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Active Transportation in Urban Areas: Exploring Health Benefits and Risks

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evidence review

Summary

- Active transportation refers mainly to walking and cycling for transportation.

Health Benefits:

- People who use active transportation are, on average, more physically fit, less obese, and have a reduced risk of cardiovascular disease compared to people who use only motorized transportation.
- A shift from motorized transportation to active transportation has the potential for societal benefits such as reduced emissions of air pollutants and greenhouse gases, reduced traffic noise, and more liveable neighbourhoods with less motor-vehicle traffic.

Health Risks:

- People who choose active transport modes face an increased risk of injury from collisions, relative to motor vehicle users.
- Active transport users may also be exposed to elevated levels of air pollution.

Realizing the Benefits, Mitigating the Risks:

- The proportion of trips that are made using active transportation modes remains low in Canada compared to many European countries. There is an opportunity to increase walking and cycling and realize the associated population health benefits.
- Infrastructure modifications such as separated cycle lanes, connected networks of sidewalks and signalized crossing-points for busy roads can reduce injury risks for current pedestrians and cyclists, while encouraging new users to try active transportation modes.
- Increased use of public transportation may have a corresponding increase in active transportation trips to access transit stops.
- There is a "safety in numbers" effect for pedestrians and cyclists, so increasing the proportion of trips by active transportation modes can lower the rate of injuries.

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- Compared to those travelling by motor vehicles, people who walk or cycle may be able to reduce their exposure to air pollution through informed route choices, but this depends on the traffic levels on selected routes, and timing and duration of the trip.

- In order to realize the benefits of active transportation, risks to individuals who walk and cycle should be evaluated. Further research is needed to understand how to best mitigate these risks.

Introduction

The aim of this document is to provide Canadian policy makers, transportation engineers and urban planners with an overview of the potential health benefits and risks of active transportation in urban areas, based on a review of the academic literature. It is hoped that the information provided will be of value to decision-makers who aim to provide safe, healthy, and sustainable transportation options in urban areas. Active transportation refers to trip-making by non-motorized means. The most common forms of active transport are walking and bicycling, but other types include running, in-line skating or skateboarding. In this document, the terms “pedestrian” and “cyclist” are used to refer to a person who has chosen to walk or cycle for a particular trip or part of a trip. The terms do not preclude the fact that trips may be multi-modal (for example, a person may walk to the bus-stop), nor do they imply that an active transport user does not also use public transport or a motor-vehicle.

Evidence shows that active transportation is more easily sustained than other forms of physical activity or exercise programs.[1] Thus walking and cycling as a means of transportation offers a promising way to address widespread levels of inactivity in the population, which could have a dramatic impact on population health. A transition away from motorized transportation modes and towards active transportation modes may also offer co-benefits such as reduced traffic-related emissions and noise.

Health Benefits and Risks: Overview

Table 1 (pages 7-9) lists the potential benefits and risks of active transportation at the individual level (affecting those who choose to walk or bicycle) and at the societal level (affecting the general population). Metrics used to quantify each benefit and risk are described. Key findings and limitations of the literature were identified; for example, the search did not identify evidence for any societal level risks associated with active transportation. Where literature specific to active transportation was not found, studies reporting the benefits of physical activity were cited and are identified in the table with "(PA)". The following sections discuss the benefits and risks of active transportation in detail, considering findings from specific studies, and highlighting challenges and methodological gaps in this research area.

Health Benefits and Risks to Active Transportation Users

Health benefits

The 1996 US Surgeon General's Report[2] represented a shift in thinking about the health benefits of physical activity. Its recommendations highlighted the need for an adequate amount of exercise rather than focusing on the intensity of physical activity. The report concluded that 30 minutes of moderate activity most days of the week, even if completed in 2-3 bouts of activity per day, was sufficient to achieve significant health benefits. This recommendation paved the way for the promotion of active transportation. Active transportation provides an opportunity for individuals to incorporate moderate intensity activities (such as brisk walking or cycling) into their daily routines, and has been shown to be more sustainable long-term than structured activity programs (e.g., running or going to the gym), yet with similar health benefits.[1]

Several studies have shown direct links between transportation-related physical activity and health outcomes. All-cause mortality, disease-specific mortality, and cardiovascular risk are lower among groups who use active transportation.[3-7] Woodcock and colleagues[8] modelled the public health impact of large increases in active transportation in London and Delhi by 2030 (the future scenario analyzed considered twice as much walking and eight times as much cycling as there is at present). They estimated that premature deaths in London would decrease by 528 per million people due to the health benefits of active transportation, which corresponds to a reduction of 5,496 years of life lost per million population.

People who commute actively to work are likely to be fitter and less likely to be overweight or obese than those who use motorized modes[9]. Obesity and physical inactivity are strongly related, and are leading public health issues in developed countries. Statistics show that one in three Canadian adults is overweight while another 15% are obese, and that more than half of adults do not get the recommended levels of physical activity.[10] Even more concerning is the dramatic increase in the number of overweight Canadian youth. The proportion of overweight and obese adolescents aged 12-17 doubled from 14% to 29% between 1979 and 2004[11], and today only 12% of children and youth get adequate levels of physical activity.[12]

Injury risks

Unfortunately, pedestrians and cyclists face significantly higher risks of fatality or injury per distance travelled than people who travel by automobile, bus or rail. The fatality risks per distance travelled for US pedestrians and cyclists are 23 and 12 times higher, respectively, than for those who travel by car.[13] Elvik[14] reports that injury rates per distance travelled for Norwegian pedestrians and cyclists are 4 and 7.5 times higher, respectively, than for those who travel by car, for all trips.

However, there is encouraging evidence that injury and fatality rates decrease as active transportation mode shares increase, an effect that has been dubbed "safety in numbers."[14, 15, 16] The safety in numbers effect is complicated by the fact that in areas with higher active transportation mode share, transportation infrastructure is often designed with the safety of pedestrians and cyclists in mind. In the Netherlands, which has some of the highest cycling rates in the world (almost 30% of all trips are by bicycle) the injury risk for cyclists is 1.1 cyclists injured per 10 million km cycled.[17] In comparison, in the UK and the US only about 1% of trips are made by bicycle, and the risk is 3.6 and 37.5 cyclists injured per 10 million km cycled.[17] Unfortunately, even though there is consistent evidence that the risk of cycling and walking injuries declines with increased active transportation mode share there may still be a net increase in the absolute number of injuries, because of the change from lower to higher risk modes. Woodcock and colleagues' model examining the health effects of large increases in active transportation (an eightfold increase in distance travelled per person per year) found that the road traffic injury burden in London is likely to increase only marginally, by 11 fatalities and 418 years of life lost per million population.[8]

Air Pollution Exposure: Health Risk?

An individual's intake of air pollution is related to a variety of factors, the most important being the concentration of air pollutants encountered during travel, the travel time, and the individual's breathing rate. Results of personal exposure studies (which incorporate only the first two factors) are mixed. Some studies show that pedestrians and cyclists are exposed to lower concentrations of air pollution than motorized modes.[18, 19] Other studies show increased exposure due to longer travel times[20] and increased breathing rates[21] when individuals cycle and walk. It is possible that individuals who cycle instead of taking the bus or driving will experience a moderate increase in their inhaled dose of air pollution, due to increased breathing rates, which have been estimated to be about double that of motor-vehicle passengers.[22, 23] It is not clear whether this also holds true for pedestrians. It is also unclear whether air pollution exposures during active transportation result in a change in health risk. Few studies were identified that measured physiological responses to air pollution exposure in an active-transport context. In one study, lung function and symptoms of respiratory distress in cyclists were measured before and after travelling on routes with varying amounts of motor vehicle traffic.[23] Although there were substantial differences in ultrafine particulate and soot exposures between the routes investigated, increased exposure was weakly associated with increased airway inflammation and decrements in lung function six hours after exposure. However in a highly-cited study that looked at pedestrian exposure to traffic air pollution in London, participants walked for 2 hours either beside a busy street, or in an urban park, and were then measured for a variety of markers of acute responses to pollution exposure.[24] The results showed significantly higher responses for participants who were walking near busy streets.

There is significant uncertainty and variability in an individual's exposure to air pollution between transportation modes as well as uncertainty in the health outcomes. More research is needed before conclusions can be drawn about the risks of air pollution exposure when using active transportation modes.

Societal-level Benefits

Lower air pollutant and greenhouse gas emissions

Active transportation modes produce no in-use emissions[25] and have low lifecycle greenhouse gas emissions.[26] In comparison, the motorized transportation sector is the largest and fastest growing source of greenhouse gas emissions in Canada.[27] Although much of this increase occurred in the freight sector, in 2007 on-road passenger transportation contributed 44% of all transportation-related emissions.

In high-income countries, technological advances for passenger vehicle engines – especially the development of the catalytic converter – have led to much lower air pollutant emissions (except for carbon dioxide). There is potential for further reductions from vehicles using advanced powertrains (e.g., hybrids, electric vehicles) but increasing vehicle kilometres travelled per person will likely drive increases in pollutant emissions in coming years.[28] As a result, the transportation sector will continue to be a major source of air pollution in urban areas, and a critical contributor to population exposure due to the proximity of vehicles to people.

Because active transportation does not produce any direct emissions, it is often cited as offering opportunities to reduce emissions and improve air quality on a neighbourhood or regional scale.[8, 29] Cross-sectional analyses by Frank and colleagues[30, 31] suggest that neighbourhoods with more walkable designs have lower per capita vehicle kilometres travelled and air pollutant emissions. Woodcock and colleagues[29] estimated that large increases in active transportation in London and Delhi over the next 20 years could halve per capita transportation-related emissions, and decrease the burden of disease associated with fine particulate matter air pollutant emissions by 21 to 99 deaths and 200 to 2,240 years of life lost per million population. However, despite the optimism of such analyses there is little empirical evidence that increased active transportation actually substitutes for motorized transportation and hence reduces greenhouse gas or air pollutant emissions.[32]

Reduced health-care costs

The health issues associated with inactivity and obesity cause hardship for individuals but they also have substantial economic costs for society.[33, 34, 35] It has been estimated that the economic costs of physical inactivity and obesity in Canada in 2001 represented 2.6% and 2.2%, respectively, of total health care costs.[34, 35] In dollar terms the estimated health care cost of physical inactivity in Canada was $5.3 billion (of which direct costs made up 30%), while the cost associated with obesity was $4.3 billion (of which direct costs were nearly 40%). It is estimated that each additional 10% increase in physical activity would translate to direct health care savings of up to $150 million annually.[34]

If active transportation modes were more widely adopted the individual-level health benefits discussed previously could result in lower aggregate health care costs. Unfortunately, there has been limited research quantifying the possible impacts of active transportation on healthcare costs. Insights may be drawn from a notable study modelling the health care cost reductions associated with a potential light rail investment and the associated increase in active transportation[34]. The analysis took into account estimates of future obesity rates in the area and assumed that there would be an increase in walking to and from the transit stations with corresponding population health benefits, but did not consider the possibility of a change in injury rate. The study found that there could be a modest public health benefit (expressed as a 9-year cumulative public health cost savings of US$12.6 million) associated with the adoption of light rail. It would be useful to conduct similar analyses for changes to active transportation levels in other contexts.

Reduced traffic noise and congestion

In recent years traffic noise has been shown to be an urban health risk, with impacts on childhood development and adult cardiovascular disease.[36, 37] Traffic congestion is a significant economic issue, with impacts estimated at up to 3% of GDP for many cities.[29] Active transportation has been promoted as an approach for reducing both traffic noise[13, 29] and congestion[13, 38], but to our knowledge there have been no studies that have found that increases in active transportation result in measurable reductions of motor vehicle noise, or traffic congestion.

Urban design for connectivity and accessibility

The question of whether neighbourhood design leads to greater use of active transportation, or whether people who prefer to use active transport modes choose to live in connected, accessible neighbourhoods, is difficult to untangle. However, the research suggests that urban form is a determinant of active transportation levels, at least to some degree. As such, urban design, connectivity and accessibility are linked to health, via transportation. Purpose-built infrastructure for walking and cycling can increase active transportation. For example, a recent review of infrastructure types and policies concluded that provision of bike-friendly infrastructure with supportive land-use planning (such as restrictions on car use) is an effective way of increasing cycling rates.[39] Supportive urban form can thus affect health in the broader sense. In addition, walkable neighbourhoods have higher social capital: people living in walkable neighbourhoods are more likely to know their neighbours, participate politically, trust others, and be socially engaged.[40] Jane Jacobs, a luminary in this field, emphasized the need for walkability (and in particular the concept of "eyes on the street") in North American cities. She posited that a connected network of sidewalks in dense, multi-use urban areas is a critical component of safe, lively and liveable cities.[41]

Economic benefit-cost analyses

Some researchers have conducted economic valuations of interventions and policies aimed to increase active transportation. This research area faces a number of methodological challenges, including: identifying the population affected by a change; assessing behaviour changes; quantifying the improvements in health outcomes; determining individual-level risks and unintended impacts; assigning appropriate monetary values to both health benefits and risks (including issues of direct versus indirect costs); and, selecting an appropriate time-period for the evaluation. In spite of these challenges, economic valuation studies yield some instructive insights, as outlined briefly here.

One recent paper proposed a systematic approach to quantifying the economic benefits of infrastructure changes that result in increased rates of walking or cycling.[42] This approach, however, did not consider the potential for increased risk of injury from collisions with motor vehicles. Similarly, a research report for the New Zealand Transport Agency found significant economic benefits from walking and cycling (with the value of increased walking being twice that of cycling on a per kilometre basis), but it also did not include costs associated with changes in injury rate.[43] A comprehensive systematic review[44] evaluated 16 earlier studies that conducted economic valuation of investment in walking and cycling infrastructure, and concluded that benefit-cost ratio is positive, with a median value of 5:1 in the reviewed studies. Although the results of such studies are highly variable and contain significant uncertainty, such a benefit-cost ratio would be considered very high value for investment in the transportation realm.

Realizing the Benefits, Mitigating the Risks

Active transportation has been receiving increasing attention as a topic that should be at the forefront of transportation planners' agendas, because of its potential for public health and climate benefits. Yet the literature demonstrates that there are risks associated with walking and cycling. A future scenario with broad adoption of active transportation would result in a transportation system very different from today's system. Our understanding of both the benefits and the risks of active transportation are based on contemporary perspectives, limited by existing conditions and the methodological challenges faced in this area of research. As a result there are significant uncertainties and challenges in assessing how the risks and benefits of active transportation will co-evolve, and what the balance of these may be in the long term. If wider adoption of active transportation is desired it will be critical to mitigate risks, particularly during the initial stages of transition.

A number of evidence-based strategies for managing these risks exist. For example, to minimize the risk of injury, it is important that urban transportation infrastructure be carefully designed for active modes. There is now ample evidence that it is possible to modify the built environment in ways that substantially reduce the risk of pedestrian-vehicle crashes.[45] In addition, a recent review of the impact of infrastructure on cyclist safety concludes that purpose-built bicycle facilities (e.g., on-road bike routes, on-road marked bike lanes, and off-road bike paths) reduce crashes and injuries for cyclists.[46] Urban planners and municipal engineers in some cities have chosen to offer cyclists low-traffic alternative routes in parallel to main traffic arteries, which reduces their risk of injury and exposure to air pollution. Trip planning tools can be used to route cyclists on to streets with lower motor-vehicle densities and speeds, and may also take into account exposure to air pollution.[47] In recent years there has been a growing movement in the United States for "complete streets", promoting policies for safer, more welcoming street design that supports all modes: motor vehicles, public transit, cyclists and pedestrians (see http://www.completestreets.org).

Cyclists can be encouraged to wear helmets, which reduce the chance of severe head injury in the event of a crash.[48, 49] However, there is contradictory evidence over whether mandatory helmet laws have a net positive or negative effect on health, because of possible reductions in cycling modal share where helmets are required.[50, 51]

Communication with potential walkers and cyclists is very important. If rates of active transportation are to be increased in urban areas, it is essential that the public is aware of safety improvements that have been made. For example, it has been suggested that public perception of safety improvements to bicycling infrastructure can attract people to bicycle commuting.[52] Literature reviews that examined interventions to promote a shift to active transportation showed that behaviour-change programs aimed at certain groups of the population have had some success in the short-term (the most successful interventions could increase walking among targeted participants by up to 30-60 minutes a week on average), but the evidence of long term impact of such interventions is limited.[53, 54] There is evidence of dramatic improvements in cycling modal shares in many European cities due to policy and infrastructural changes over the decadal time-scale[17], and a similar pattern is emerging in North America.[55] For example, there is a positive relationship between total length of bicycle pathways and percentage of bicycle commuters in US cities.[56] Policies that lead to incremental increases in active transportation can result, over time, in urban transportation systems that are substantially more pedestrian- and cyclist-friendly.

While some consider active transportation to be a fringe transport mode adopted by only a fraction of the population and thus with limited impact on health and the environment, European cities show a markedly different picture. Studies have provided promising evidence that active transportation has net benefits. Perhaps the most thorough effort at quantifying the tradeoffs between benefits and risks specifically for cycling was completed for the British Medical Association 25 years ago.[57] The author reported that "in spite of the hostile environment in which most cyclists currently ride, the benefits in terms of health promotion and longevity far outweigh the loss of life years in injury on the roads".[57] The author enumerated the ratio at 20:1 in terms of years of life lost, an indisputable benefit despite uncertainties in the estimate. More recent modelling exercises support the conclusion that the health benefits of increased active transportation are likely to greatly outweigh the risks, and furthermore, that strategies to promote active transportation will have far more positive health effects than technological improvements to motor vehicles.[8]

Knowledge Gaps and Challenges

- Although it appears likely that there will be societal benefits from increased active transportation, there is limited evidence that directly supports this assumption and more studies would be helpful. If it can be shown that travel by active transportation substitutes for motor vehicle trips. the large body of data on the adverse health effects of air pollution, greenhouse gas emissions, and noise from motor vehicle traffic could reasonably used as a surrogate.
- Based on currently available evidence for air pollution exposure, it is unclear whether active transportation is associated with positive or negative health effects resulting from a reduction or increase in air pollution exposure at both the individual and societal level.
- The contention that increased active transportation leads to safer streets and more liveable communities is a well-accepted theory, but has limited supporting evidence.
- Study design is a major challenge for observational research in this area: most of the existing studies are ecological or cross-sectional studies. True experimental designs are difficult, but quasi-experimental or longitudinal studies are needed to further probe the relationship between active transportation and changes in GHGs, air pollution, noise, and urban design. Studies also need to account for possible confounding and mediating processes in the political, cultural and environmental realms, and address measurement and sampling issues. See Krizek and colleagues[58] for discussion of these and other issues.
- Modelling studies (particularly of air pollution exposure, but also of injury risk) face significant challenges, due mainly to (a) heterogeneity in studied populations and locations, (b) variability in an individual's movement through the environment and the resulting exposure to risk, and (c) uncertainty regarding the state of current transportation systems and how they will evolve in the future.

Table 1. *The benefits and risks of active transportation at the individual and societal level*

	Metrics	Key Findings from the Literature [a]
Health Benefits to active transport users		
Increased physical activity due to travelling by active modes	Minutes of physical activity per day/week, meeting recommended guidelines	- People who commute by active modes get more physical activity on average than people who use motorized transport[4]
Improved cardiovascular fitness	Change in heart rate (at rest and during activity), blood pressure, lung capacity, VO_2 max, serum measures (fasting measures of lipid, glucose, and insulin levels)	- People who commute by active modes experience significant improvements in cardiovascular indicators of fitness compared to those who use motorized modes[4, 9]
Reduced overweight/obesity	Body mass index (BMI); obesity defined as BMI > 30 kg.m^{-2}	- Data from national surveys of travel behaviour and health indicators show that countries with the highest levels of active transportation generally have the lowest obesity rates[59] [b]

Table 1 continues...

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	Metrics	Key Findings from the Literature [a]
Reductions in chronic diseases	Morbidity and mortality rates, both overall ("all-cause") and disease specific (i.e., cardiovascular disease, cancer, diabetes)	- Decreased relative risk of all-cause mortality for both men and women (all age groups) who participate in moderate leisure time physical activity, but also specifically in those who use bicycle for transportation[3] - Men who cycled at least 25 km/week or did vigorous brisk walking had less than half the non-fatal and fatal coronary heart disease of those who were not physically active[6] - A recent meta-analysis concluded that active commuting was associated with an 11% reduction in cardiovascular risk[7] - A recent meta-analysis concluded that walking approximately 30 minutes a day, 5 days a week was associated with 19% reduction of coronary heart disease risk[60] *(PA)* - Systematic reviews show strong evidence for an inverse association between physical activity and postmenopausal breast cancer, with reported risk reductions ranging from 20% to 80%[61] *(PA)*
Improved mental health and quality of life	Psychometric scales for stress, depression, anxiety, mood, sleep quality	- A meta-analysis reports that exercise as treatment for depression is more effective than no treatment, is as effective as traditional interventions in some instances, and has equivalent adherence rates to medication[62] *(PA)* - Regular activity at least once a week (and for men, walking at a brisk pace for more than 6 blocks) was associated with reduced risk of any sleep disorder[63] *(PA)* - Physical activity in adults age 70+ was weakly related to improved quality of life, subjective well-being and physical self-perceptions[64] *(PA)*
Health Risks to active transport users		
Increased risk of injuries, fatalities from collisions and falls	Injuries/fatalities per distance travelled, per trip, per unit time, or per capita; years of life lost (YLL); disability-adjusted life years (DALY)	- Pedestrians and cyclists are more likely to be killed or injured than car and public transport users, on both a per trip and a per distance basis[13, 14]
Other Impacts to active transport users (Inconsistent evidence of risk / benefit)		
Exposure to air pollution and associated health effects	Personal exposure concentrations (measured, or modelled based on fixed monitoring stations and activity patterns)	- Pedestrians and cyclists generally experience lower exposures to fine and ultrafine particulate matter, volatile organic compounds and carbon monoxide compared to those inside vehicles[18, 65, 66]. The benefits of lower exposures may be offset to some degree by increased pollutant uptake during active transport due to increased respiratory ventilation, which is approximately twice that of motor-vehicle passengers[67] - There is some evidence that pedestrians and cyclists may experience higher exposures than car-drivers if they travel on busy routes[24, 68]. However, those engaging in active transportation can reduce their pollution exposure significantly by choosing low-traffic routes that avoid known high pollution areas[22, 23, 69] - People who change from car-driving to walking over the same travel route are likely to experience increased personal exposures to traffic-related air pollution, due to increased travel time along these routes[20] - Models have indicated that if urban designs are made more active transportation-friendly, some individuals who cycle and walk more as a result of the change could experience significant increases in air pollution exposure (but aggregate societal level exposures are decreased – see below)[70, 71]

Table 1 continues...

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	Metrics	Key Findings from the Literature [a]
Societal-level Benefits		
Safety in numbers: Reduced risk of injuries, fatalities from collisions and falls	Injuries/fatalities per distance travelled, per trip, per unit time, or per capita; years of life lost (YLL); disability-adjusted life years (DALY)	- Rates of collisions, injuries and fatalities per capita decline when the numbers of people walking or bicycling increases.[14, 15, 16] . Pedestrians and cyclists in The Netherlands and Germany, where larger proportions of the population walk and cycle, have lower injury and fatality risks than in North America.[13]
Reduced pollutant emissions	Traffic emissions (modelled for a given location and time period, taking into account different vehicle types and pollutants, and vehicle activity)	- Increased "walkability" (mixed use and more compact community design) of an area could lead to lower vehicle kilometres travelled and reduced vehicle emissions[30, 31, 72] - Models suggest that active transport interventions can reduce emissions and significantly reduce the burden of disease associated with air pollutant emissions aggregated at the population level[8, 70]
Reduced energy consumption and greenhouse gas emissions	Life cycle energy consumption and greenhouse gas emissions for a given transportation mode (calculated per traveller/time/distance, and taking into account trip distances, vehicle fuel consumption, and number of passengers per vehicle)	- Walking and cycling have very low life cycle energy consumption and greenhouse gas emissions[25], of approximately the same magnitude (per person-kilometre) as that of someone using full-capacity bus or light rail[26] - Models suggest that active transport interventions can significantly reduce fuel use and greenhouse gas emissions because of fewer personal motor vehicles and fewer vehicle kilometres travelled[8]
Reduced national healthcare costs	Direct and indirect economic costs of physical inactivity and overweight/ obesity	- In North America, the direct economic costs of physical inactivity and obesity are high (estimated at 4.8% and 9.4% of total health care costs for Canada and US respectively)[33, 34, 35] *(PA)*; therefore it may be possible to realize significant cost savings through the health benefits of increased active transportation rates. - In a US study, light rail investment and the associated mode-switching to more active commuting were predicted to produce modest healthcare cost savings[73]
Potential societal-level benefits (no direct evidence identified)		
Reduced traffic noise	Peak and sustained noise levels as measured with commercial noise level analyzers; reported "noise annoyance"	- Exposure to elevated traffic noise increases the risk of adverse health effects such as myocardial infarction and total ischemic heart disease[36]. However, no studies that linked active transportation and reduced traffic noise were identified.
Reduced vehicle kilometres travelled	Traffic counts; trip times and distances	- If increasing active transportation results in trip substitution of cycling and walking for automobiles, some decreases in vehicle kilometres travelled would be expected[13, 38]. However, no studies that linked vehicle kilometres travelled to active transportation were identified.
More aesthetic & accessible neighbourhoods	Walkability/bikeability assessments (quantitative or qualitative)	- Neighbourhoods that are good for active transportation may also be more aesthetically pleasing and accessible. However, no studies were identified that provide evidence of active transportation causing the aesthetic and accessibility improvements.

[a] Where literature specific to active transportation were not identified, surrogate studies reporting the health benefits of general physical activity are cited, and denoted with "*(PA)*".
[b] This study is an ecological study, i.e., the correlation is between *national* levels of walking and cycling with *national* rates for obesity.

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APPENDIX A: Literature Search Strategy

A.1 Databases / Indices / Search Tools

The literature search employed the following databases / indices:

- **Web of Science**: An online catalogue of citations which includes the Science Citation Index, the Arts and Humanities Citation Index, and the Social Sciences Citation Index; http://apps.isiknowledge.com

- **PubMed**: A service of the U.S. National Library of Medicine that includes over 16 million citations from MEDLINE and other life science journals for biomedical articles back to the 1950s; http://www.pubmed.gov

- **Transportation Research Information Services**: A database, produced and maintained by the Transportation Research Board of the National Academies, that includes references to books, technical reports, conference proceedings and journal articles in the field of transportation from 1960 to present; http://tris.trb.org

- **Google Scholar**: A service that provides a simple way to broadly search online for scholarly literature, including "grey literature" (publications that are not published commercially or indexed by major databases). Allows searching across many disciplines and sources: peer-reviewed papers, theses, books, abstracts and articles, from academic publishers, professional societies, preprint repositories, universities and other scholarly organizations; http://scholar.google.com

A.2 Search Terms and Date Ranges

Text word searches of article titles and abstracts in the indices listed above were conducted using search terms related to active transportation and potential benefits and risks. Combinations of the following primary keywords were used in the searches, (with “wildcards” used where appropriate to capture variants on terms, e.g., bicycl*): *active transportation, pedestrian, walking, cyclist, bicycling, physical activity, traffic, benefit, risk, cost, safety, health, injury, accident, air pollution, exposure, noise.* Boolean operators and restriction to articles specifically on active transportation and associated health outcomes were used to reduce the search results to those articles possibly relevant. Additionally, existing research briefs and reports from leading organizations in this area (World Health Organization, US Centre for Disease Control, Statistics Canada, Robert Wood Johnson Active Living Research program) were accessed to identify relevant data and references. Finally, during the internal review process, expert colleagues were requested to note any additional references that they thought should be included.

The literature search was conducted in January and February 2010 and updated through to end of March 2010. There was no restriction of searches to specific time/date ranges, but higher value was placed on articles that have been published within the last 10 years (2000 – 2010), and to research in the Canadian or North American context.

A.3 Inclusion Criteria

All papers identified by the search were initially screened for relevance using the title and/or abstract. We sought English-language literature in the following main categories:

(1) Studies that directly examined benefits and/or risks of an active transport mode or modes. We did not limit our search by study design; hence the literature identified included experimental studies, observational studies, ecological comparisons, and socio-economic studies.

(2) In the event that direct evidence of benefits or risks was not available, we searched for papers that provided indirect evidence that could be used as surrogates. An example of literature that fell into this category would be studies that addressed the population-level risks of traffic noise exposure.

(3) Papers that reviewed the above literature or those that addressed research challenges faced in this research area.

Those papers considered potentially relevant were collected, and the full text versions were then further reviewed for inclusion in the research brief. Reference lists of all relevant papers (including literature reviews) were searched as a source of additional citations.

A.4 Literature Organization / Storage

Bibliographic data for the electronic and print literature obtained through the above methods were entered into an EndNote online citation management database (http://www.myendnoteweb.com), which was accessible to all authors. Electronic copies of all relevant references (in PDF format) have been stored in a centralized electronic repository for easy access by authors.

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