85**
			(0.74, 0.98)	**(0.74, 0.98)**	**(0.74, 0.97)**	**(0.74, 0.98)**	**(0.74, 0.98)**
Intercept	**0.56**	**0.56**	**0.36**	**0.36**	**0.36**	**0.36**	**0.36**
	(0.53, 0.60)	**(0.53, 0.60)**	**(0.31, 0.42)**	**(0.31, 0.42)**	**(0.31, 0.42)**	**(0.31, 0.42)**	**(0.31, 0.43)**

Bolded values indicate a statistically significant p-value ($p < 0.05$).

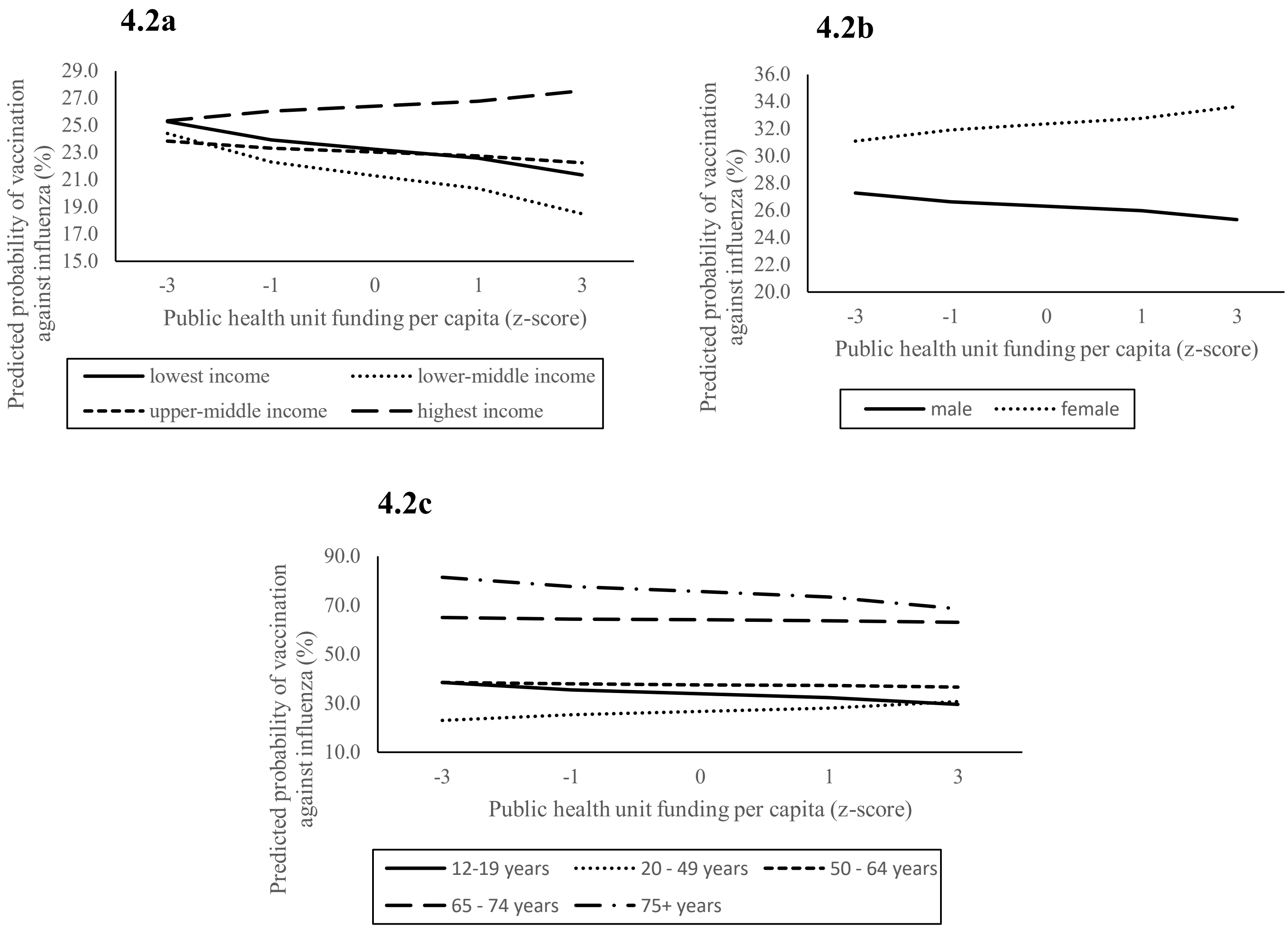

Figure 4.2. Predicted probability of having the influenza vaccine and the interaction between z-transformed public health unit funding per capita and **(a)** household income, **(b)** gender, and **(c)** age categories in 2018/19.

4.5 Discussion

Based on this study's findings, PHU funding per capita was associated with influenza vaccine uptake in 2013/14 but not in 2018/19 among a population-based representative sample of Ontarians aged 12 and older. In 2013/14, cross-level interactions between PHU funding per capita and household income and age groups, respectively, further revealed that higher PHU funding per capita was associated with an increased likelihood of influenza vaccination reported among individuals from the lowest household income group (compared to highest household income group) and individuals between the ages of 50 and 64 years (compared to ages 20-49 years). No heterogeneous associations were observed between PHU funding per capita and gender in 2013/14 or between PHU funding per capita and household income, age groups, and gender in 2018/19.

To our knowledge, this paper may be the first to examine the association between PHU funding per capita and influenza vaccination in Canada using individual level data. Findings from the 2013/14 analysis is consistent with studies that examined the impact of public health funding on population health, whereby local public health systems that received higher funding per capita in the United States were associated with improved health outcomes, such as lower rates of mortality, morbidity, and chronic and infectious diseases.[37-39,53-59] With regards to vaccination, Zhao & Bishai[40] found that higher per capita public health spending at the state-level was associated with increasing an individual's intent to vaccinate against the H1N1 (swine flu) virus in the US. Similarly, Toffolutti et al[41] demonstrated that county-level mumps, pertussis, and rubella (MMR) vaccination coverage increased as county-level per capita public health expenditure increased in Italy. Together, these results demonstrated that with the right resources, the major role public health systems play in protecting and promoting the health at a population level, such as improving flu vaccine uptake can be achieved.

As stated in the Ontario Public Health Standards, PHUs are highly encouraged to deliver programs that would improve public knowledge and confidence towards immunization, as well as improve the uptake of provincially funded vaccines.[27] More importantly, as a structural determinant of health, PHUs have the ability to reduce health inequities by identifying priority populations that faced barriers toward immunization; design targeted interventions; and mitigate health inequities by ensuring that the underserved and priority populations have access to provincially funded vaccines, such as the UIIP, as well as other immunization programs and services.[27] Based on the literature, public health departments' ability to reduce health inequities have also been demonstrated in the United States, such as the reduction of black and white maternal mortality gap, a decrease of all-cause mortality deaths, and a decrease in infant mortality. [37-39] To ensure that Ontario PHUs can deliver and maintain these health promoting/ prevention programs and services in the short term and long run, having appropriate and sustainable funding/ resources is crucial. However, based on a systematic review and a couple of qualitative studies examining Ontario PHUs work on health equity, one of the challenges that PHUs face in their work in health equity was limited funding and resources.[35,36,60] Without proper funding, PHUs may have to work under limited capacity and reduce the number of services that would benefit the marginalized populations.[35,36] This is evident by our 2013/14 findings, where PHUs with higher funding per capita was associated with a higher likelihood of influenza vaccine uptake among individuals from the lowest household income group. This is not usually the case for individuals from low household income as they have been previously associated with lower vaccine uptake.[14] Therefore, this suggests the possibility of funding as an enabler to the organizational capacity and goal of PHUs as a structural determinant to address the social determinants of health, promote vaccine uptake among priority populations, and reduce health inequities.

In 2018/19, many of the analysis results were unexpected. In the fully adjusted model, for example, PHU funding per capita was not significantly associated with influenza vaccination. As for the cross-level interactions, although the results were not statistically significant, the interactions demonstrated that increasing PHU funding per capita was associated with a decrease in influenza vaccination across household income groups (lowest income, lower-middle income, and upper-middle income), males, and age groups (12-19 years, 50-64 years, 65-74 years, and 75+ years). In other words, only individuals from the highest household income, females, and those who were between the ages of 20 and 49 years, respectively, were observed to have an increased likelihood of vaccination for every standard deviation increase in PHU funding per capita. Several reasons may attempt to explain the lack of association and the inverse relationship between PHU funding per capita and some of the variables. Firstly, it can be difficult to attribute population health to the level of public health funding if funding was allocated based on need. For example, if delivering public health programs in rural areas were more cost-intensive or the complexity of the disease burden or population impacted requires additional resources. This is a commonly highlighted challenge among United States- and United Kingdom-based studies that examined the impact of public health funding on population health outcomes.[35,53,61-64] In this case, for example, according to the Public Health Agency of Canada[7], the 2018-19 influenza season ran longer than the previous five seasons (2013-2018) with annual hospitalization rates that were above the average since the 2013-2014 season. As a result, some PHUs that were facing a higher burden of influenza may have spent or requested for a higher funding to reduce the impact of the outbreak and deliver vaccination programs. Secondly, the expansion of UIIP to include pharmacists in the administration of influenza vaccines in 2012 have led pharmacists to become more popular than PHUs.[31,65] As presented by Bouma[65], the proportion of pharmacist-administered influenza vaccines increased by about 4.8-fold from 8.8% in 2012/13 to 42.6% in 2017/18. In contrast, the proportion of influenza vaccines administered by PHUs decreased by about 4.5 times from 9.8% in 2012/13 to 2.2% in 2017/18.[65] Additionally, the responsibilities that PHUs previously held in managing influenza vaccine-related orders and distributions also diminished over the years.[66] Instead, community pharmacies would now work with the Ontario Government Pharmaceutical and Medical Supply Services (OGPMSS) or with approved pharmacy distributors, such as private pharmaceutical distributors, to obtain their supply of influenza vaccines.[66] This shift in responsibility could mean that funding towards PHUs that were once allocated for influenza vaccine-related services and programs or outreach/ targeted programs may have been directed to other foundational programs and standards, thus resulting in no relationship observed between PHU funding per capita and influenza vaccine uptake in 2018/19. Thirdly, another possible explanation for our findings is the presence of a lag effect. Authors, such as Bernet et al[53] and Marton et al[64] have critiqued that many studies on public health spending were often cross-sectional and did not take in account that the effect of public health spending on health outcomes were often not immediate. Currently, due to the lack of available funding data from 2014 to 2017, our study was not able to examine the long term/ lag effect of PHU funding per capita on influenza vaccine uptake. As OPHID is currently collecting PHU funding data from 2018 to 2021, future researchers could improve on this analysis by adjusting for the year and addressing the presence of a lag effect.

Limitations

Several limitations were associated with this study. Firstly, as this study utilized a cross-sectional study design, a temporal association cannot be made. Since both the financial data and CCHS were taken as a snapshot in time, the ability to determine if the exposure precedes the outcome cannot be made. In other words, this study would not be able to determine if the benefits of PHU funding per capita took effect before or after an individual received the vaccine.

Secondly, this study may also be subjected to selection bias due to exclusion of those who did not respond to any of the variables of interest. Based on the demographic of people who refused to answer, selected "don't know" or did not state their answer to the vaccination questions, the majority of them were male, 75+ years and older, had no chronic medical conditions, and had less than a high school diploma (**Table A.3.**). These same demographics were also found to be less likely to receive the influenza vaccine, thus leading to the possibility of differential misclassification, which may cause a bias in the odds ratio towards the null (**Table A.4.**).

Since this study only used aggregated PHU funding, it did not consider how funding was allocated or spent within each PHUs across the province. This means that the PHU funding per capita that was measured in this study includes a broad range of public health activities that were not specific to influenza vaccine-related services or programs. Moreover, since children aged 11 and younger were excluded from this study, PHU funding that were allocated towards promoting school immunization programs would not be accounted for in this study. Thus, this further underestimates the effect of PHU funding per capita on influenza vaccination. That said, McLaughlin et al[54] argues that the different programs could work together to influence the health outcome. In our study, there may be a possibility that immunization programs for other vaccine-preventable diseases or programs from other program standards may altogether play a role in promoting healthy behaviours, creating awareness around healthy living, and enabling Ontarians to make informed decisions. Additionally, while increased funding is key in enabling the work capacity of public health systems, it may not be a direct predictor of the impact, implementation or effectiveness of a program/ service, nor does it ensure or improve the performance of a public health system.[35] In other words, the decision to implement outreach vaccination campaigns or clinics, for example, may not come solely from having sufficient funds but from other factors, such as existing policies, other public health priorities, availability of resources, and approval from higher authorities. Lastly, this study also did not consider non-provincial funding that were assigned to PHUs nor influenza-related services or programs from external organizations and sectors that may have been funded by the Ontario government, which may act as a residual confounder. Furthermore, this study also acknowledges that there may be other unmeasured confounders between PHU funding per capita and influenza vaccine uptake that were not accounted for.

Another possible limitation is the lack of, or inconsistent data used in this study, which may affect the comparability of the findings from 2013/14 and 2018/19. For example, in 2018/19, due to the missing funding information from 4 PHUs, CCHS participants belonging to those PHUs were also removed from the study. This may have affected the overall average of PHU funding per capita, demographic characteristics, and analysis results of this study. This is due to the possibility that the regions that were omitted had a different vaccination coverage that did not fall within the current range that was examined. Additionally, financial statements were also used to replace missing the ASPs in 2018/19. This itself presents a couple of issues due to the different date of submission and format of the financial statements compared to the ASPs.

Firstly, the financial statements collected for this study were compiled and submitted at the end of the year (December 31st), whereas the ASPs were submitted at the beginning of the year (March 31st). This means that the provincial share funding found in the financial statements may not reflect the provincial share funding in the ASPs. Secondly, unlike the ASPs, it is not always clear how provincial funding was allocated for mandatory cost programs in the financial statements due to the different formatting. Besides that, throughout a six-year period from 2013/14 to 2018/19, data variables from CCHS and the ON-Marg Index were also modified, removed, or substituted. Extra precaution was taken to ensure that the CCHS variables were as similar as possible between 2013/14 and 2018/19.

5. Conclusion

Public health systems play a substantial role in promoting the health of the people, preventing diseases, and reducing health inequities. When it comes to influenza, this can be achieved by identifying populations with low influenza vaccine coverage and addressing the factors that influence vaccine uptake, especially the social determinants of health, which may contribute to health inequities. For public health systems to achieve this, funding is therefore crucial. As shown in this paper, increasing public health unit funding per capita was associated with an increased likelihood of influenza vaccination in 2013/14. Moreover, higher funding was also observed to decrease health inequities of influenza vaccination in 2013/14, where individuals from the lowest household income group and between the ages of 50 and 64 years were more likely to be vaccinated when PHU funding per capita increases. As one of the first studies to examine the impact of PHU funding per capita on influenza vaccine uptake in Canada, findings from this study will contribute to the growing literature of public health systems, structure, and funding on population health outcome. An important note that was discussed in this paper and many of the previous literature; the impact of public health funding on population health are often not immediate and may take some time before meaningful improvements can be seen. This may be attributed to nature of public health activities, which has a focus on prevention and upstream interventions at the population level. At this time of uncertainty, where the state of the economy and political pressures threaten budget cuts and the restructuring of public health systems, this study, thus aims to inform local public health units, policymakers, and governments about the importance of ongoing financial support to enable public health units to maximize their potential. With sufficient funding, public health units may have the opportunity to expand their organizational capacity; deliver programs in accordance to the OPHS and population needs in a timely and efficient manner; address the unequal distribution of the social determinants of health; and reduce health inequities associated with acquiring influenza vaccine. As more Ontario public health funding data are being collected by the OPHID team, future research should continue to explore the impact of public health funding on other health outcomes using better statistical methodologies to account for the presence of a lag effect. Future studies should also include an important measure of health inequity such as race/ethnicity that this study was not able to due to the small population size.

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Appendix Section

Appendix 1 – Figure A.1. and A.2.

Notification of Approval

Date:	April 21, 2020
Study ID:	Pro00099672
Principal Investigator:	Roman Pabayo
Study Title:	Public Health in a time of Austerity: measuring the divestments in Ontario's public health system and evaluating their impacts on population health and health inequities
Approval Expiry Date:	April 20, 2021
Approved Consent Form:	**Approval Date** 2020-04-21 — **Approved Document** Consent Form
Sponsor/Funding Agency:	CIHR - Canadian Institutes for Health Research — CIHR

RSO-Managed Funding:

Project ID	Project Title	Speed Code	Other Information
RES0049345	Public Health in a time of Austerity: measuring the divestment in Ontario's public health system and evaluating their impacts on population health and health inequities		

Thank you for submitting the above study to the Research Ethics Board 1. Your application, including the following, has been reviewed and approved on behalf of the committee:

- Recruitment Letter, Version 2, April 20, 2020;
- Complete Instrument for Interview Questions, Version 1, April 10, 2020;
- Proposal, Version 1, April 10, 2020.

Any proposed changes to the study must be submitted to the REB for approval prior to implementation. A renewal report must be submitted next year prior to the expiry of this approval if your study still requires ethics approval. If you do not renew on or before the renewal expiry date, you will have to re-submit an ethics application.

Approval by the Research Ethics Board does not encompass authorization to access the staff, students, facilities or resources of local institutions for the purposes of the research.

Approval by the Research Ethics Board does not encompass authorization to recruit and/or interact with human participants at this time. Researchers still require operational approval (e.g., Alberta Health Services) and must meet the requirements imposed by the public health emergency (link to Alberta COVID page).

Sincerely,

Anne Malena, PhD
Chair, Research Ethics Board 1

Note: This correspondence includes an electronic signature (validation and approval via an online system).

Figure A.1. Ethics Approval Certificate – Original (2020-2021)

Notification of Approval (Renewal)

Date:	March 22, 2023
Renewal ID:	Pro00099672_REN3
Principal Investigator:	Roman Pabayo
Study ID:	Pro00099672
Study Title:	Public Health in a time of Austerity: measuring the divestments in Ontario's public health system and evaluating their impacts on population health and health inequities
Sponsor/Funding Agency:	CIHR - Canadian Institutes for Health Research CIHR

RSO-Managed Funding:

Project ID	Title	Grant Status	Sponsor	Project Start Date	Project End Date	Purpose	Other Information
RES0049345							

Approval Expiry Date:	March 21, 2024

Thank you for submitting this renewal application. Your application has been reviewed and approved.

This re-approval is valid for one year. If your study continues past the expiration date as noted above, you will be required to complete another renewal request. Beginning at 30 days prior to the expiration date, you will receive notices that the study is about to expire. If you do not renew on or before the renewal expiry date, you will have to re-submit an ethics application.

Approval by the REB does not constitute authorization to initiate the conduct of this research. The Principal Investigator is responsible for ensuring required approvals from other involved organizations (e.g., Alberta Health Services, Covenant Health, community organizations, school boards) are obtained, before the research begins.

Sincerely,

Mary-Jane Sykes, REB Specialist, on behalf of

Theresa Garvin, Ph.D, MUA, BA
Chair, Research Ethics Board 1

Note: This correspondence includes an electronic signature (validation and approval via an online system).

Figure A.2. Ethics Approval Certificate – Latest Update (2023-2024)

Appendix 2 – Figure A.3.

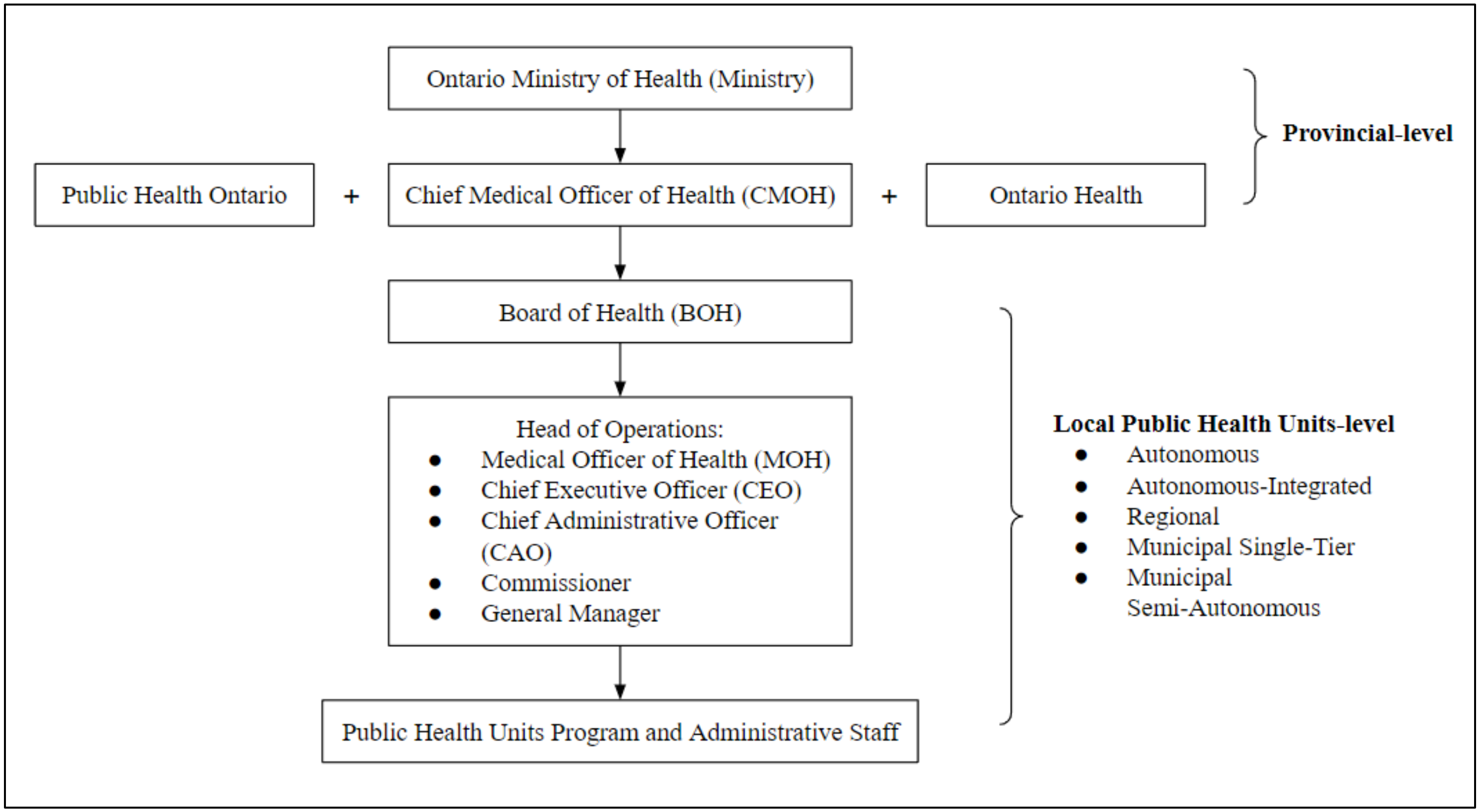

Figure A.3. Governing Structure of Ontario's Public Health System

Source: Smith et al. (2021). Profiles of Public Health Systems in Canada: Ontario. National Collaborating Centre for Healthy Public Policy. Retrieved from: https://www.inspq.qc.ca/en/publications/2820

Appendix 3 – Figure A.4.

Foundational Standards:

1. Population health assessment
2. Health equity
3. Effective public health practice
4. Emergency management

Program Standards:

1. Chronic disease prevention and well-being
2. Food safety
3. Healthy environments
4. Health growth and development
5. Immunization
6. Infectious and communicable diseases prevention and control
7. Safe water
8. School health
9. Substance use and injury prevention

Figure A.4. List of Foundational and Program Standard to Guide the work of Public Health Units.

Source: Ontario Ministry of Health and Long-Term Care. (2021). Ontario Public Health Standards: Requirements for Programs, Services and Accountability. Retrieved from: https://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/docs/protocols_guidelines/Ontario_Public_Health_Standards_2021.pdf

Appendix 4 – Table A.1.

Table A.1. 2013/14 and 2018/19 CCHS questionnaires and recoded responses based on variables of interest.

Variables	Concept Questions		Recoded Responses
	2013/14	2018/19	
Influenza vaccination status	"Have you ever had a seasonal flu shot?" "When did you last have your seasonal flu shot?	Same as CCHS 2013/14 Same as CCHS 2013/14	0= Never had flu shot or had the flu shot more than 1 year ago 1= Had the flu shot less than 1 year ago **.** = don't know, refusal, not stated
Gender	"Is [respondent name] male or female?"	Same as CCHS 2013/14	0= male 1= female
Age category	"What is your age?"	Same as CCHS 2013/14	0= 20-49 years 1= 12-19 years 2= 50-64 years 3= 65-74 years 4=75+ years
Chronic Medical Conditions	Derived using variables listed below	Same as CCHS 2013/14	0=no chronic medical conditions 1= have at least one chronic medication condition, including asthma, COPD, heart disease, stroke, diabetes, or cancer **.** = don't know, refusal, not stated
• Chronic conditions (CCC) - Core content	"Now I'd like to ask about certain long-term health conditions which ^YOU2 may have. We are interested in "long-term conditions" which are expected to last or have already lasted 6 months or more and that have been diagnosed by a health professional. "	Same as CCHS 2013/14	

• Asthma	"Do you have asthma?"	Same as CCHS 2013/14	0=no 1=yes 9=Don't know or refuse
• COPD	"Do you have chronic bronchitis, emphysema or chronic obstructive pulmonary disease or COPD?"	Same as CCHS 2013/14	0=no 1=yes 9=Don't know or refuse
• Diabetes	"Do you have diabetes?" "Exclude respondents who have been told they have prediabetes. Only respondents with type 1, type 2 or gestational diabetes should answer yes to this question."	Same as CCHS 2013/14	0=no 1=yes 9=Don't know or refuse
• Heart disease	"Do you have heart disease?"	Same as CCHS 2013/14	0=no 1=yes 9=Don't know or refuse
• Cancer	"Do you have cancer?"	Same as CCHS 2013/14	0=no 1=yes 9=Don't know or refuse
• Stroke	"Do you suffer from the effects of a stroke?"	Same as CCHS 2013/14	0=no 1=yes 9=Don't know or refuse
Household education	[Derived variable] Highest level of education – household, 4 levels	[Derived variable] Highest level of education – household, 3 levels	0= university or post-secondary certificate diploma 1= less than secondary school graduation 2= secondary school graduation, no post-secondary . = not stated
Household income group	Derived using variables listed below	Same as CCHS 2013/14	0= Highest (1 or 2 persons & $60,000 or more) or (3+ persons & $80,000 or more)

			1= Lowest (1 or 2 persons & < 15k) or (3 or 4 persons & < 20k) or (5+ persons & < 30k) 2= Lower-middle (1 or 2 persons & $15,000 to $29,999) or (3 or 4 persons & $20,000 to $39,999) or (5+ persons & $30,000 to $59,999) 3= Upper-middle (1 or 2 persons & $30,000 to $59,999) or (3 or 4 persons & $40,000 to $79,999) or (5+ persons & $60,000 to $79,999)
• Household size	Number of persons living in a household	Same as CCHS 2013/14	1= 1-2 persons 2= 3-4 persons 3= 5+ persons
• Household income	Total household income – all sources	Same as CCHS 2013/14	Continuous data
Has regular medical doctor	"Do you have a regular medical doctor?"	"Do you have a regular health care provider?" "Is that regular health care provider a…?"	0= have regular medical doctor/ family doctor or general practitioner 1= no regular medical doctor/ health care provider . = don't know, refusal, not stated
Urbanicity	Population centre	Same as CCHS 2013/14	0= urban 1= rural
Perceived health	"In general, would you say your health is…?"	Same as CCHS 2013/14	0= excellent 1= poor to fair 2= good to very good . = don't know, refusal, not stated
Immigrant status	[derived variable] Immigrant flag	Same as CCHS 2013/14	0= non-immigrant (Canadian-born)

		1= immigrant (landed immigrant/ non-permanent resident) . = not stated

Source: Questionnaires were taken from the <odesi> website (https://odesi.ca/), which contains public use microdata files of CCHS.

Appendix 5 – Table A.2.

Table A.2. Weighted summary statistics of the 2013/14 and 2018/19 data.

Variables	2013/14 (n=10,780,494)	2018/19 (n=10,653,927)
	%	%
Influenza vaccination in the last 12 months		
Not vaccinated	66.8	64.9
Vaccinated	33.2	35.1
Individual-level variables		
Gender		
Male	48.8	48.6
Female	51.2	51.4
Age		
12-19 years	10.9	9.6
20-49 years	48.7	47.8
50-64 years	24.3	24.5
65-74 years	9.9	11.2
75+ years	6.2	7.0
Presence of Chronic Medical Conditions (CMC)		
No CMC	80.4	80.6
Have at least one CMC	19.6	19.4
Education		
Less than high school	18.7	14.4
High school	25.1	22.6
University	56.2	63.1
Household Income Group		
Lowest	5.7	3.9
Lower-middle	14.6	9.1
Upper-middle	27.4	21.7
Highest	52.3	65.3
Presence of regular medical doctor		
Has regular medical doctor	91.8	88.1
No regular medical doctor	8.2	11.9
Urbanicity		
Urban	84.2	86.5
Rural area	15.9	13.5
Self-perceived health		
Poor to fair	10.9	10.1
Good to very good	67.7	65.6
Excellent	21.4	24.3
Immigration status		
Canadian born	67.6	64.6
Immigrant	32.4	35.4
Area-level variables	**Mean (SD) (n=36)**	**Mean (SD) (n=31)**
Public health unit funding per capita	48.7 (14.1) range: 29.8 – 84.0	52.2 (14.4) range: 34.0 – 89.2
Material deprivation index	-0.06 (0.25) range: -0.56 – 0.63	0.03 (0.24) range: -0.47 – 0.49

Appendix 6 – Table A.3. and Table A.4.

Table A.3. Weighted descriptive statistics of the excluded and included participants based on their response to the influenza-related questions in the 2013/14 and 2018/19 CCHS data.

Variables	2013/14 CCHS			2018/19 CCHS		
	Included (97.1%)	Excluded* (2.87%)	p	Included (94.7%)	Excluded* (5.3%)	p
	%	%		%	%	
Gender						
Male	48.7	55.4	<0.017	48.5	55.7	0.061
Female	51.3	44.6		51.5	44.3	
Age						
12 - 19 years	10.7	21.9	<0.001	9.5	25.5	<0.001
20 - 49 years	48.3	21.0		47.5	31.2	
50 - 64 years	24.6	14.8		25.6	9.5	
65 - 74 years	10.0	10.9		11.4	13.2	
75+ years	6.3	31.4		7.06	20.6	
Presence of Chronic Medical Conditions (CMC)						
No CMC	80.3	64.3	<0.001	80.5	72.1	<0.001
Have at least one CMC	19.7	35.7		19.5	27.9	
Education						
Less than high school	18.7	50.2	<0.001	14.6	44.7	<0.001
High school	25.0	26.8		22.6	21.9	
University	56.3	23.0		62.9	33.4	
Household Income Group						
Lowest	5.8	7.0	0.001	3.8	5.2	<0.001
Lower-middle	15.3	22.8		9.4	14.9	
Upper-middle	27.9	30.8		22.1	26.5	
Highest	51.1	39.4		64.7	53.4	
Presence of regular medical doctor						
Has regular medical doctor	91.8	94.6	0.011	88.1	86.5	0.224
No regular medical doctor	38.2	5.4		11.9	13.5	
Urbanicity						
Urban	84.3	84.2	0.971	86.6	86.0	0.729
Rural	15.7	15.8		13.4	14.0	
Self-perceived health						
Poor to fair	11.1	34.0	<0.001	10.1	28.7	<0.001
Good to very good	67.7	52.4		65.6	52.8	
Excellent	21.3	13.6		24.2	18.5	
Immigration status						
Canadian born	67.5	60.5	0.003	64.6	59.1	0.005
Immigrant	32.5	39.5		35.4	40.9	

*participants were excluded from the study if they refused, did not state, or selected “don’t know” to any of the influenza-related questions.

Table A.4. Multilevel logistic model estimating the likelihood of being excluded from the study based on their response to the influenza-related questions across individual demographic and socio-economic status in 2013/14 and 2018/19.

Excluded*	**2013/14**				**2018/19**			
		95% CI				**95% CI**		
	OR	Lower bound	Upper bound	p-value	OR	Lower bound	Upper bound	p-value
Individual-Level								
Gender (ref: male)								
Female	**0.57**	**0.48**	**0.68**	**<0.001**	**0.56**	**0.46**	**0.69**	**<0.001**
Age (ref: 20 - 49 years)								
12 - 19 years	**2.99**	**2.21**	**4.04**	**<0.001**	**2.54**	**1.78**	**3.64**	**<0.001**
50 - 64 years	**0.72**	**0.52**	**0.99**	**0.042**	**0.47**	**0.35**	**0.62**	**<0.001**
65 - 74 years	1.45	0.98	2.14	0.063	1.19	0.93	1.53	0.159
75+ years	**4.78**	**3.48**	**6.56**	**<0.001**	**2.31**	**1.70**	**3.13**	**<0.001**
Presence of CMC (ref: no CMC)								
Have at least one CMC	**1.21**	**1.01**	**1.45**	**0.044**	1.05	0.85	1.30	0.659
Respondent's Education (ref: university)								
Less than high school	**3.18**	**2.58**	**3.92**	**<0.001**	**3.08**	**2.27**	**4.17**	**<0.001**
High school	**2.05**	**1.60**	**2.63**	**<0.001**	**1.64**	**1.27**	**2.13**	**<0.001**
Household Income Group (ref: highest)								
Lowest	0.85	0.54	1.34	0.481	1.05	0.69	1.58	0.829
Lower-middle	0.84	0.66	1.07	0.167	1.26	0.93	1.71	0.144
Upper-middle	0.99	0.83	1.16	0.869	1.03	0.86	1.25	0.721
Presence of Regular Medical Doctor (ref: has regular doctor)								
No regular medical doctor	0.97	0.68	1.38	0.857	1.04	0.80	1.34	0.775
Urbanicity (ref: urban)								
Rural	0.95	0.78	1.16	0.621	1.10	0.85	1.43	0.480
Self-Perceived Health (ref: excellent)								
Poor to fair	**3.19**	**2.56**	**3.98**	**<0.001**	**3.57**	**2.85**	**4.47**	**<0.001**
Good to very good	0.88	0.70	1.10	0.248	1.13	0.91	1.39	0.264

Immigration Status (ref: Canadian born)								
Immigrant	**1.28**	**1.01**	**1.64**	**0.044**	**1.47**	**1.27**	**1.70**	**<0.001**
Intercept	0.01	0.01	0.01	<0.001	0.02	0.02	0.03	<0.001

Bolded values indicate a statistically significant p-value ($p < 0.05$).
*participants were excluded from the study if they refused, did not state, or selected "don't know" to any of the influenza-related questions.

Appendix 7 – Table A.5. and Table A.6.

Record of Intraclass Correlation Coefficient and Level-2 Variance Coefficient for Table 7 and 8.

Table A.5. Intraclass correlation coefficient and level-2 variance coefficient for the unadjusted and adjusted multilevel logistic models using 2013/14 CCHS Data

Variables	**(M1) Null**	**(M2) Crude**	**(M3) Individual**	**(M4) Main effects**	**(M5) Int-income**	**(M6) Int-gender**	**(M7) Int- age**	**(M8) Final model**
ICC	0.0069	0.0058	0.0064	0.0061	0.0061	0.0061	0.0062	0.0061
Level-2 Variance Coefficient (RSE)	0.0229 (0.0067)	0.0191 (0.0054)	0.0211 (0.0067)	0.0203 (0.0065)	0.0202 (0.0066	0.0203 (0.0065)	0.0204 (0.0066)	0.0203 (0.0066)

ICC, Intraclass Correlation Coefficient

RSE, Robust Standard Error

Table A.6. Intraclass correlation coefficient and level-2 variance coefficient for the unadjusted and adjusted multilevel logistic models using 2018/19 CCHS Data

Variables	**(M1) Null**	**(M2) Crude**	**(M3) Individual**	**(M4) Main effects**	**(M5) Int-income**	**(M6) Int-gender**	**(M7) Int- age**
ICC	0.0056	0.0056	0.0070	0.0069	0.0069	0.0069	0.0069
Level-2 Variance Coefficient (RSE)	0.0186 (0.0083)	0.0184 (0.0081)	0.0232 (0.0107)	0.0229 (0.0101)	0.0227 (0.0101)	0.0229 (0.0101)	0.0230 (0.0099)

ICC, Intraclass Correlation Coefficient

RSE, Robust Standard Error

Appendix 8 – Figure A.5.

Overall predicted probability: $\frac{1}{1+e^{-\gamma OO}}$

Where: e = Exponential

$-\gamma OO$ = Coefficient of the intercept

Figure A.5. Formula for overall predicted probability.

(Source: Figure adapted from the supplementary material of the study by Pabayo et al.)

Pabayo R, Kawachi I, Gilman SE. US State-level income inequality and risks of heart attack and coronary risk behaviors: longitudinal findings. *Int J Public Health*. 2015;60(5):573-588. doi:10.1007/s00038-015-0678-7)