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Potential Health Implications and Health Cost Reductions of Transit-Induced Physical Activity

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Abstract

Transit has the potential to increase an individual's level of physical activity due to the need to walk or bike at the beginning and end of each trip. Consideration of these health benefits would allow transit proponents to better demonstrate its true costs and benefits. In light of transit's potential health-related impacts, this study contributes to the growing discussion in the emerging field of health and transportation by providing a review of the current level of understanding and evidence related to the physical activity implications of transit use and its associated health cost benefits. Findings from the review revealed that transit use is associated with increased levels of physical activity and improved health outcomes, but the magnitude of these effects is uncertain. There were few studies that estimated the health care cost savings of transit systems, and those that did tended to be imprecise and simplistic. Objective physical activity measures and frequency-based transit measures would allow for greater consistency across studies and help more directly attribute physical activity gains to transit ridership. Additionally, research in this area would benefit from disaggregate estimation techniques and more robust health datasets that can be better linked with existing transit data.

Keywords

Public transportation; physical activity; health implications of transit; health care cost; transit cost savings

1. INTRODUCTION

Public transportation (transit) provides numerous mobility benefits to communities and individuals, and has the potential to become a viable replacement for motorized vehicles. Because of the low entry barriers for transit use, such as the lack of personal vehicle down payments and maintenance costs, the mode is accessible to a wide variety of travelers.

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Transit is also capable of reducing congestion and delays, improving air quality, and increasing overall productivity levels (due to less time wasted in traffic congestion) (Center for International Economics, 2001; ECONorthwest & Parsons Brinckerhoff Quade & Douglass, Inc., 2002; Litman, 2010, 2014; Public Transport Victoria, 2014). Furthermore, transit offers riders the opportunity to multi-task (Lyons and Urry 2005, Lyons *et al.* 2007) so that they can travel while accomplishing other tasks such as working, reading, or sleeping. It is theorized that social capital can be increased through transit use and more pervasive transit provision (Currie and Stanley 2008).

Finally, and of particular importance to this research, transit can help the user population become healthier since it encourages human-powered travel (Besser and Dannenberg 2005, Edwards 2008, Centers for Disease Control and Prevention 2010, Mackett and Brown 2011, Rissel *et al.* 2012, Freeland *et al.* 2013). In particular, transit has the potential to increase an individual's level of physical activity due to the need to walk or bike at the beginning and end of each trip. Given that the majority of the population can use transit with low initial capital outlay and little or no training, the inherent physicality associated with transit travel may not only impart higher levels of well-being but may also be the answer to health problems associated with sedentary lifestyles.

Despite its demonstrated benefits compared to auto-oriented modes, transit generally receives a disproportionately lower share of transportation funding. In the United States, for example, declining transportation revenues have resulted in transit budget shortfalls (Kirk and Mallett 2013, General Accountability Office 2014). One possible reason for the lack of reliable transit funding is the limited empirical evidence of transit's positive health cost effects for individuals and the population at large. Improvements to personal health not only improve individuals' lives but also reduce public expenditures (e.g., public funds spent on subsidized health care coverage), private industry costs (e.g., lost productivity), and inflation (DeVol 2007). These impacts likely result in a benefits multiplier effect that is more pervasive than the current funding process acknowledges. Still, voters and decision makers have limited resources to allocate, making it critical to quantifiably demonstrate financial benefits. Transit costs are typically evaluated in terms of direct expenditures, revenues, and traveler accessibility gains. The additional consideration of transit-related health benefits would allow transit proponents to better demonstrate transit's true costs and benefits in order to enable sustainable revenue streams.

In light of transit's potential health-related impacts, this study explores the current level of understanding related to the physical activity implications of transit use and its associated health cost benefits. Not intending to be exhaustive, this paper presents the current state of the evidence and aims to contribute to the growing discussion in the emerging field of health and transportation. This is accomplished by first providing an extensive synthesis investigating the physical activity implications of transit. Building on these insights, the review then continues with a discussion of the health care costs associated with physical inactivity and the expenditures that may be reduced or avoided via increased transit use. Finally, the paper concludes with a discussion of review findings and conclusions about methodological considerations to advance research in these fields.

2. HEALTH, PHYSICAL ACTIVITY, AND TRANSIT

2.1. Health Implications of Physical Inactivity

There is a well-established body of literature examining the health effects of physical inactivity. Physical inactivity has been directly tied to negative health outcomes and an increased likelihood of early mortality. Most studies have linked physical inactivity with higher rates of obesity and being overweight, which increases the risk of cancer, heart disease, hypertension, and type 2 diabetes (Bijnen *et al.* 1994, Blair and Brodney 1999, Hu *et al.* 2005, Lopez-Zetina *et al.* 2006, Warburton 2006, Hamburg *et al.* 2007, Naci and Ioannidis 2013, Zarr 2014, Myrie and Daniel 2014, Schiller 2014, World Health Organization 2014). According to the World Health Organization (WHO), physical inactivity is the main cause for as much as 25 percent of breast and colon cancer diagnoses (World Health Organization 2014). These findings have now been strengthened by various extensive studies over the last several decades. For example, Hu *et al.* (2005) highlighted a strong independent effect of physical activity on mortality. Their results suggest an increased risk of mortality from cancer (among other disease processes) due to increased prevalence of physical inactivity. Another study by Naci and Ioannidis (2013) supported this notion, suggesting that physical activity health interventions had the same, if not greater, positive effect on mortality as prescription medication when used to treat chronic disease (e.g., heart disease, diabetes, and stroke recovery).

Risks related to physical inactivity affect all ages, races, genders, cultures, and socioeconomic strata (World Health Organization 2014). Additionally, physical inactivity is so pervasive in developed nations that some experts suggest population-wide interventions (Sallis *et al.* 1998). Ongoing physical activity is necessary for long-term health sustainability for individuals, communities, and nations. Simple reductions in body weight or brief bouts of a physically active lifestyle may not be enough to maintain a healthful condition (Blair and Brodney 1999, Hamburg *et al.* 2007). Instead, repetitive physical activity (e.g., activity associated with regular transit use) integrated into daily routines is necessary to achieve longstanding benefits (US Department of Health and Human Services 2008).

2.2. Transit and Self-Reported Physical Activity

The Centers for Disease Control (CDC) and WHO recommend a minimum of 150 minutes of physical activity per week (The World Health Organization 2010, Centers for Disease Control and Prevention 2011). If a person is active for 30 minutes per day, the amount of weekly physical activity recommended by CDC and WHO is achievable in five days—a typical work week. Because riders often walk or bicycle at either end of a transit trip, a higher transit mode share might serve as an effective way to integrate physical activity into daily routines on a broad scale.

The amount of walking or bicycling conducted for transit varies depending on a number of factors including location, level of transit service, transportation alternatives, and land use characteristics. In less vehicle-dominated areas of the world, walking associated with transit use can be quite prevalent. Travel surveys conducted by Olevera *et al.* (2013) in Guinea and Cameroon indicated that walking and public transit had combined mode shares of 94 percent

and 98 percent, respectively, and approximately 20 percent reported walking trips paired with transit. Additional survey data from Lomé, Togo, where public transit is primarily comprised of motorcycle taxis or shared taxis, found that over 10 percent of transit trips comprised a walking segment of at least 10 minutes. Across a number of African cities, bus riders report walking approximately 10 minutes to reach a transit stop, though many walk much longer distances out of necessity (Kumar and Barrett 2008). In Cape Town, South Africa, walking distances to transit are longer than in most cities, with an average of 1.4 km for bus trips and 2.1 km for rail (Hitge and Vanderschuren 2015). In contrast, BRT riders in Bangkok walk an average of just 0.4 km to access the bus, often relying on motorcycle taxis for longer access journeys (Chalermpong and Ratanawaraha 2015).

Bicycling as an access or egress mode for transit can also be used to support daily physical activity goals while increasing the catchment area around a station (Ensor *et al.* 2010), making transit more accessible to a greater number of users. In areas where bicycle mode share is low, the proportion of riders using a bicycle for the access or egress trip typically follows suit. Research in the United Kingdom, Rio de Janeiro, and Singapore has revealed that transit access trips by bicycle are uncommon, at approximately 2 percent mode share (Martens 2004, Souza *et al.* 2010, Tay 2012, Sherwin and Parkhurst 2013). In contrast, more bicycle-supportive regions demonstrate the potential for complementary interactions between bicycling and transit. In Nanjing, bicycle access and egress rates at metro stations range between 5–12 percent (Chen *et al.* 2012), while Munich and Copenhagen have bicycle access rates of 13 percent and 26 percent, respectively. The Netherlands, in particular, has been a leader in bicycle-supportive policy and infrastructure, leading to a 38 percent bicycle mode share for rail access trips and 10 percent for egress trips (Givoni and Rietveld 2007). Because it is typically easiest to ride a bicycle to a station and park it, bicycling for the access trip can be as much as six to eight times higher than the egress trip (Martens 2004).

When converted to travel times, the distances covered on bicycle for paired bicycle/transit trips are roughly equivalent to the previously reported transit walking times. Martens (2004) found that bicycle access trips are typically as long as 4–5 km, which is in line with the findings of Sherwin and Parkhurst (2013), who reported an average distance of 3.7 km for rail access trips by bicycle in the United Kingdom. Similarly, transit riders in Philadelphia and San Francisco who bicycled to or from transit reported a median bicycle trip distance of 3.2 and 5.3 km, respectively (Flamm and Rivasplata 2014). Nearly all of these riders also reported that if unable to bike to transit they would still have made the trip otherwise, with most (approximately 70 percent) continuing to use transit combined with some other mode. Given that some of these respondents would likely have otherwise relied on motorized modes, these findings provide further evidence of the physical activity benefits of bicycling to or from transit. With the growth in bicycle-supportive transit facilities in recent years (Pucher and Buehler 2009), the synergistic relationship between bicycling and transit should only strengthen. Still, more research is needed to better establish a direct link between transit and bicycle-related physical activity. If, for example, combining bicycle and transit modes primarily served to replace longer bicycle-only trips, then any physical activity gains would be overstated.

To find stronger evidence for the link between transit use and physical activity, some studies have compared self-reported activity levels for transit and non-transit users. In the United States, Besser and Dannenberg (2005) found that 3.1 percent of adult participants in the 2001 National Household Travel Survey (NHTS) walked to and from a transit access point on their travel day. These transit walkers achieved an average of 24.3 minutes of walking time per day—within six minutes of the CDC- and WHO-recommended 30 minutes of physical activity per day (out of five days)—suggesting that transit walking may be an effective means of achieving recommended physical activity levels. Corroborating these findings, Rissel et al. (2013) surveyed students and staff at the University of Sydney in Australia. Those that used public transit or active modes for the school commute reported an average of 174 minutes of physical activity per week, compared to just 115 minutes for drivers.

The results of Besser and Dannenberg (2005) indicate that demographic and land use traits play a role in determining levels of transit-related physical activity. Minorities, low-income travelers, and residents of high-density urban areas were more likely to achieve 30 minutes of daily transit walking. When comparing the NHTS data for two cities—one with mixed land use and walkable infrastructure and one with limited walkability and segregated land use—the likelihood of walking and biking to destinations increased for residents living in the area with mixed uses and increased walkability. Similarly, Wasfi et al. (2013), using travel survey diary data collected from nearly 7,000 Montreal residents, found that transit-induced increases in walking levels vary according to sociodemographic and built environment characteristics. Notably, those living in affluent suburban areas served by rail transit were especially likely to achieve recommended activity levels. Approximately 11 percent of respondents reported walking for 30 minutes solely as a result of trips to and from transit stops.

Complementing these findings, Frank et al. (2004) determined that mixed-use development and walkability are directly correlated with reduced obesity incidence and increased physical activity/active transportation. Further examining NHTS data from 2001 and 2009, Freeland et al. (2013) discovered that residents of large urban areas with bus and rail transit modes are 72 percent more likely to walk 30 minutes or more per day. According to the authors, individuals that walk for transit have similar demographic characteristics to individuals that experience compromised health—populations that may benefit the most from more transit options. Specifically, household income, race, and the size of a person's city of residence were found to be predictors of high levels (30 minutes or more) of transit-related walking.

To control for confounding sociodemographic influences, some researchers have associated physical activity and active commuting with transit use using multivariate logistic or probit regression models. For instance, Lachapelle and Noland (2012) estimated an ordered probit model to associate commute mode to walking frequency. Among the sample of New Jersey commuters, those who used transit exhibited higher rates of walking, which is unsurprising given that walking accounted for over 90 percent of transit access trips. Similarly, Djurhuus et al. (2014) developed logistic regression models to predict rates of self-reported physical activity and active commuting among Danish commuters. Those with better access to public transit were more likely to have higher rates of self-reported physical activity and active

commuting. Bopp et al. (2015) used a similar methodology for commuters in the mid-Atlantic region of the United States. The study revealed that public transit was the most significant predictor of active commuting status. These findings provide further evidence for the link between transit and walking or bicycling, even beyond active travel associated with the transit trip itself.

2.3. Transit and Objectively Measured Physical Activity

To better estimate transit-related physical activity, Morency et al. (2011) created a pedestrian network to calculate walking levels using Montreal trip diary data. This method assumed that transit users took the shortest path to or from transit stops, and developed back-of-the-envelope estimates for the number of steps taken. Based on the analysis, the average transit commuter in Montreal achieved about one quarter of their recommended daily physical activity simply by walking to or from transit. While the calculations were rough, they provided a more objective method of generating physical activity data since self-reported estimates are prone to under- or overestimation.

Even more convincing are studies that have directly measured physical activity levels of transit users using pedometers, global positioning system (GPS) devices, or accelerometers. Outfitting New Jersey commuters with pedometers, Wener and Evans (2007) found that train commuters walked 30 percent more than those who drove to work and were over four times as likely to achieve the commonly recommended goal of walking 10,000 steps per day. These results were consistent with another pedometer-based study of students at the University of Western Australia. Like the previous study, transit users were approximately four times more likely to walk 10,000 steps per day. Overall, walking was more prevalent among transit users, even after controlling for sociodemographics and recreational physical activity levels.

Consistent with previous studies, other researchers have used GPS devices and accelerometers to more accurately measure the duration and intensity of physical activity events. Lachapelle et al. (2011) modeled levels of physical activity with the aid of accelerometers for commuters in Seattle, Washington, and Baltimore, Maryland. After controlling for personal and environmental characteristics, those that commuted via public transit achieved higher levels of physical activity, with a stronger effect seen among more frequent transit users. Likewise, analysis of GPS and accelerometer data for the Ile-de-France region in France revealed that transit trips (metro, bus, train, and tramway) achieved higher levels of moderate to vigorous physical activity (MVPA) than trips by any other mode, including walking (Chaix *et al.* 2014). Similarly, Saelens et al. (2014) measured activity levels using GPS and accelerometers among residents living near a recently opened light rail system in King County, Washington. They reported that transit users had a lower body mass index (BMI) and higher levels of overall physical activity. In contrast, non-transit-related physical activity levels were similar between transit and non-transit users. These findings suggest that walking for transit did not substitute for activity in other areas of life, providing stronger evidence for the influence of transit on physical activity levels.

Yet even studies using objective measures of physical activity are unable to directly attribute physical activity gains to public transit use given that they are generally cross-sectional. As a

result, researchers have exploited the opening of new transit facilities to conduct longitudinal natural experiments. Brown and Werner (2007) measured activity levels using accelerometers for one week in the summer before and one week in the summer after the opening of a light-rail station in Salt Lake City, Utah. The study revealed that rail trips were associated with an increase in physical activity episodes of moderate intensity—an effect observed beyond the activity associated with walking to or from the rail stop itself. An extension line installed in 2013 provided another opportunity for longitudinal analysis. Follow-up analysis found that transit use was significantly associated with increased physical activity levels and a reduced BMI (Brown *et al.* 2015, Miller *et al.* 2015).

2.4. Transit and Health Outcomes

Transit has been strongly linked to higher rates of active travel and physical activity; however, it is also important that the associated physical health benefits of this more active lifestyle are weighed against potential health threats. For instance, in terms of safety from vehicle traffic or emissions, walking and bicycling to transit can be riskier travel options than other modes due to their higher levels of physical and environmental exposure. For this reason, by travel distance, active travelers suffer from injuries and fatalities at a higher rate than drivers (Elvik 2009, Reynolds *et al.* 2009, Teschke *et al.* 2012). Additionally, walkers and bicyclists may suffer disproportionately from vehicle emissions compared to other modes, particularly during higher-exertion events during which oxygen uptake will be elevated.

Despite these health threats, on the whole, the physical health benefits of active travel appear to outweigh negative health risks (Teschke *et al.* 2012). Similarly, research evaluating the net health impacts of transit use indicates a link with positive health outcomes. In England, the implementation of a program providing free bus passes to older travelers provided a natural experiment allowing Webb *et al.* (2012) to study the health effects of transit. They found that non-transit users who began to ride the bus after the implementation of the policy had the lowest reported BMI levels and the smallest total increase in waist circumference over time. Another British study supported these findings, revealing that survey participants who changed their primary commute mode from private vehicle to transit were less likely to be overweight or obese (Martin *et al.* 2015). After controlling for sociodemographic characteristics, the study determined that switching to transit was related to a reduction in BMI levels. Lindström (2008) found that public transit users in Sweden also had lower rates of overweight and obesity. Public transit use among men was associated with lower odds of being overweight or obese after adjusting for sociodemographic variables, although no effects were seen for women.

MacDonald *et al.* (2010) evaluated BMI and obesity for residents in Charlotte, North Carolina, before and after the implementation of a light-rail system. The light-rail commuters demonstrated lower odds of becoming obese as well as reductions in BMI. Langerudi *et al.* (2015) also associated transit use with lower rates of obesity and a reduced incidence of heart attack and asthma in the Chicago metropolitan area. Their disaggregation procedure allowed them to link county-level health data with census-tract-level travel data. Another study based in the United States observed greater levels of physical activity among

drivers compared to transit users, and found little difference in terms of biologic health indicators such as white blood cell (WBC) count, C-reactive protein (CRP), or gene-specific methylation (Morabia *et al.* 2012). While these findings contradicted previous research, the study failed to consider transit-related physical activity and did not control for potential confounding factors.

Overall, the body of research has clearly linked public transit use with increased levels of physical activity as well as improved health outcomes, though the vast majority of these studies have only evaluated basic weight-based measures such as BMI. Given the somewhat tenuous link between BMI or overweight status and mortality (Zajacova *et al.* 2011), it would be beneficial for future research to investigate additional health measures such as CRP or WBC count. CRP level, for instance, has been associated with pain, fatigue, and poorer overall physical health (Carpenter *et al.* 2012). Also of note, people that are already active may self-select into areas of a community that are conducive to their chosen activity levels. Self-selection may account for as much as 40 percent of higher transit mode shares in areas serviced by rail transit (Cervero 2007) but does not fully account for transit effects. The proclivity for individuals with a greater preference for physical activity to select environments that are conducive to healthful behaviors only partially explains the observed physical activity increases resulting from transit infrastructure.

3. HEALTH CARE COSTS WITH A FOCUS ON PHYSICAL ACTIVITY AND TRANSIT

3.1. Health Costs Associated with Physical Inactivity

Many studies have examined the relationship between physical inactivity, obesity or overweight, and financial health costs. Based on their worldwide systematic review, Withrow and Alter (2011) revealed large increases in personal medical costs associated with obesity. According to the authors' findings, obese people spend approximately 30 percent more on necessary medical costs than non-obese peers. These costs amount to between 0.7 and 2.8 percent of countries' total annual health costs. Litman (2010) reinforced this conclusion with findings indicating lower medical expenditures among physically active adults. Specifically, individuals that are active for the recommended amount of time per week reduce their annual medical expenditures by an average of 32 percent, or \$300 per year.

A Canadian study investigating the costs of obesity and physical inactivity quantified both the direct medical costs and the indirect costs associated with the conditions. In the study, Katzmarzyk and Janssen (2004) found that indirect costs (e.g., the value of lost productivity, the cost of disability status from a work-based injury, and the lost output resulting from premature death) are approximately double the direct medical costs. Obesity, in 2001 Canadian dollars, resulted in direct medical costs of \$1.6 billion and indirect costs of \$2.7 billion, while physical inactivity resulted in \$1.6 billion of direct medical costs and \$3.7 billion of indirect costs. At the time of the study, nearly 54 percent of Canadians were physically inactive, and almost 15 percent of them were obese (Katzmarzyk and Janssen 2004).

Wang et al. (2011) examined populations in both the United States and the United Kingdom to understand the economic effect of increased obesity rates. They found that obesity trends forecast 76 million more obesity cases between the United States and the United Kingdom (65 million in the United States alone) by 2030. Investigating the cost of treating obesity-related diseases such as diabetes, heart disease, stroke, and cancer, the authors discovered that they would result in as much as \$66 billion of increased medical costs in the United States and £2 billion in the United Kingdom by 2030. Given these immense costs, increased rates of physical activity have the potential to dramatically reduce system-wide medical expenditures. Pratt et al. (2000) estimated that if all inactive Americans were to become more physically active, annual health care costs could be reduced by nearly \$77 billion (in 2000 USD).

3.2. Transit's Quantifiable Health Cost Benefit

As discussed previously, transit encourages increased levels of non-motorized travel, particularly walking. Walking imparts health benefits that help individuals avoid heart disease, diabetes, and other negative health outcomes associated with a sedentary lifestyle. Therefore, transit use can reduce the costs of health care incurred by individuals, governments, and employers. Furthermore, improved health increases worker productivity, reducing the economic costs of lost output. Yet despite the demonstrated relationship between transit use and improved public health, there is little research financially quantifying its health cost savings. For transportation planners and transit agencies struggling with tight budgets and financial pressures, a quantitative demonstration of these benefits could provide an effective way to justify public transit expenditures.

Edwards (2008) attempted to place a dollar figure on transit-related health cost savings using 2001 NHTS data. After estimating an additional 8.3 minutes of walking per day as a result of transit, Edwards suggested that transit use could reduce obesity-related medical costs by as much as \$5,500 per person (USD). Edwards further estimated that about 80 percent of the savings would be public costs, meaning that the government, and therefore taxpayers in general, would see the greatest financial benefit from physical activity increases.

Also focusing on obesity-related costs, Stokes et al. (2008) estimated the potential health cost savings associated with a light-rail transit line in Charlotte, North Carolina. Their methodology estimated ridership, area obesity rates, and the effect of light-rail transit on physical activity rates. Based on these estimates, it was found that the implementation of the light rail system would result in increased physical activity worth \$12.6 million (USD) in public health savings over nine years. The authors noted that because the calculation does not include cost savings associated with any health improvements beyond weight loss, this estimate may understate the true savings in medical expenditures.

Litman (2015) conducted a case study of transit-related monetary health benefits for the Portland, Oregon, area. The study compared differences in vehicle, transit, and active travel rates for residents of transit-oriented development (TOD) and non-TOD areas. After adjusting for residential self-selection by assuming that 20 percent of the difference in travel rates resulted from selection effects, the annual per-capita health benefits were estimated at \$355 (USD) for a high-quality transit system and \$541 for a high-quality system with TOD.

In arriving at these figures, a uniform rate of \$0.48 was associated with each mile of walking and \$0.19 for each mile of bicycling. Ensor et al. (2010) used a much larger figure, \$1.35 (New Zealand dollars) per bicycle mile, to estimate the economic health benefits of bicycling to transit in New Zealand, though the methodology used attributed all transit-related bicycle mileage to transit itself, rather than estimating net physical activity gains.

Hendrigan and Newman (2013) investigated the benefits of high-quality transit and TOD for Perth, Australia. The study looked at both health care cost savings and productivity gains due to transit. Based on walking levels seen in other transit-oriented neighborhoods, the authors estimated that their proposed plan would result in an additional 600,000 km walked per day. This figure was roughly translated to a health care cost savings of \$44 million (Australian dollars) over the next 50 years, to go along with a benefit of \$402 million to the economy as a result of improved economy. Also working in the Perth metropolitan area, Matan et al. (2015) demonstrated another back-of-the envelope method for estimating the monetary value of transit-related health benefits. Based on previous studies, they assumed that each additional public transit user walked an additional 15 minutes each day, and the health benefits of this additional activity were valued at \$3.24 (Australian dollars) per hour. From these assumptions, they calculated a total benefit of approximately \$450,000 (Australian dollars) per year for their case study looking at implementing local bus service in the Cockburn Coast area.

Lastly, Mowat et al. (2014) assessed reductions in health costs related to transport physical activity in the greater Toronto-Hamilton area (GTHA) in Canada, where physical inactivity and obesity cost the GTHA \$4 billion (Canadian dollars) annually. Based on the proposed system improvements in the GTHA's 2008 long-range transportation plan, the authors estimated that transit use would increase by 7.8 percent. Under this assumption, and with the aid of the WHO's Health Economic Assessment Tools, the proposed system would be responsible for the prevention of 338 premature deaths annually and \$2.2 billion (Canadian dollars) in health savings per year. Because this calculation accounts for impacts related to emissions reductions, reduced traffic fatalities, and increased adoption of non-transit-related active modes, it is not solely representative of the positive effects of increased physical activity associated with increased transit use. Still, these findings suggest that increasing transit use, encouraging active transportation, and reducing car dependence could save GTHA more than half of what is currently being spent on physical-inactivity-related and obesity-related costs annually.

As described previously, there have been a limited number of research efforts that have attempted to place a value on the societal health benefits of transit use. Estimates varied widely among the reviewed studies due to differences in methodologies and the uncertainty associated with health-related valuations, but it appears that increased physical activity from transit may significantly reduce health expenditures. The limited nature of existing research related to the health cost benefits resulting from transit use highlights the need for more frequent and thorough study of the relationship between transit-related physical activity and health cost savings.

4. DISCUSSION

The literature review revealed that public transit use is associated with increased levels of physical activity and can be a cost-effective way to improve public health outcomes, though much of the reviewed research was centered on culturally Western countries such as the United States, Canada, Australia, and Western Europe. Further research is needed in other regions where transportation patterns are changing quickly. A wider body of global studies has linked transit accessibility to increased physical activity in areas such as Hong Kong, Japan, and Brazil (Ding *et al.* 2013, Hino *et al.* 2014), but research isolating transit users is scarcer.

While there is general agreement in the literature that transit users are more active than nontransit users, the measured effect varies between studies. Given the diversity of studies reviewed, this disparity primarily stems from inconsistent methodologies and differing study contexts. Notably, there are substantial differences in how physical activity is measured, ranging from self-reported estimates to direct measures. The link between transit and local land use policies is also important to recognize. Transit use and transit-related physical activity depend on the prevalence of attractive and walkable/bikeable destinations.

Objective measures of physical activity allow for easier comparison and greater consistency across studies. Yet even among studies using accelerometer data, Rissel *et al.* (2012) noted that transit-related physical activity might be underestimated because it often includes only a single mode of active travel (typically walking). Additionally, some studies only measured active travel for transit or transportation, while others considered all daily activity including recreational physical activity episodes. This broader concept of physical activity events can further strengthen the link between transit and health, given the possibility that some transit users may compensate for increased physical activity by reducing their activity levels in other areas. The need for comprehensive surveys or trip diaries can make it difficult to capture all daily physical activity events, but the growing prevalence of GPS, accelerometers, and pedometers provides a means of passively collecting activity data.

In a similar vein, it is important to consider non-transit-related active travel rates when estimating the effects of increased transit use. Most studies assumed that active travel rates would remain stagnant as transit share rises; however, Co and Vautin (2014) note that transit investments are likely to reduce levels of active travel as transit substitutes for some share of walking and bicycling trips. Therefore, some of the estimated health gains resulting from increased transit use would likely be negated by decreased levels of active travel. In addition to focusing on transit trips, it is necessary to understand how other modes will respond to transit investments.

Research in this field would additionally benefit from consideration of the frequency of transit use because many researchers only compared activity levels between transit and non-transit users. While simpler to implement, this methodology aggregates all transit users, obscuring the effects of increased frequency. For instance, several studies defined transit users as anyone who had used transit in a given week, yet it is not reasonable to assume that transit-related physical activity effects can be applied equally to a daily transit rider and an

occasional commuter. A frequency-based measure of transit use would more accurately attribute physical activity gains to ridership rates. Additionally, a true measure of the physical activity benefits of transit should ideally involve a comparison with competing modes. These non-transit alternatives—typically walking, bicycling, or driving—all comprise their own physical activity effects. Should a transit trip take the place of one that would otherwise be conducted by an active mode, there is unlikely to be a net physical activity gain realized. On the other hand, transit generally provides physical activity benefits when transit substitutes for a trip by private vehicle, though not in every instance. Even though they are often considered entirely sedentary events, vehicle trips themselves typically necessitate walking to and from the parking location.

While multiple studies have verified the positive health effects of transit, determining the monetary value of these costs has proven to be more difficult. As a result, only a small group of studies has taken up the problem of estimating the potential health care cost savings of transit systems, and those that did relied on rough estimations and simplistic assumptions. Physical inactivity and the resulting negative health implications accounts for substantial portions of health care spending. Because transit can help users achieve recommended daily physical activity levels, it can be used as a means to increase physical activity, improve public health, and reduce health-related expenditures. Placing a value on transit's potential health cost savings has been difficult, but such evidence could increase transit's viability when competing for funding with other modes.

Improved tools for attributing health care costs and benefits to transit are needed given that current data and methodologies are unable to support such endeavors. Perhaps the greatest challenge when it comes to estimating the potential health cost savings of transit are the limitations of health datasets. Due to privacy concerns, typically only broadly aggregated health data are available, making it difficult to link them to transit datasets. For these reasons, disaggregation procedures may be needed in order to better align health and transit data (e.g., Langerudi et al., 2015). While disaggregate health data may be available in some cases (e.g., the insurance data used by Garrett et al. [2004]), they are difficult to acquire and may necessitate a partnership with a medical agency or insurance company. Otherwise, extrapolating localized small-scale survey efforts may be the most effective way to estimate the true cost savings potential of transit. As it stands now, the monetary benefits of public health improvements associated with transit-related investments are relatively uncertain.

5. CONCLUSION

This study reviewed existing research pertaining to public transit and physical activity, which consistently asserts that transit use is associated with increased levels of physical activity and improved health outcomes. Despite general agreement on the demonstrated physical activity and health benefits of transit, there is still uncertainty regarding the magnitude of these benefits. Based on the reviewed literature, a number of insights were presented that can help drive research in this area.

Research efforts dedicated to empirically measuring transit and non-transit related physical activity will allow for an improved understanding of physical activity substitution effects.

Frequency-based measures of transit use can additionally help establish enhanced estimates of transit-induced walking or bicycling. Studies financially quantifying transit-related health cost savings were scarce and inexact, but appear to indicate that transit investments can lead to economic gains. Research in this area would benefit from disaggregate estimation techniques and more robust health datasets, which can be better linked to existing transit data. Additionally, a number of other pathways link transit and public health, such as vehicle safety and emissions. While the focus of this work is specifically on transit's physical activity benefits, future studies would benefit from investigating these other issues. Such efforts are likely to present powerful evidence that transit can make populations healthier and substantially reduce health-related expenditures for the public, governments, and private industry.

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Highlights

- Transit use is linked with increased physical activity and improved health outcomes.
- Frequency-based transit measures can enhance estimates of health impacts.
- Transit can reduce health costs, but empirical studies are scarce.
- Health datasets should be better linked with existing transit data.
- Research in this area would benefit from disaggregate estimation techniques.