Municipal transportation policy as a population health intervention: estimating the impact of the *City of Ottawa Transportation Master Plan* on diabetes incidence

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Abstract

Intervention Physical inactivity is an important behavioral risk factor for chronic disease in Canada. *Individual-level* strategies are used in clinical medicine to target individuals for preventive intervention based on one or more risk factors. In contrast, this study examines the impact of a *population-level* intervention: a municipal policy outside the healthcare sector that influences the built and social environment.

Research question What is the preventive effect of a municipal transportation policy to increase active transportation on a chronic disease outcome measure—diabetes incidence—when it is viewed as a population-level health intervention to increase physical activity?

Methods The impact of increases in active transportation for regular commuting to work in the city of Ottawa, Ontario was modeled to estimate number of diabetes cases prevented over 10 years. As a health-sector comparison, the reduction in incidence was equated to an individual-level approach to prevention targeting those who are inactive, meant to represent a clinical preventive intervention.

Results The population-level policy shift could prevent as many as 1620 incident cases of diabetes over 10 years, the largest number prevented by increases in public transit use. This population effect was equal to 17,300 inactive individuals or 12,300 inactive individuals > 45 years old undertaking a clinical preventive intervention to increase physical activity.

Conclusion The results demonstrate why public health matters today as population-level interventions that exist as policies outside the healthcare sector, supported by public health, may have an unrecognized and therefore underappreciated impact on population health.

Résumé

Intervention La sédentarité est un important facteur de risque comportemental de maladie chronique au Canada. Des stratégies *individuelles* sont utilisées en clinique pour cibler les personnes qui ont besoin d'une intervention préventive parce qu'elles présentent un ou plusieurs facteurs de risque. Notre étude, par contre, porte sur l'impact d'une *intervention en population* : une politique municipale hors du secteur des soins de santé qui influence le milieu bâti et l'environnement social.

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Question de recherche Quel est l'effet préventif d'une politique municipale visant à accroître le transport actif sur un indicateur de résultat de maladie chronique—l'incidence du diabète—quand cette politique est considérée comme une intervention sanitaire pour accroître l'activité physique dans la population?

Méthode Nous avons modélisé l'impact des hausses du recours au transport actif pour se rendre au travail à Ottawa (Ontario) afin d'estimer le nombre de cas de diabète évités sur une période de 10 ans. Par mesure de comparaison avec le secteur de la santé, la baisse d'incidence a été assimilée à une démarche individuelle de prévention ciblant les personnes sédentaires, afin de représenter une intervention clinique préventive.

Résultats Un tel changement de politique touchant l'ensemble de la population pourrait éviter jusqu'à 1620 cas incidents de diabète sur 10 ans, le plus grand nombre de cas étant évités par les hausses de l'utilisation des transports en commun. Cet effet populationnel était égal à 17,300 personnes sédentaires ou à 12,300 personnes sédentaires de > 45 ans ayant suivi une intervention clinique préventive pour accroître leur niveau d'activité physique.

Conclusion Nos résultats montrent que la santé publique importe encore aujourd'hui, car les interventions en population qui existent sous forme de politiques hors du secteur des soins de santé mais avec le soutien de la santé publique peuvent avoir un impact méconnu, et donc mal apprécié, sur la santé des populations.

Keywords Active transportation · Physical activity · Diabetes · Public health · Policy

Mots-clés Transport actif · Activité physique · Diabète · Santé publique · Politique (principe)

Introduction

Substantial gains in life expectancy and quality of life in Canada could be achieved through increases in physical activity (Manuel et al. 2016). Low levels of physical activity raise an individual's risk of premature death and chronic diseases including diabetes, cardiovascular disease, some cancers, and depression (Warburton et al. 2010; WHO 2010). The importance of physical inactivity as risk factor for chronic disease is not only a reflection of the individual hazard but also its high prevalence in many populations where technological advancement has created an environment where physical activity is no longer a requirement of everyday life (Guthold et al. 2018; Ng and Popkin 2012). Canadian physical activity guideline recommendations call for 150 min per week of moderate to vigorous-intensity activity for adults to reduce the risk of premature death and prevent chronic disease (Tremblay et al. 2011).

A range of health intervention strategies have been proposed to address the problem of physical inactivity—many are intensive individual-level interventions such as exercise programs or lifestyle counseling targeting individuals who are physically inactive (Kahn et al. 2002). It has been argued that the pervasiveness of physical inactivity makes it unlikely to be solved solely through a classic medical approach and requires broader community-wide strategies, addressing the social and environmental context in which people live, which often fall within the domain of the public health sector (Kohl 2012). According to Last (2001), public health is the “organized efforts of society to keep people healthy and prevent injury and premature death.” Public health action focuses on population-level interventions via programs or policies that exist in sectors that may lie outside the formal healthcare system, in recognition that the environment and social contexts in

which people live are important determinants of health (Hancock 2017). The field of population health intervention research is the study of these interventions in terms of their differential value and health impacts (Hawe and Potvin 2009). Physical inactivity in the Canadian population is a model risk factor for evaluating a population-level intervention to address chronic disease incidence. Recently, there is a growing body of literature on population-level strategies that aim to alter the built environment to make physical activity a more integrated component of daily life through changes to infrastructure and the social environment that, in turn, promote uptake of walking, cycling, and/or public transit (McCormack and Shiell 2011). As lack of leisure time is often cited as a barrier to individuals meeting physical activity guideline levels, active transportation, defined broadly as using human-powered transport to get to destinations, offers a practical solution by incorporating energy expenditure into a necessary activity of daily living (Cerin et al. 2010). Since interventions intended to change patterns of active transportation often occur on a broad scale and are difficult to measure directly, modelling approaches have become increasingly used to estimate their impacts on health (Tétreault et al. 2018).

Intervention

The population-level intervention is the active transportation policy component of the *City of Ottawa Transportation Master Plan* (TMP) that aims to increase modal share of public transit, walking, and cycling for regular commuters to/from workplaces (City of Ottawa 2013). Modal share is a measure of the proportion of trips that are taken using a particular mode of transit additive to 100%, so increases in one active

transportation mode such as cycling are meant to occur at the expense of the share of trips taken regularly by automobile, considered a less desirable form of transportation from a planning perspective. In this study, the TMP policy targets, intended to increase modal share of AM peak-period trips which approximate regular commuting trips to a workplace, is viewed as a population-level intervention to promote health through the prevention of a chronic disease: diabetes. It is important to note that the rationale for these policy targets was devised outside the health sector and that health impacts were not a primary consideration in their development, but rather the costs associated with infrastructure and traffic congestion from automobile use balanced with what has been achieved in other jurisdictions through changes in urban planning. To translate the effect that the TMP policy shift would have on the health sector, we compare the number of diabetes cases prevented to the number of individuals who would need to be given a hypothetical, individual-level intervention that targets inactive adults to increase physical activity to a volume-level equivalent with *Canadian Physical Activity Guideline* recommendations. This is meant to mimic a classic, clinical preventive medicine approach, such as may be seen in a primary care setting, where individuals are identified as having a risk factor that places them at increased risk of a disease, in this case physical inactivity, and are provided an intervention to reduce their risk.

Research question

What is the preventive effect of a municipal transportation policy to increase active transportation, as outlined in the *City of Ottawa Transportation Master Plan*, on a chronic disease outcome measure—diabetes incidence—when it is viewed as a population-level health intervention to increase physical activity?

Methods

The modelling approach of this study followed the methodology of Mowat et al.'s *Improving Health by Design Report* (2014) which estimated the health benefits of funding a plan to vastly increase infrastructure for public transit and active transportation via walking and cycling in the Greater Toronto/Hamilton Area, a larger metropolitan area located in the same province as Ottawa. For simplicity, we modeled the number of diabetes cases that would be prevented over a span of 10 years if the 2031 target levels of active transportation in the TMP are achieved, assuming no change in the population size or structure from 2011. The model equation used to calculate the intervention effect is: *Population-level effect* = *average baseline risk* × *intervention efficacy* × *population coverage*. The

overall method for the analysis is shown in Fig. 1. The calculation of each of the three model input parameters is described below.

Average baseline risk

Average baseline risk of diabetes for the adult population of the City of Ottawa was estimated using the population-based risk algorithm known as the Diabetes Population Risk Tool (DPoRT), which was created using Canadian Community Health Survey (CCHS) responses (Statistics Canada 2013a) and validated and calibrated to the Ontario population using the Ontario Diabetes Registry (Rosella et al. 2011). In the adult (> 20 years old), non-pregnant population, incident physician-diagnosed diabetes is known to be almost exclusively type 2 diabetes mellitus (Lipscombe and Hux 2007). SAS 9.4 was used to apply the risk algorithm to the CCHS Public Use Microdata File for the City of Ottawa to estimate the 10-year risk of developing physician-diagnosed diabetes in both men and women classified by two age categories: 20–44 and 45–64. An average risk was calculated by weighting the age-category risk to the age structure of the population. The 20–64 age range was chosen to estimate the average risk of the bulk of the working-age population that would commute on a regular basis. The CCHS excludes persons living on reserves and other Aboriginal settlements in the provinces, full-time members of the Canadian Forces and the institutionalized population (collectively representing less than 3% of the total Canadian population). Additionally, we excluded those who were classified as pregnant, those who had missing information for BMI, and those who self-reported being diagnosed with diabetes, as diabetes was the primary outcome of interest. The average 10-year baseline risk was 11.7% for the 20–64-year-old population. Since it is likely that those who will take up active transportation are younger than the general population and increasing age is an important risk factor for new cases of diabetes, a sensitivity analysis was undertaken using the average baseline risk assuming only individuals < 45 years old shift to active transportation under the TMP, which was a population baseline risk of 4.7%.

Intervention efficacy

To determine the intervention efficacy or relative-risk reduction associated with an individual's increase in routine active transportation, we estimated average daily energy expenditure based on the volumes expected to occur on average over 1 year for public transit (via coincidental walking), walking, and cycling to/from the workplace (i.e., two-way trips). We followed the method used to calculate the leisure-time Physical Activity Index (PAI) for the CCHS (Gilmour 2007), where average daily energy expenditure is calculated by multiplying the number of times the activity was performed by the average

Fig. 1 Depiction of the comparative analysis of the population-level intervention in terms of cases of diabetes prevented (primary outcome) matched to the number needed to receive the individual-level intervention

duration of the activity and the estimated energy cost in Metabolic Equivalents of Task (METs). MET is a measure of the rate of energy expenditure from an activity with the reference value of 1 MET being energy expenditure rate at rest equal to 1 kcal/kg/day. Different individuals may expend energy at different rates (METs) for the same activity, so MET values are often expressed as ranges by physical activity type. In our analysis, we employed the reference MET values for walking and cycling that are used by Statistics Canada to calculate the Physical Activity Index (PAI) (Statistics Canada 2013a). This uses a conservative at the lowest end of the MET range estimates for walking (3.00 METs) and cycling (4.00 METs). The calculation of energy expenditure provides a value with the units of MET-hours which represents the equivalent number of hours at a MET rate of 1 or a resting metabolic rate. This enables energy expenditure to take on additive values that can be used to compare volumes of physical activity over time periods. To estimate the average volumes of walking and cycling used for active transportation to/from work in Ottawa, the Ottawa Origin–Destination Survey (ODS) for 2011 provided the average trip length in kilometres based on calculations of approximated locations of home and workplace following city transportation network routes (TRANS Committee 2013). The duration of the average trip was then calculated assuming a speed of walking of

4.8 km/h and a speed of cycling of 14 km/h. Since the distance covered by walking for public transit trips is not captured in the ODS, only the full trip distance, we assumed that public transit results in 15 min of extra walking per day based on Rissel et al. (2012). Averaged out over the year assuming frequencies that would represent regular commuting patterns because of weekends and holidays based on the estimates of Mowat et al. (2014), this equaled about 10 min of additional walking per day as part of taking public transit, and about 17 additional minutes for walking and cycling. An example calculation of additional daily energy expenditure is shown in Fig. 2. The additional daily energy expenditure was 0.48 MET-hours for public transit via walking, 0.83 MET-hours for walking, and 1.1 MET-hours for cycling.

A published meta-analysis of prospective cohort studies was used to provide the average diabetes relative risk reduction for the equivalent of 150 min of moderate-intensity physical activity per week (Jeon et al. 2007). We adjusted the risk reduction by taking the average volume of walking and cycling used for each type of active transportation and assuming a log-linear dose–response relationship between the additional daily energy expenditure and diabetes risk reduction observed in the meta-analysis. Table 1 shows the summary of the inputs used to calculate the risk reduction for diabetes for each type of active transportation. The estimated 10-year risk reduction

Fig. 2 Example calculation of additional daily energy expenditure from walking to/from work

$$\begin{aligned}
 \text{Average frequency (days per year)} &= 4 \text{ days/week} \times 46.5 \text{ weeks/year} \\
 &= 186 \text{ days per year} \\
 \text{Duration (hours/day)} &= \frac{1.30 \text{ km trip distance} \times 2 \text{ trips/day}}{4.80 \text{ km/hour}} \\
 &= 0.540 \text{ hours/day} \\
 \text{MET-rate value of walking} &= 3.00 \text{ METs} \\
 \text{Additional daily EE} &= \frac{\text{Frequency (days/year)} \times \text{Duration (hours/day)} \times \text{MET-rate value (METs)}}{364.25 \text{ days/year}} \\
 &= \frac{186 \text{ days/year} \times 0.54 \text{ hours/day} \times 3.00 \text{ METs}}{364.25 \text{ days/year}} \\
 &= 0.83 \text{ MET-hours}
 \end{aligned}$$

for diabetes was 0.12 for regular commuting by public transit, 0.23 for walking, and 0.32 for cycling.

Population coverage

We assumed 400,000 regular commuters to workplaces in Ottawa based on the National Household Survey estimates of total employed population aged 15 years and over by place of work status (Statistics Canada 2013b). To account for the fact that a proportion of this population already meet the physical activity guidelines during leisure time and would therefore not benefit from increased physical activity through active transportation, we removed 31.6% of the population representing the cohort who are considered “active” in leisure time according to the CCHS, leaving a population of 273,600 commuters who could benefit from switching to active transportation. We then calculated the absolute difference in the number of individual commuters who would need to take up each domain of active transportation to/from work to reach the targets for modal share from the 2011 baseline for public transit, 26.0% from 22.4%; walking, 10% from 9.5%; and cycling, 5.0% from 2.7%. As the intent of the policy targets outlined in the TMP is that individuals will switch from regular commuting by automobile to one of these forms of active transportation, we assumed that the increases would replace automobile users and that there is no

switching between active transportation types to meet the targets. In absolute terms, the assumption was that 17,500 adults in Ottawa would switch from automobile use to one of three forms of active transportation for regular commuting to work: 9850 to public transit, 1370 to walking, and 6290 to cycling.

Outcome comparison

As a comparator intervention to place the population-level intervention in a health sector context, we modeled a classic clinical preventive intervention approach using the same equation, but in reverse. Starting from the number of diabetes cases prevented by the population-level intervention, we estimated the number of currently inactive individuals who would need to take up 150 min of brisk walking per week to meet the *Canadian Physical Activity Guidelines* recommendation for aerobic physical activity for adults (Tremblay et al. 2011). Inactivity for this group was defined based on the CCHS definition (Gilmour 2007): a PAI of less than 1.5 kcal/kg/day. The efficacy of the intervention for the individual-level approach was taken from the same meta-analysis used to estimate efficacy for the population-level intervention, Jeon et al., which provided a point estimate relative risk of 0.70 based on 150 min of brisk walking per week compared to almost no walking (2007).

Table 1 Summary of inputs for calculation of intervention efficacy of the population-level intervention through daily active transportation for each domain

	Public transit	Walking	Cycling
Average two-way trip distance (km)	N/A	2.60	10.2
Average trip speed (km/h)	N/A	4.80	14.0
Average number of days per week	5.00	4.00	4.00
Average number of weeks per year	46.5	46.5	36.0
Average daily duration over 1 year (h/day)	0.160 ^a	0.276	0.289
MET rate of activity (METs)	3.00 ^a	3.00	4.00

^a Assumed average total of 15 min daily walking as per Rissel et al. (2012)

Results

The estimated number of diabetes cases prevented via the population-level intervention was 1620, or roughly 4% of all incident cases of diabetes expected to develop in the 10-year period for the 20–64 year-old population of Ottawa (Table 2). The largest number of cases prevented was for public transit, 1000 cases, followed by cycling at 500 cases and then walking at 123 cases. In sensitivity testing, where only the young adult population was presumed to be impacted by the population-level intervention, the total number of cases prevented was 650; 403 from public transit, 50 from walking, and 201 from cycling.

Table 3 shows that based on the effect of the population-level intervention, the number of currently inactive individuals who would need to receive an individual-level intervention is approximately 17,300. When the individual-level intervention was assumed to be limited to only those > 45 years old who are at higher risk, this number decreased to 12,300. The sensitivity analysis was also applied to this calculation by assuming that only young adults would take up active transportation for commuting, which would equate to 6930 inactive individuals or 4940 inactive individuals > 45 years old receiving an individual-level clinical preventive intervention.

Discussion

Using routinely collected data, we were able to derive an estimate of the impact of the City of Ottawa's TMP active transportation goals for the commuting-to-work population on the incidence of diabetes in Ottawa. This effect was also translated into a health-sector relevant comparison showing the scale required for an individual-level clinical preventive intervention to have comparable effectiveness on diabetes incidence. A high-degree of caution is needed in interpreting the results due to the numerous modelling assumptions and the estimates should be considered as “ballpark” figures rather than precise measures. Nevertheless, there is value in the comparative analysis and a number of insights can be gleaned

from the results. Notably, the impact of a transportation policy outside the health sector could have an underappreciated impact on population health and healthcare, which goes unnoticed simply because it has not been quantified in health terms. As noted, the policy targets of the TMP were devised independently of health considerations and were adopted based on perceived benefits to the transportation network and environment from reduced automobile use during peak hours, so the impacts on health are considered additional secondary benefits. Second, population-level interventions have the potential to be quite powerful due to the “strength in numbers” despite a relatively weak individual-level effect. This is readily seen in the increases in public transit accounting for the greatest proportion of diabetes cases prevented, despite having the smallest relative risk reduction of the three active transportation types modeled. In other words, even though routine public transit use results in only a small decrease in individual risk, the population-level impact is largest because many people would be impacted by adding 10–15 min of physical activity to their regular routine. The results also demonstrate the importance of baseline risk on the impact of the intervention. It was evident that the simple demographic indicator of increased age has a powerful effect on baseline diabetes risk, surpassing that of younger adults who report low levels of physical activity. As such, targeting an older age group for intervention in combination with those who are sedentary vastly improves the efficiency of the preventive strategy. This means that both population-level interventions and clinical preventive interventions would have a greater impact if focused on older adult populations.

Although population-level and individual-level preventive interventions are not mutually exclusive, nor is one solely within the domain of any one sector, it is largely the public health sector that seeks to employ population-level health interventions, often realized through partnerships with other sectors or decision-making support to policy-makers. In Ottawa, the public health sector is municipally based, which creates an opportunity to collaborate with municipal partners in the transportation sector and inform policy-makers about the health impacts

Table 2 Number of diabetes cases prevented via the population-level intervention assuming a general adult (age 20–64 years) and a young adult (age 20–44 years) population (pop.) taking up active transportation (AT) as a result of the City of Ottawa TMP

AT mode	Average baseline 10-year diabetes risk (%)		Efficacy of intervention (relative risk)	Population coverage (number of individuals taking up AT)	Number of diabetes cases prevented ^a	
	General adult pop.	Young adult pop.			General adult pop.	Young adult pop.
Public transit	11.7	4.70	0.870	9850	1000	400
Walking	11.7	4.70	0.770	1370	120	50
Cycling	11.7	4.70	0.680	6290	500	200
Total	—	—	—	17,500	1620	650

^a Totals are rounded to three significant figures

Table 3 Number of inactive individuals, and inactive individuals age ≥ 45 years, needing to adhere to an individual-level intervention to match the effect of the population-level intervention assuming general adult (age 20–64 years) and young adult (age 20–44 years) populations (pop.) taking up active transportation (AT) as a result of the City of Ottawa TMP

Target pop. for individual-level intervention	Number of diabetes cases prevented to equal population-level intervention ^a		Average baseline 10-year diabetes risk (%)	Efficacy of intervention (relative risk)	Number of individuals needing to adhere to the individual-level intervention	
	General adult pop.	Young adult pop.			General adult pop.	Young adult pop.
Inactive	1620	650	13.4	0.700	17,300	6930
Inactive and age ≥ 45 years	1620	650	18.8	0.700	12,300	4940

^a Matched to number of diabetes cases prevented by increases in active transportation as a result of the City of Ottawa TMP (see Table 2)

of planning decisions. The City of Ottawa public health unit, Ottawa Public Health, is one of several local public health agencies in Canada that collaborate with city land and transportation planning departments to support policies that promote health and reduce health inequities (Miro et al. 2014).

This study's findings are comparable to those of other studies that have modeled the effects of population-level transportation strategies supported by public health at the local or regional level to prevent chronic disease and related mortality. Mowat et al. (2014) found that if a similar transportation policy initiative in the Greater Toronto and Hamilton Area (GTHA) called *The Big Move* was implemented in the current population, it would result in 1061 prevented cases of diabetes per year over its lifespan with an estimated cost-savings of \$250 million in lifetime medical costs of diabetes cases prevented. The GTHA study also demonstrated significant benefits in terms of prevented deaths and reductions in air pollution. A modelling study in San Francisco Bay area also found that a large-scale transportation policy, with a primary intended aim of reducing greenhouse gas emissions, would have a large net improvement in population health based on reductions in cardiovascular disease and diabetes (Maizlish et al. 2013).

There are several limitations to the study that must be considered with each of the three components of the model: average baseline risk, efficacy of the intervention, and population coverage. In estimating baseline risk of diabetes in the study population, the DPoRT algorithm was used on publicly available data, but other risk algorithms for diabetes, such as those used in clinical settings, may have resulted in slightly different estimations of diabetes risk, although in what direction is not clear. Additionally, average baseline risk was determined by using group averages for three different age categories. Since risk was estimated based on aggregate data, there is a loss of precision in the estimate of diabetes cases prevented that would not have occurred if each individual's risk had been calculated using a multivariable risk algorithm independently. A primary limitation to this study is the estimate of intervention efficacy. The relative risk reduction was applied uniformly to those

receiving the intervention for each type of activity modeled. In other words, it is assumed that the relative risk reduction is the same for all individuals when individuals within the population will undoubtedly vary with regard to the benefit obtained from AT due to variation in distances traveled, frequency, and intensity. The relative risk reduction from additional energy expenditure from physical activity also depends on the baseline level of activity in all domains, which was not available for this study. The exact dose–response curve for physical activity and health outcomes such as diabetes have not yet been fully characterized in the literature (Götschi et al. 2015), but there is likely a steep rise in the risk reduction for chronic disease health outcomes going from zero or extremely low levels of activity to low-moderate activity levels and a threshold at which further activity has no health benefit (Lee and Skerrett 2001). We attempted to account for this plateau at higher levels of physical activity by excluding a proportion of the population that already is considered “active” from obtaining benefit from the population-level intervention.

However, among the commuters taking up active transportation, some individuals would reach levels along the plateau of the curve, in excess of the additional benefits of physical activity on diabetes prevention. This results in an overestimate of the effect of the population-level intervention and could be improved by taking into account individual baseline activity levels in the model.

We also assumed that the setting in which physical activity occurs (e.g., for recreation, active transportation or an occupation) has no bearing on overall risk reduction. Physical activity for different purposes may have a different impact on risk of chronic disease at equal volumes of energy expenditure because of different levels of intensity over time in these different domains. There is also the potential that those who take up active transportation may decrease their activity in other domains through activity replacement, resulting in a reduction in the estimated net gain in additional energy expenditure. Furthermore, we assumed that the risk of the individuals who take up the intervention was similar to that of the general

population when, in reality, this is unlikely and results in an overestimate of the effect, as those who choose to take up AT are more likely to have fewer lifestyle risk factors for diabetes and therefore have a lower baseline risk than the general population. A similar effect is demonstrated in the sensitivity analysis, which showed that increasing active transportation among young adults has a much lower effect on diabetes prevention. This highlights the importance of active transportation policies and programs enticing those who are not already physically active in their leisure time if they are to maximize the population health benefit. Another limitation is that the overall population of commuters in the adult population is not well known, which may affect the population coverage estimate. The ODS data provided information based on volume of trips as opposed to individual commuter (person-level) data, so our volume of commuters in the adult population is based on National Household Survey responses, which included all individuals > 15 years of age with a place of employment outside the home, meaning that our estimate of the regular commuting population in the 20–64 age range may be high. This likely has only a minor impact on the results as it is the difference between baseline and target numbers rather than the total population size that defines the population coverage of the intervention, and the intent of the policy targets was clearly to shift a large number of regular workplace commuters to active transportation in Ottawa on the order of what was modeled in this study. Given that the above assumptions combined tend toward an overestimate of effect, the estimates of diabetes cases prevented should be viewed as optimistic or high end of what might be expected in the real-world setting.

Despite the limitations, there are several reasons that the modelling approach is useful for population health intervention research. As many large cities in Canada, including Toronto, Montreal, Vancouver, and Ottawa, embark on massive infrastructure projects to update and plan future mass transit (Infrastructure Canada 2017), the public health sector has an opportunity to help guide how this infrastructure is built to take full advantage of the potential health benefits in terms of chronic disease reduction. Given the impact of public transit in this study, one specific example of future utility of a risk modelling approach would be estimating the health impact of the City of Ottawa's Light Rail Transit (LRT) project which is anticipated to begin service in early 2019. Public health can use baseline risk information to help target population-level interventions such as massive transportation projects or new policies by identifying subpopulations that would be more greatly impacted by different policy choices. This may be valuable information to policy-makers and transportation planners to inform decisions about locations of transit lines and station stops, connections to cycling corridors and walking paths, and enticing ridership among population groups that carry a greater burden of disease risk. In addition to age, which is an important risk factor for diabetes, differences in

chronic disease risk by other simple demographic variables such as sex can be compared using the DPoRT model, which calculates risk for men and women through separate equations.

Modelling approaches can also be used as the foundation for cost–benefit analyses where estimated costs are compared in combination with the modeled outcomes of different preventive approaches. This can be used to communicate the value of the policies across sectors that are separated by budget siloes, such as health and transportation sectors (Rutter et al. 2007). A benefit of modelling estimates is that they can be repeated many times with different inputs to provide a range of possible outcomes under different scenarios. As in this study, the goal of these analyses is often primarily to assist in decision-making by providing comparative estimates between alternatives as opposed to obtaining a precise measurement. The World Health Organization Health Economic Assessment Tool (HEAT) is an example of a simple modelling tool that can be easily applied to estimate the value of reduced mortality that results from regular walking or cycling (Rutter et al. 2007). The modelling approach outlined in this study provides a similar rapid estimation method for a single dimension of a chronic disease outcome that can be assigned a value in terms of burden of medical care/treatment costs for health economic analyses. This study focused on only one aspect of the health benefit of replacing regular automobile use with active transportation; however, there are a multitude of benefits of increased physical activity that were not quantified. Sophisticated models that offer more precise estimates are also available for health impacts of active transportation that consider the additional benefits of reductions in greenhouse gas emissions and air pollution as well as the negative impact of injuries related to cycling and walking (Maizlish et al. 2013). These models have clear utility for demonstrating the population health impact of policy decisions within the transportation sector.

Conclusion

Interventions in the form of active transportation policies and programs outside the health sector may have an unrecognized impact on population health that can be estimated using modelling approaches. Population-level interventions may have an underappreciated impact due to a small effect on a large number of individuals. As many Canadian cities look to increase active transportation and reduce regular automobile use for logistical, economic, and environmental purposes, public health can play a critical role in demonstrating the health impacts of municipal policy and planning decisions in the transportation sector and support alternatives that promote health by preventing chronic disease.

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