Spatial Access by Public Transport and Likelihood of Healthcare Consultations at Hospitals

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ABSTRACT

As healthcare is a right in Canada, analyzing the distribution of spatial access to medical consultations, which are crucial for the prevention, diagnosis and early treatment of illnesses, is fundamental to understanding health equity. Spatial accessibility can influence whether individuals can reasonably reach the services they seek. However, as an indicator of potential access, it does not guarantee realized access due to predisposing and need factors. This study examines the relationship between spatial accessibility to hospitals and the likelihood of consulting with a healthcare professional at a hospital in eight Canadian metropolitan regions while controlling for individual characteristics through multilevel regression modelling. Spatial accessibility was computed using the two-step floating catchment area (2SFCA) method. Self-reported consultations and socio-demographic characteristics were obtained from the Canadian Community Health Survey. We found that the likelihood of consultations differed between genders (female OR: 1.133, CI: 1.023-1.255; compared to male), followed a positive household income gradient (high-income OR: 1.236 CI: 1.094-1.397; middle-income OR: 1.039 CI: 0.922-1.172; compared to low-income) but is not influenced by age. Living in areas with higher spatial accessibility was positively linked to consultations (OR: 1.014 CI: 1.000-1.028), even after controlling for perceived health (OR: 0.540 CI: 0.471-0.621), chronic conditions (OR: 1.738 CI: 1.587-1.904) and having a regular doctor (OR: 1.313 CI: 1.187-1.452). Policies that may improve spatial accessibility to healthcare services through increasing supply, managing demand and enhancing level of public transport service should be considered to improve individuals' ability to consult healthcare professionals, potentially leading to better health outcomes.

Keywords: spatial accessibility, healthcare utilization, consultations

1. INTRODUCTION

Healthcare utilization refers to the use of services by individuals to prevent and treat health problems, promote well-being or obtain information about one's health (*1*). Consulting with a healthcare professional is an important act of health-seeking individuals and can lead to better health outcomes as illnesses can be addressed at an earlier stage or be prevented altogether. To measure healthcare utilization, surveys are administered to the general public to collect self-reported information, an example being the Canadian Community Health Survey. Such surveys allow researchers to track the services that respondents report using over a period of time (e.g. the number of visits to the doctor's office).

The utilization of healthcare, according to the Healthcare Utilization Model (*2*), is affected by predisposing factors, enabling factors, and need. Predisposing factors reflect the individuals' propensity to use healthcare services based on their health beliefs and need factors represent individuals' needs to use healthcare services which are related to their perceived and actual health conditions. While predisposing and need factors may not be within the control of policy-makers and planners, they can on the other hand influence the enabling factors of healthcare utilization - policies that are in place that allow individuals to access services. One of the major barriers of access, especially for vulnerable population (*3*), is the physical distance that separates individuals from the services that they seek, which on a macroscopic level, is the result of both the distribution of healthcare facilities throughout a region as well as the performance of the transport system, where the level of service provided by the transport system has an impact on the ability of individuals to reach potential destinations within the cost threshold. This topic has been studied under the term of spatial accessibility and which can be measured in the healthcare context using the two-step floating catchment area (2SFCA) method. The 2SPCA method accounts for both capacity and demand, expressed through the service-to-population ratio at a healthcare facility and whether individuals can realistically reach that particular facility within a reasonable amount of time. The transport mode taken to access healthcare also strongly influences care utilization as research has shown that, compared to driving or being driven, those who use public transport are less likely to utilize healthcare services and unreliable or infrequent service has resulted in more instances of missed appointments (*4*). Nonetheless, it is generally found that disadvantaged groups in society rely more heavily on public transport to access services related to their daily needs, highlighting the importance of research on spatial accessibility by public transport.

While there have been numerous studies that make use of the 2SFCA method (*5-7*) to measure accessibility, few have used it to evaluate the relationship between spatial accessibility and the realization of healthcare, specifically on health-seeking acts such as consultations. In this study, we examine the relationship between spatial accessibility to hospitals and the likelihood of consultations with a healthcare professional at a hospital using the 2SFCA method, using data obtained for eight Canadian metropolitan regions (**Figure 1**). Self-reported consultations as well as variables related to their predisposition and needs for healthcare are obtained from the Canadian Community Health Survey (CCHS) and the pooled data obtained from the 2012-2014 cycles as well as for the eight metropolitan regions was used. Multilevel regression is carried out to model the correlation between spatial accessibility and the likelihood of consultations while controlling for predisposing factors (e.g. age, sex, household size, etc.) and healthcare needs of individuals (e.g. presence of chronic conditions and self-perceived health). This study contributes to the literature on healthcare utilization and whether an adequate bed-to-population ratio and good access to hospitals by public transport are positively associated with the likelihood of an individual consulting a healthcare professional.

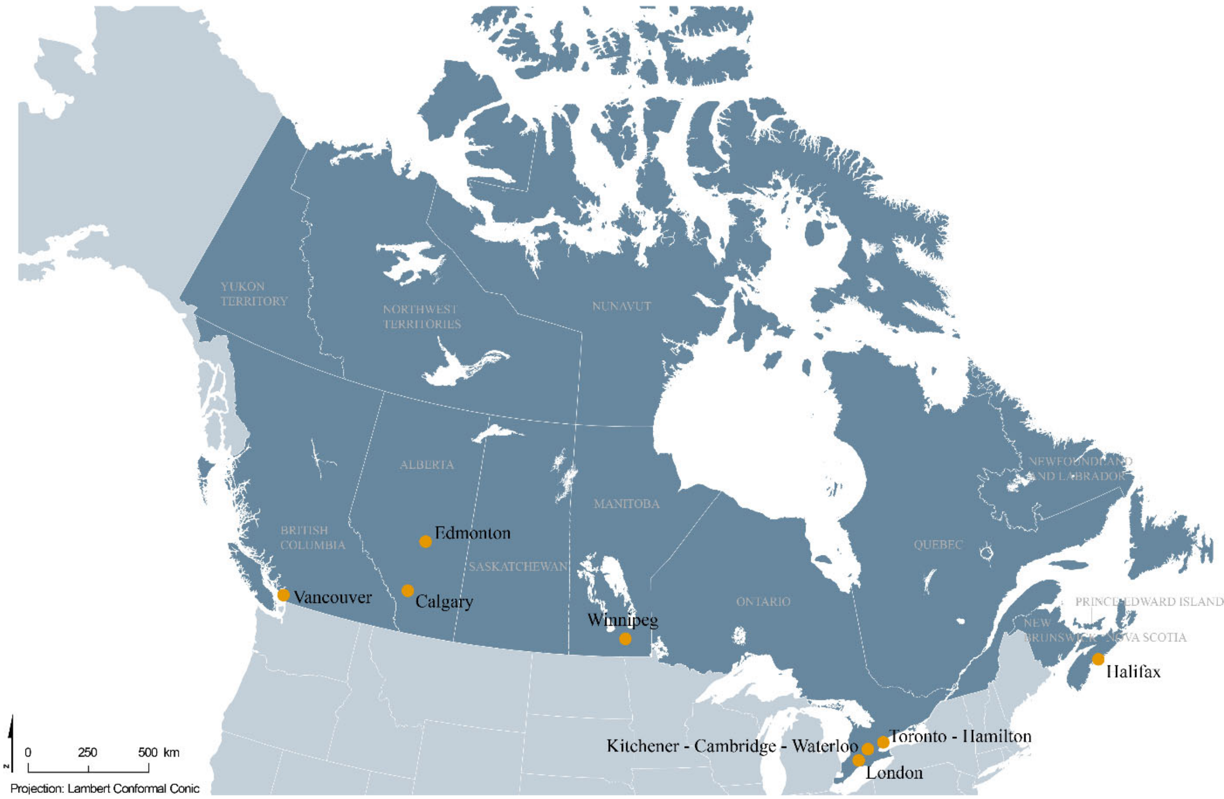

Figure 1 Context map of the eight metropolitan regions in the study

2. LITERATURE REVIEW

Health researchers have generally quantified spatial accessibility using relatively simple metrics such as the distance or time to the nearest service (*8*) as well as the service-to-population ratio which measures the availability of the service once potential demand from the population is accounted for (*9*). At the same time, transport researchers quantify accessibility as the number of opportunities that can be reached from a point within a time threshold by a specific mode, e.g. number of hospitals that can be reached within 45 minutes by public transport, which is also referred to as cumulative accessibility (*10*). Other researchers have used gravity-based accessibility measures to account for the increased friction of distance associated with services that are located further away (*11; 12*). However, cumulative measures are sometimes preferred for their ease of computation and interpretation while being highly correlated with gravity-based measures (*13*). Recent research has attempted to improve the measure of accessibility to incorporate variability in both the availability of opportunities at different times of the day (*14*) as well as availability of the transport system (*15*). However, Cui et al. (*16)* have shown that the use of more detailed data, which is time and resource-consuming to gather, does not always improve the evaluation of the impact of accessibility on various travel outcomes, such as commute duration and mode choice.

When used by themselves, these measures all have shortcomings: the service-to-population ratio does not consider whether an individual is able to realistically reach the healthcare service and is often calculated at aggregated spatial units too large to be meaningful (*17*); cumulative and gravity-based accessibility as well as distance to service measures do not consider the capacity of the service, i.e. the demand for access to one of 100 beds available at a hospital in a downtown centre is higher compared to one of 100 beds in a less dense suburban area. To address these shortcomings, researchers have developed the two-step floating catchment area (2SFCA) method

(*5; 6*) to control for travel impedance, capacity restrictions and competition effects (*9*). The 2SFCA method consists of two stages where the service-to-population ratio is first generated for each healthcare facility and then accessibility to the facilities is generated where the service-to-population ratio for each facility is summed for travel times less than the threshold travel time.

There is a significant body of empirical research quantifying spatial accessibility using the 2SFCA method (*18-21*). Some of this research aims to identify healthcare professional shortage areas using methods of spatial analysis (*18*) where others evaluate whether identified gaps are more pronounced for more disadvantaged groups in society (*20; 21*). In addition, researchers have examined the spatial accessibility to healthcare by various modes and found that accessibility is greater by car than public transport and walking, implying that limited access to healthcare can also be due to lack of access to a personal vehicle, or to inefficiencies in public transport systems (*19*). In other words, transport can be a barrier for accessing healthcare, with some studies indicating that individuals living in rural regions have it worse (*22*) .

Few studies have evaluated the degree to which spatial accessibility to healthcare influences reported healthcare utilization. Most studies use simple measures of spatial accessibility such as travel distance or time to the care facility (*8; 23; 24*) which, as mentioned previously, do not account for demand. However, two similar studies (*25; 26*) make use of the 2SFCA method with a gravity-based accessibility measure to evaluate the role of accessibility to healthcare on the odds of using emergency departments for primary care treatable conditions. In both studies, a lack of resources for primary care was linked to higher rates of preventable hospitalizations. Researchers Casas and Delmelle (*27)* have also considered the relationship between accessibility and healthcare utilization patterns in the context of a dengue fever outbreak in Colombia while accounting for the demand and supply of healthcare measured through a travel time usage index and a travel time index. They found that more than 90% of patients did not seek treatment at the closest healthcare facility, indicating that more influential factors aside from physical distance to a facility that shape healthcare utilization patterns.

The use of healthcare depends also on the predisposition of the individual to use services as well as their needs for care (*2*). Higher rates of consultation are observed for females (*28; 29*) and between age groups, those at the extreme ends of the spectrum exhibit higher consultation rates (*28*). However, for both sex and age, it has been observed that the difference is minimized when the need for care is accounted for (*30*). Psychological and attitudinal factors such as perceived susceptibility and perceived costs and benefits from seeking medical care are examples of determinants reflecting the perceived need for care (*31*). A low perception of one's health is correlated with more consultations (*32*). In addition, individuals who have chronic conditions that necessitate regular check-ups are more likely to consult general practitioners (*28; 33*); as are those who have a regular doctor whom they can visit easily (*29; 34*). Furthermore, utilization patterns differ between income groups for different types of healthcare services, but findings are mixed. Low-income populations have sometimes been linked to lower levels of regular and chronic care service utilization Arcury et al. (*22)*, and sometimes higher consultation rates for most types of services except for preventative services (*28*). This is consistent with other research indicating that preventive services are not delivered to those with the highest-risk (*35*).

3. DATA AND METHODOLOGY

3.1 Consultation with healthcare professionals

The dependent variable that we are concerned with in this study is whether an individual, living in one of the eight Canadian metropolitan regions, has consulted a healthcare professional at a hospital. As consultations can be, in most cases, a voluntary act of health-seeking individuals as opposed to emergent care, it is more worthwhile to examine the correlation between spatial accessibility and the utilization of this type of healthcare service. This information was obtained from the 2012, 2013, and 2014 cycles of the annual component of the Canadian Community Health Survey (CCHS) collected by Statistics Canada. The CCHS is a national, cross-sectional survey that collects information related to the health status, healthcare utilization and health determinants for the Canadian population. Each cycle of the survey, which has been conducted annually since 2007, relies on a sample of 65,000 participants from all provinces and territories (although not all components of the survey are answered by respondents in all provinces and territories depending on the survey cycle). Sample respondents are selected from the household Canadian population 12 years of age and older with an exclusion rate of 3%. Eight metropolitan areas were considered for this study for the purpose of pooling survey data to get a sample with enough observations for the statistical model. This also allows us to assess the general relationship between spatial accessibility and likelihood of consultations at a hospital.

In the survey (where the wording was the same for the three survey cycles that were used), a series of questions were asked regarding consultations with healthcare professionals. First, respondents were asked *"[In the last 12 months,] have you seen, or talked to any of the following health professionals about your physical, emotional or mental health*" with the healthcare professionals being: a) *a family doctor or general practitioner*, b) *eye specialist*, c) *other medical doctor or specialist*, d) *nurse*, and e) *dentist, dental hygienist or orthodontist*.

For each healthcare professional category, the respondents were then asked about the frequency of visit in the last 12 months. They were also asked about the location of the most recent contact (consultation) with a *family doctor or general practitioner*, another *medical doctor or specialist*, or *a nurse*. Since the accessibility data that we generated is to beds at a hospital, we consider a respondent as having consulted a healthcare professional at a hospital, if they have consulted with one of these three healthcare professionals at a hospital (*hospital emergency room* or *hospital outpatient clinic)*, as opposed to the other possible locations such as a doctor's office. A respondent observation was given a value of zero for the dependent variable if they did not consult these healthcare professionals or if they did not do so at a hospital.

For each respondent, their measured spatial accessibility (for the census tract of their residence) was matched using the postal code associated with each respondent against a vector data file containing the locations of postal code centroids to identify the census tract that each postal code is located within.

3.2 Spatial accessibility to hospital-based healthcare services

Three data inputs are required to generate accessibility measures to healthcare at the census tract level using the two-step floating catchment area (2SFCA) method: population, supply of healthcare services, and travel time by public transport between census tracts. Population data for each census tract was obtained from the 2016 Census. In this study, we define the supply of healthcare services to be the number of hospital beds staffed and in operation. This information was obtained through the Canadian Institute for Health Information (CIHI) for Canadian provinces in 2015-2016 (*36*) where the total number of beds associated with each hospital (including emergency rooms, outpatient clinics and specialized care) was provided and then geocoded using a Google API using the hospital name and address. As the CIHI data was not available for Quebec at the time of analysis, our geographic scope of analysis is limited to eight metropolitan regions, and does not include Ottawa-Gatineau, Montreal and Quebec City.

We decided to focus on hospitals as the healthcare service location of interest for two reasons: access to hospitals is generally less restricted across the country (e.g. physicians/family doctors can exercise discretion when choosing to take on patients so meaningful spatial access cannot be generated for these practices); and geographic access to these services implies longer travel distances which would require users to travel via motorized modes such as public transport. Furthermore, the specification of access to the number of beds available at each hospital captures the healthcare supply available to individuals and is a proxy for the level of service provided by the hospital (*37*).

To compute travel time by public transport between census tracts, the General Transit Feed Specification (GTFS) data containing the scheduled service for May 2017 (or as close as possible to May 2017) was first obtained from the transport agencies operating in each of the metropolitan areas. Then, using the *Add GTFS to a network dataset* toolbox in ArcGIS, a joint network between public transport and streets was created which enabled computation of travel time matrices between all pairs of census tracts within each metropolitan region. The public transport travel time includes access, egress, waiting, in-vehicle, and transfer times as applicable. The matrix was computed using fastest route calculations at 10 a.m. representing off-peak level of service on a regular Tuesday. While this time period was selected to reflect a more realistic view of the behavior of health-seeking individuals who may schedule non-emergent appointments at off-peak times, it may be valuable for future studies to examine the relationship between accessibility and utilization at different times of day, including at night.

The first step of the 2SFCA method is to generate the service to population ratio V_j for each hospital using **Equation 1**:

$$V_j = \frac{S_j}{\sum_k P_k\, f(t_{kj})} \; and \; \mathrm{f}(t_{kj}) = \begin{cases} 1 \; if \; t_{kj} \leq 45 \; minutes \\ 0 \; if \; t_{kj} > 45 \; minutes \end{cases} \qquad (1)$$

Where j denotes a hospital, S_j represents the capacity of the hospital (number of beds), P_k is the population in census tract k and t_{kj} is the travel time between census tract k and hospital j. $P_k\, f(t_{kj})$ can therefore be interpreted as the population at location k that can reach the hospital within 45 minutes by transit, assuming on-board capacity is unrestrained.

Then, accessibility to healthcare services A_i is computed using **Equation 2** by summing the service-to-population ratios for the hospitals that can be reached from each census tract centroid within 45 minutes:

$$A_i = \sum_j V_j \; \mathrm{f}(t_{ji}) \; and \; \mathrm{f}(t_{ji}) = \begin{cases} 1 \; if \; t_{ji} \leq 45 \; minutes \\ 0 \; if \; t_{ji} > 45 \; minutes \end{cases} \qquad (2)$$

Where i denotes a census tract, V_j is the service-to-population ratio for hospital j, and t_{ji} is the travel time between j and i via public transport. This measure indicates the number of beds that can be accessed within the threshold while accounting for the impact of competition as summarized by the service-to-population ratio. As specialized healthcare is typically provided at the metropolitan rather than the neighborhood level, the travel time threshold was selected to reflect regional accessibility where 45 minutes is commonly used in transport planning (*38*).

3.3 Other covariates and model development

In addition to the main explanatory variable of interest (accessibility), covariates obtained from the CCHS for each respondent living in one of the eight metropolitan regions of interest included: socio-demographic characteristics; self-perceived health; the presence of chronic disease conditions and whether they lived in an urban or rural area (**Table 1**). In addition, the survey cycle years (*Year*) are also included in the model as dummy variables to control for temporal influences.

Multilevel mixed effects logit models, extensions of logit regressions to address variability at both the census tract and region level, were developed to determine the correlation between spatial accessibility to hospitals of the home census tract, mediated by various socio-demographic characteristics, and the likelihood of an individual consulting a healthcare professional at a hospital using information collected in eight metropolitan areas. A three-level multilevel model is appropriate for this study due to the innately hierarchical structure of the survey data for survey respondents located within different census tracts within different metropolitan regions. This type of model accounts for the variations that occur not only with respondents from the same census tract, but also between census tracts (Level 2) and between the metropolitan regions (Level 3) considered in the study. Furthermore, a bootstrap technique was employed to minimize the effects of sampling error that arise when the model is run only once. By drawing samples each with a size n out of N observations with replacement and then repeating the regression process 50 times, we ensure that the models have converged and that the significance and confidence intervals of the explanatory variables are representative of the data.

Various trials of multilevel mixed-effects logit regressions models were carried out to test the influence of the various socio-demographic variables. We found that the personal education level of the individual was highly correlated with their household income level. As a result, this variable was removed from the final model. In addition, variables that were found to be insignificant, did not improve model fit and did not affect model stability when removed were finally removed from the final model including the number of children aged 5 and younger in the household and whether the respondent is a recent immigrant. We also tested the models with a squared term for age in addition to the linear term but found that both terms were insignificant. As a result, the squared term was dropped from the final model.

4. RESULTS AND DISCUSSION

4.1 Descriptive analysis

Descriptive statistics of the sample (the population that consulted with a healthcare professional at a hospital) were first generated (**Table 2**) where a few trends can be observed. A greater percentage of respondents who live in very high access census tracts, are older than 64, have four people living in the household, have no children aged 5 and younger, are part-time workers, have household income less than $50,000 CAD, have a post-secondary education, have a negative perception of their health, have a chronic condition or have a regular doctor reported having consulted with a healthcare professional at a hospital. Interestingly, the difference in the percentage of females who consulted compared to males is minimal. However, the subsequent step of regression modelling would provide more accurate results on the relationship between each of these variables and the likelihood of consultation, while controlling for the influence of all others.

TABLE 1 Variables used from the 2012, 2013, and 2014 cycles of CCHS

Variable	Description	Coding	Question in CCHS
Access	Accessibility to hospitals in 45 minutes	0…99.975	N/A
Age	Age of the respondent	12, …,102	DHH_AGE
HHsize	Number of persons in the household	0, …, 14	DHHDHSZ
Sex	Sex of the respondent	1 = female 0= male	DHH_SEX
HH5yr	Number of children 5 years old or younger in the household	0, …, 4	DHHDLE5
Work status	Work status of the respondent	1 = full-time 0 = part-time	LBSDPFT
Recent immigrant	Whether the respondent immigrated to Canada within 5 years of the year of the survey	1 = recent immigrant 0 = not recent immigrant	Coded using SDCFIMM
HHincome	Household income of the respondent	1 = none to $49,999 2 = $50,000 to $99,999 3 = more than $100,000	Coded using INCDHH
Pers. Edu.	Highest education level of the respondent	1 = Less than secondary 2 = secondary 3 = post-secondary	Coded using EDUDR04
Pos. Health	Whether the respondent has a positive perception of his/her general health	1 = good, very good, excellent 0 = poor, fair	Coded using GENDHDI
Chronic	Whether the respondent has a chronic condition*	1 = has a chronic condition 0 = does not have a chronic condition	CCC_031 – CCC_290
Regular Doc	Whether the respondent has a regular medical doctor	1 = has a regular doctor 0 = does not have a regular doctor	HCU_1AA

*Chronic conditions include asthma, arthritis, back problems, high blood pressure, migraine headaches, COPD, diabetes, heart disease, cancer, stomach or intestinal ulcers, effects of stroke, urinary incontinence, bowel disorder, Alzheimer's disease or dementia, mood disorder, anxiety disorder, fibromyalgia (2013 & 2014), scoliosis (2013 & 2014), chronic fatigue (2013 & 2014), and chemical sensitivities (2013 & 2014)

TABLE 2 Descriptive statistics of the population that consulted with a healthcare professional at a hospital in past 12 months, CCHS 2012, 2013, and 2014 cycles

Variable		Observations	Consulted a professional at a hospital (%)
Access	*< 45th percentile*	26,589	12.5
	45th to 90th percentile	27,524	12.4
	> 90th percentile	5,645	14.3
Year	*2012*	14,630	12.2
	2013	15,100	12.3
	2014	30,028	13.0
Age category	*12-17*	464	9.7
	18-24	4,657	9.9
	25-64	31,960	12.1
	65+	16,099	15.6
HHsize category	*1*	15,277	12.8
	2	20,300	12.4
	3	9,149	13.8
	4	9,730	14.5
	5+	5,302	11.7
Sex	*Female*	33,002	9.6
	Male	26,756	9.4
HH5yr category	*0*	53,301	12.9
	1	4,497	10.8
	2	1,748	8.5
	3+	212	10.4
Work status	*Full-time*	24,340	11.0
	Part-time	6,026	12.5
Recent immigrant	*Yes*	1,982	6.9
	No	15,847	11.2
HHincome category	*0 to 49,999*	21,440	13.4
	50,000 to 99,999	19,969	12.1
	> 100,000	18,349	12.2
Pers. Edu.	*< Secondary*	11,367	11.4
	Secondary	14,158	12.5
	Post-secondary	32,995	13.1
Pos. Health	*Yes*	52,150	11.1
	No	7,491	24.4
Chronic	*Yes*	35,361	16.3
	No	24,397	7.7
Regular Doc	Yes	54,513	13.0
	No	5,185	8.8

4.2 Statistical analysis

The aim of this paper is to understand the relationship between accessibility by public transport to hospitals and the likelihood of consultations with a healthcare professional within these hospitals. We applied a stepwise regression approach to reach the best model fitting and statistical significance among the tested variables derived from theory. Results of the multilevel logit regression that we ran using Stata 15 (**Table 3**) show that living in a census tract with higher spatial accessibility correlates with an increase in an individual's odds of consultation with a healthcare professional at a hospital, while controlling for predisposing and need factors. Specifically, we find that a one unit increase in accessibility (one additional bed/1000 individuals) is associated with an increased likelihood of hospital consultation of 1.4% (OR 1.014, p<0.1).

This result has two implications for professionals. The availability of healthcare services, measured using a service-to-population ratio, considers the balance between supply of services and potential competition between users. In other words, either the supply of services at the hospitals (proxied by the number of beds) or the demand from individuals within reach of the hospital can be managed. On the supply side, an increase in the number of beds or variety of services at hospitals can be beneficial to improve the consultation rates of health-seeking individuals. On the demand side, while it is undesirable to reduce competition for these services by limiting certain individuals' access to them, measures can be taken to manage the demand. For example, healthcare service providers can ensure that individuals are informed of the availability of beds or services at all nearby hospitals to distribute demand more appropriately.

On the other hand, adequate access to healthcare is also dependent on the quality of the transport system. As planners advocate for the use of public transport as opposed to private vehicles, it is important to consider its implications on access to healthcare and subsequent impacts on individuals' health outcomes. When public transport is unreliable or infrequent, (*39*) this makes it difficult for users to reach facilities on time for appointments or treatments. This issue is particularly evident for those who are older or have lower income and therefore less likely to have access to a personal vehicle. Therefore, improvements in transport services such as an expansion of the service area may be a way to improving public transport accessibility. As well, it is important to recognize healthcare facilities as key destinations to be connected to the existing system when planning for system expansions in order to improve access to these facilities.

Regarding the predisposing and need factors, we find that older individuals are not more likely to consult (based on a linear relationship) despite results from the summary statistics shown in **Table 2**. This finding has been observed by Nabalamba and Millar (*29)* as well where they cite that this is perhaps due to the inclusion of other factors in the model that better address the need for consultations like the presence of chronic conditions, which are more prevalent in older individuals. We find that females are more likely than males to consult even after the effects of chronic conditions and self-perceived health are accounted for. This finding is also supported in the same study by Nabalamba and Millar (*29)*.

Moreover, the likelihood of consultation does differ between income groups and a consultation gradient can be observed where, compared to the low-income, the middle- and high-income households, are more likely to consult for healthcare. Although the difference is less pronounced and not statistically significant for middle-income households (OR 1.039), the likelihood of consultations is substantially higher for high-income individuals by around 24% (OR 1.236, p<0.01). This finding has been previously observed as well (*29*). While this is contrary to what is shown in **Table 2**, this may demonstrate that there are additional factors at play that once controlled for, decrease the likelihood of consultations for the low-income group. In addition, household size is negatively correlated with consultations where an increase of one additional person decreases the likelihood of consultation by 5.7% (OR 0.943, p<0.01). Individuals who worked part-time were more likely to consult a healthcare professional at a hospital than full-time workers, likely due to more flexible schedules that allow them to engage in consultations.

As expected, individuals having a positive perception of one's health status are half as likely to consult a healthcare professional at a hospital (OR 0.540, p<0.01) whereas the presence of a chronic condition greatly increases the likelihood of consultations by 74% (OR 1.738, p<0.01). Lastly, having a regular doctor increases the likelihood of consultations at a hospital by 31% (OR 1.313, p<0.01) as individuals with regular doctors are more likely to have more health problems (*29*), so even if they have a family doctor as their regular doctor, they may be more likely to visit a hospital for a consultation with a specialist or other professional other than their regular doctor. Note that the survey year does not seem to corelate with an increase or decrease in the likelihood of consultation and these cycle variables are dropped from the final model output.

TABLE 3 Results of multilevel mixed-effects logit regression model

Variable	Odds Ratio		95% CI	
Access	1.014	*	1.000	1.028
Age	0.998		0.994	1.002
HHsize	0.943	***	0.909	0.978
Sex (ref. = male)	1.133	**	1.023	1.255
HHincome (ref. = low)				
Middle	1.039		0.922	1.172
High	1.236	***	1.094	1.397
Work status (ref. = full-time)	1.130	**	1.024	1.248
Pos. Health (ref. = negative)	0.540	***	0.471	0.621
Chronic (ref. = no)	1.738	***	1.587	1.904
Regular Doc (ref. = no)	1.313	***	1.187	1.452
Constant	0.098	***	0.070	0.135
No. of observations	30,339			
Log likelihood	-9645.74			
AIC | BIC	19319.48 | 19435.97			
Intraclass correlation	Estimate	Std. Err.	95% CI	
ctuid	9.06E-27	1.96E-13	.	1
cma|ctuid	0.119	0.011	0.098	0.143
Random-effects parameters	Estimate	Std. Err.†	95% CI†	
Var. of level two intercept	3.38E-26	0.530	.	.
Var. of level three intercept	0.444	0.545	0.040	4.917

* p<0.1 ** p<0.05 *** p<0.01

† Bootstrapped standard error and confidence interval

5. CONCLUSION

This study examines the association of spatial accessibility to hospitals by public transport with the likelihood of the last medical consultation with a medical doctor or nurse at a hospital using data for eight Canadian metropolitan regions. We used the preferred method for measuring spatial accessibility – the two-step floating catchment area (2SFCA) method – to account for both the supply and demand for healthcare as quantified by the service-to-population ratio and the performance of the public transport system. A multi-level logit regression model was then developed to estimate the correlation between accessibility, while controlling for factors reflecting the individual predisposition to seek healthcare and the need for care, and the likelihood of hospital consultations. Self-reported consultations and socio-demographic information were obtained from multiple cycles of the Canadian Community Health Survey (CCHS) for respondents residing in the eight metropolitan regions.

This study confirms that spatial accessibility is positively associated with the likelihood of consultations where an one unit (one bed/1000 individuals) increase in accessibility correlates with a 1.4% increase in the likelihood of an individual consulting a healthcare professional at a hospital, after controlling for the influence of other determinants of healthcare utilization related to individual characteristics and their need for healthcare. We also observed a positive income gradient. Age was not a significant variable as observed in other studies when the need for healthcare, whether perceived or real, are accounted for. However, we found that females were more likely to consult with a healthcare professional compared to males, which has been observed in similar research as well. Regarding need, a positive perception of health, the existence of chronic conditions and access to a regular doctor were strong predictors of hospital consultations.

However, there is potentially still a disconnect between spatial accessibility and healthcare utilization as individuals may not be aware of their actual spatial accessibility and, for various reasons, have a different perception of the accessibility of their home location to healthcare than the one that can be measured. As mentioned in Section 2, researchers can obtain information about individual's perceived access to healthcare using surveys that are specific to this topic. Future studies should capitalize on this information to examine whether measured spatial accessibility (e.g. computed using the 2SFCA method) corresponds with individuals' perceptions of accessibility. If there is a significant mismatch between the two, further actions to improve their objective spatial access may not necessarily be effective and more analysis is needed to decipher the real reasons for the perceived barrier when there isn't one.

There are certain limitations associated with the data and methodologies employed in this study. Even though existing literature has shown that car ownership is an important determinant of healthcare accessibility, this information was not asked in the CCHS and therefore did not enter the model as a control variable. In addition, as the CCHS data used in the study is from 2012-2014 and the public transport network data is from 2017, this could have introduced some inaccuracies in the study results as there may have been changes to the public transport system after the survey period that could have influenced healthcare utilization by survey respondents, yet we expect these to be minor. As well, the interaction between the socio-demographic variables such as income and accessibility can be examined further in the model to reveal additional changes in the income gradient. Furthermore, it is valuable to note that averaged over the three survey years, 5.5%, 22.4% and 30.2% of all consultations with family doctors or general practitioners, nurses and other medical doctor or specialists, respectively, occur at hospitals. For family doctors and other doctors, the main location of consultations (79.2% and 56.3% respectively) is at the doctor's offices, which is to be expected. On the other hand, consultations with nurses occur at a wide range of locations, including doctor's offices (17.7%), as well as at community health centres (13.9%) and at home (13.7%). While hospitals may not be the main location of consultations with all three healthcare professionals, a fair number of consultations do take place there, particularly for consultations with nurses and other doctors. However, it may be even more valuable to examine whether spatial accessibility to other facilities for consultations including doctor's offices is correlated differently with the likelihood of consultations at those locations. In addition, the use of hospital beds to reflect the capacity of hospitals may not be completely suitable when examining the likelihood of consultations where beds are not necessarily needed. However, information about more relevant indicators such as the number of doctors or services available were not available to us but would be useful in future studies. Lastly, it is important to note that the CCHS does not specify the type of consultation that was done but this information would be useful for future studies to reveal additional socio-demographic differences, particularly between sexes and age groups, on the likelihood of consultations for different purposes.

This research demonstrates the important role that spatial accessibility plays to enable individuals to access healthcare services. Particularly, better spatial accessibility to hospitals may lead to higher rates of healthcare consultations and this could have far-reaching implications for public health: as more individuals, particularly those with chronic health conditions or with higher needs for care, are able to consult healthcare professionals, it may be more likely that illnesses can be addressed early on to improve overall quality of life and to alleviate stress on the healthcare system. Moreover, more equitable spatial accessibility could be a mechanism to reduce disparities in health between advantaged and disadvantaged groups. Various strategies can be implemented to improve spatial accessibility to healthcare, namely through better public transport services connecting individuals to hospitals and a supply management that considers the current spatial accessibility. The study emphasizes the importance of considering spatial accessibility within healthcare policies. Certainly, as virtual consultations become more popular in the future, it will offer a new opportunity to overcome the physical distance separating individuals from healthcare facilities. This will have implications for how healthcare services will be delivered in the future as more individuals are able to receive treatment advice at home to a certain extent. Nonetheless, in-person consultation will remain a key component of health care services.

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AUTHORS CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Boisjoly, Wasfi, Orpana, Manaugh, Buliung, Kestens, & El-Geneidy; data collection: Cui, Boisjoly, Wasfi, Orpana, Kestens, & El-Geneidy; analysis and interpretation of results: Cui, Boisjoly, Wasfi & El-Geneidy; draft manuscript preparation Cui, Wasfi, Orpana, Manaugh, Buliung, Kestens, & El-Geneidy. All authors reviewed the results and approved the final version of the manuscript. The authors do not have any conflicts of interest to declare.

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