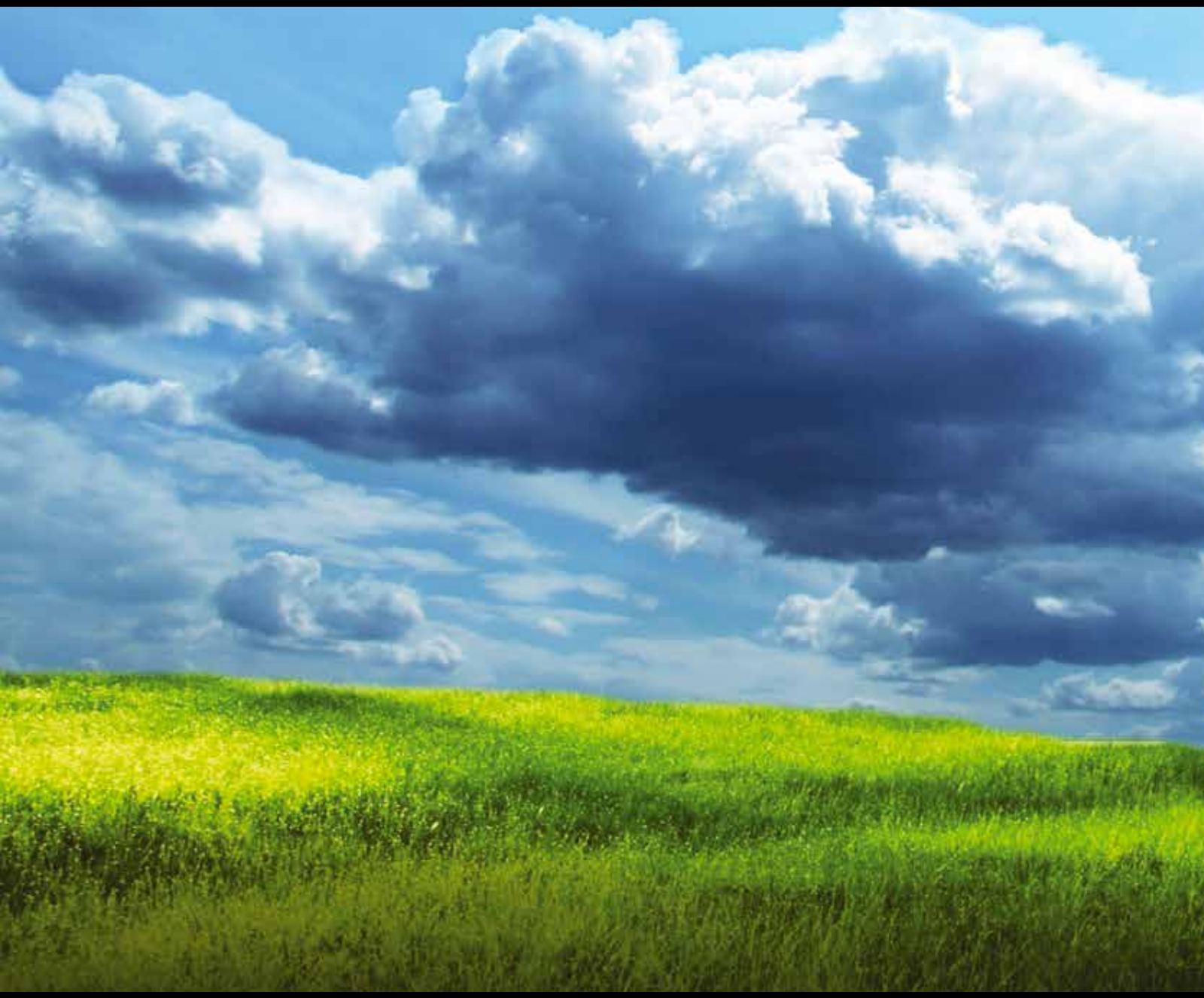
Journal of Environmental and Public Health

The Effect of Active Transport, Transport Systems, and Urban Design on Population Health

Guest Editors: Li Ming Wen, Chris Rissel, and Hua Fu



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Editorial

The Effect of Active Transport, Transport Systems, and Urban Design on Population Health

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Without doubt, active transport (working, cycling, and the use of public transport), transport systems, and urban design significantly impact population health. A 2013 systematic review of the relationships between active transport and health outcomes found that active transport was significantly associated with improved cardiovascular health and lower body weight. However, the strength of the evidence varied from weak (mental health and cancer), moderate (body weight), to strong (cardiovascular health). The evidence was limited by lack of comparability of study outcomes, weak study designs, small sample sizes, and lack of experimental studies [1].

Although the links between active transport and population health are still emerging, the evidence linking active transport directly to health outcomes has not been examined extensively and the relationship between active transport and health still remains unclear. More research is needed to better understand the important correlates related to active transport and its contributors to population health, and develop effective strategies to promote active transport. With this in mind we selected the theme for this special issue. We wish to highly commend the authors for their well written papers exploring a range of issues related to promoting active transport, which include health benefits associated with it and potential strategies to promote active transport as well as challenges in measuring the effectiveness of promoting active transport.

The paper by M. Bopp et al. examined the association between health-related factors and mode of travel to the workplace. The study used a convenience sample of employed adults who completed an online survey regarding demographics, health-related factors, and the number of times per week of walking, biking, driving, and using public transit to work. Logistic regression was used to predict the likelihood of each mode of transport and meeting physical activity (PA). The study found that about 10 percent of respondents met PA recommendations based on the use of active transport to work alone, which has an important implication for promoting physical activity through active transport.

The paper by R. Zhou et al. examined the perceived neighborhood environment characteristics associated with PA in urban areas in China. Cross-cultural comparisons of how the environment can influence behaviour warrant more attention. In this study, adult cross-sectional data was collected using accelerometers, the International Physical Activity Questionnaire (IPAQ), and Neighborhood Environment Walkability Scale-Abbreviated (NEWS-A) survey. Consistent with western countries, residents from downtown areas had higher levels of transportation PA and leisure-time PA than respondents living in the suburbs. Residential density was positively associated with recreational and leisure-based PA, and moderate-vigorous PA was found to be negatively associated with traffic safety.

An interesting paper by S. R. Lu et al., however, found that, contrary to expectations, there was no benefit to population health from active transport. They conducted a population-based cross-sectional study in Jiangsu, China. 8400 community residents aged 18 or above were interviewed following a multistage random sampling method. Face-to-face questionnaire survey data, anthropometric measurements,

and biochemical data from blood tests were collected. Results showed an inverse correlation between active transport and some health outcomes, including cholesterol disorder, risk of diabetes, and risk of obesity.

Another paper focused on cycling was the paper by N. T. R. Romanow et al., which used a case-control study design to examine environmental risk factors for bicycling injuries. They combined data on bicyclist injuries collected by interviews in the emergency department with street-level environmental audits of injury locations, capturing path, roadway, safety, land use, and aesthetic characteristics. They focused on more severe injuries—being struck by a motor vehicle or cyclists that were hospitalized. Adjusted logistic regression analyses found that the factors contributing to motor vehicle events included greater traffic volume intersections, retail establishments, and path obstructions. Protective factors included locations where the road was in good condition and where there was high surveillance from surrounding buildings. Safety issues are an ongoing concern in the promotion of cycling.

C. Rissel et al. conducted two pilot studies on the effect of bicycling on balance and leg strength among older adults. The preliminary results showed that participants who had cycled in the last month performed significantly better on balance measures of decision time and response time in Study 1; and cycling at least one hour a week was associated with significant improvements in balance (decision time and response time) and timed single leg standing from Study 2.

In addition, the paper by T. Xia et al. reviewed the evidence of links between vehicle emissions and air quality, as well as the health and economic benefits from alternative transport use and methodological issues relating to the modeling of these cobenefits. The review concluded that current analyses of transport mitigation strategies in terms of health and economic aspects are still at an early stage. Most of the previous research regarding the transport sector has only focused on one of those possible benefits and has rarely quantified the overall cobenefits of alternative transportation planning. Additionally, most of the current co-benefit studies are more interested in the long-term effect of alternative transportation, while the short-term effect has not been considered adequately. Some other benefits, such as social benefits from alternative transport are also valuable for further investigation.

The paper by N. Petrunoff et al. assessed the reliability and validity of survey questions used to measure workplace travel behavior. Sixty-five respondents completed a travel diary for a week, wore an accelerometer over the same period, and twice completed an online travel survey (21 days apart). They confirmed that the survey question "How did you travel to work this week?" with daily response options over seven days is reliable and agrees well with a travel diary.

D. Cooley and S. Pedersen conducted a pilot study to test the feasibility of a workplace e-health intervention based on a passive approach to increase nonpurposeful movement as a means of reducing sitting time. The study that was trialed in a professional workplace with forty-six participants had some promising results, but there is a need for further investigation. S. Crawford and J. Garrard presented a mixed method study describing a comprehensive impact process evaluation of the Ride2School program in metropolitan and regional areas in Victoria, Australia. The paper highlights the benefits of undertaking both qualitative and quantitative methods in evaluating active transport to school programs that enables both measurement and understanding of program impacts.

Finally, the paper by D. Fuller and P. Morency called for a population approach to transportation planning: reducing exposure to motor-vehicles. This paper provided an overview of Geoffrey Rose's strategy of preventive medicine applied to road traffic fatalities and concluded that interventions should address the large number of people exposed to the fundamental causes of diseases. Public health and transportation research must critically appraise their practice and engage in informed dialogue with the objective of improving mobility and productivity while simultaneously reducing the public health burden of road deaths and injuries.

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Chris Rissel
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Review Article

Cobenefits of Replacing Car Trips with Alternative Transportation: A Review of Evidence and Methodological Issues

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It has been reported that motor vehicle emissions contribute nearly a quarter of world energy-related greenhouse gases and cause nonnegligible air pollution primarily in urban areas. Reducing car use and increasing ecofriendly alternative transport, such as public and active transport, are efficient approaches to mitigate harmful environmental impacts caused by a large amount of vehicle use. Besides the environmental benefits of promoting alternative transport, it can also induce other health and economic benefits. At present, a number of studies have been conducted to evaluate cobenefits from greenhouse gas mitigation policies. However, relatively few have focused specifically on the transport sector. A comprehensive understanding of the multiple benefits of alternative transport could assist with policy making in the areas of transport, health, and environment. However, there is no straightforward method which could estimate cobenefits effect at one time. In this paper, the links between vehicle emissions and air quality, as well as the health and economic benefits from alternative transport use, are considered, and methodological issues relating to the modelling of these cobenefits are discussed.

1. Introduction

Over the last century, the number of motor vehicles built, purchased, and used on roads globally has dramatically increased to meet people's travel demands. Although alternative fuels have been developed, more than 95% motor vehicles are still dependent on fossil fuels, a dependency which does not seem to be abating [1, 2]. Because of the large consumption of fossil fuels, transportation is regarded as a major contributor of greenhouse gases (GHGs). According to research conducted by Kahn Ribeiro and colleagues [3], a quarter of world energy-related GHG emissions can be attributed to transportation and nearly 85% of transportation-related GHG is exhausted by land transportation. Furthermore, it is predicted that transport energy usage will continue to increase at a rate of about 2% per year worldwide, whilst total transport energy usage and carbon emissions will be 80% higher than their current levels by 2030 [3].

It is widely acknowledged that exhaust fumes from motor vehicles contain a variety of air pollutants such as nitrogen dioxide (NO_2), volatile organic compounds (VOCs), carbon monoxide (CO), and particulate matter (PM). Although the contribution of road transport to local pollution may vary depending on distinct local features, such as geographic and climatic features, the technology distribution of the national fleet, driving patterns and density [4], and vehicle emission is no doubt a significant source of air pollution, especially in highly car-dependent cites. The European Topic Centre on Air and Climate Change 2005 data [5] demonstrate that road transport accounts for about 42% of total NO_x (NO and NO_2), 47% of total CO, and 18.4% of total PM emissions at European Union of 15 member states.

To reduce the emissions from motor vehicles, mitigation strategies have been implemented in various countries. These mitigation strategies could be summarised as falling into three main approaches: (1) renovation of new vehicle technology, such as developing new energy sources for motor vehicles and elevating standards for emissions [6, 7]; (2) improvement of land use and urban planning, such as an establishment of bus rapid transit systems [8]; (3) travel

behaviour change promotion in terms of promoting sustainable alternative transport use, such as public transport and active transport (e.g., cycling and walking), which has been a common approach in some European cities [9]. Besides the direct-core environmental benefit, the mitigation strategies of reshaping transport patterns via promoting mass transit and active transport have been increasingly recognised as an opportunity to gain great cobenefits. The definition of a cobenefit is "an additional benefit arising from an action that is undertaken for a different principal purpose" [10]. For example, both public transport and active transport will result in less dependency on fossil fuels and a reduction in traffic congestion. As a result of restricting vehicle use, air quality could be significantly improved and the health issues caused by air pollution could be alleviated. Additionally, active transport, in particular, also provides health benefit through regular physical activities. Moreover, economic improvements could also be gained from reduction of car use.

Exploring and understanding these cobenefits might provide invaluable information to policy makers in transport and land planning. However, to date, little research has been conducted in these areas. In order to improve understanding of the advantages of alternative transport, this paper aims to review, in detail, (1) the evidence regarding the health and economic cobenefits of alternatives to car travel, and (2) the methodological issues faced in previous studies in this field. Recommendations for further research are then discussed.

2. Method

A literature search for reviewing papers published in English between 2002 to March 2013 was conducted using the main research databases PubMed, Scopus, Web of Science, and Google scholar along with searching of references on relevant organisations' websites including World Health Organization, the International Panel on Climate Change (IPCC), and relevant transport department websites. The search focussed on two purposes: first, a review of the broad literature relevant to effects of vehicle emissions in order to summarise benefits of alternatives to car travel. The search was conducted using a combination of keywords as follows: land/road transportation, vehicle emission, transport/traffic emission, air pollution, air quality, car trips, alternative transport, public transport, active transport, bicycling, cycling, and walking. The second purpose of focus was "co-benefits" studies, specifically in the transport sector. The major goal at this stage was to identify specific studies which conduct multiple benefits evaluation of alternative transport scenarios. These "co-benefits" papers were reviewed for specific issues within the methodology of modelling cobenefit effects from alternative transport scenarios. Review of methodological issues in the "co-benefits" studies were identified according to the following criteria: (i) whether the studies focused on transport sector; (ii) whether multiple benefits of alternative transport scenarios were evaluated, and (iii) whether projective models were used. Exclusion criteria were applied: first, those focused on the whole energy system rather than transport system; second, studies only evaluating single benefit of alternative transport scenarios and review papers. Except for unavailable papers, five "co-benefits" studies were identified and are listed in Table 1, with a summary of the scenario design, target populations, modelling method/tools, environmental and health indicators, and main findings.

2.1. Public Transport. Public transport, such as bus and train, is extensively used as a dominant travel mode in developing countries. Compared to private car, public transport has a larger carrying capacity. Trams, trains, and subways rarely get stuck in traffic congestion, and bus schedule can be flexibly arranged, with multiple buses able to travel the same route simultaneously, in response to peak times or to cater for special events [16, 17]. Although public transport is not defined as a "zero-pollutant" travel mode, its average emissions per passenger are far lower than that from cars. Furthermore, cleaner and more fuel efficient public transport is becoming more common in many countries, supporting a further reduction of GHG emissions and air pollution. For example, Compressed Natural Gas (CNG) buses have been used in several countries, such as USA, Brazil, Argentina, Italy, Pakistan, and New Zealand, for many years [18]. Additionally, walking to and from public transportation may help physically inactive populations achieve the recommended level of daily physical activity. A US study found that 29% of people who use public transit could achieve ≥30 minutes of physical activity a day solely by walking to and from transit [19]. A systemic review conducted by Rissel et al. [20] reported that public transport usage could increase physical activity per day by a range of 8–33 minutes. Public transport may not be attractive for local residents as private cars because it is less flexible and can take longer to travel to one's destination. Therefore, buses or trams are often not considered as a real alternative to cars. However, these problems could be counteracted by creating priority systems for public transport for traffic lights and building quality bus corridors or priority routes, which have been implemented in many countries such Korea, USA, and Australia [21–24]. Despite such government initiatives, public transport trips continue to account for only a small portion of total trips in many urban areas. In London and Sydney, for example, only about 10% of all trips are made by public transport, while over 70% of all trips are made by car [25, 26].

2.2. Active Transport. Active transport is another attractive environmentally friendly transport alternative, particularly for short journeys. Active transportation, including travelling on foot and by bicycle and other nonmotorised transport, is recognised as largely "zero-pollutant," with respect to emissions of the travel itself (emissions are produced in the building, distributing, and servicing of bicycles, e.g.). The other advantage of the active transportation is flexible (or nonexistent) parking considerations and lower cost. At the moment, a large proportion of the total trips in most European cities are shorter than 2.5 km which is a distance relatively easy to be replaced by active transport: 44% in the Netherlands, 37% in Denmark, 41% in Germany, and 30% in UK [27]. Short trips also occupy a considerable percentage of total travel trips in major Australian cities. Taking Sydney as

Table 1: Summary of cobenefits studies in transport area.

Reference Author, year, study sites	Study design Scenarios	Methodological of modeling Environment impact assessment Method/ tools	Indicators	Key parameters resource	Health impact assessment Method/ tools	Indicators	Key parameters resource	Economic impact assessment Method/ tools	Indicators	Key parameters resource	Results Main finding
Woodcock et al. (2009) [11] London, UK, and Delhi, India	BAU 2030 Lower-carbon-emission motor vehicles (more efficient engines and fuels switching) Increased active travel (increasing walking and cycling) Towards sustainable transport (lower-carbon-emission motor vehicles and increased active transport scenarios)	London: ERG Emissions Toolkit ADMS 4 OSPM v5.0.64 Delhi: SIM-air Version 1.3	Annual mean PM_{10} and $PM_{2.5}$ concentrations	London: LAEI 2006 Delhi: inventory of aerosol and sulphur dioxide emissions from India	CRA	Annual preventable DALYs of cardio-respiratory lung cancer, acute respiratory infections (air pollution reduction), diabetes, dementia, hypertensive heart disease, cerebrovascular disease, breast cancer, colorectal cancer, depression (increased physical activity)	Global Burden of Disease Database Meta-analyses from an exhaustive literature review London: London-area travel demand models London Area Travel Survey Delhi: World Health Survey 2000				London: 60% reduction in transport CO_2 emissions from the 1990 levels; 7439 DALYs per million population would be avoided (towards sustainable transport scenarios) Delhi: 199% increase in CO_2 emissions from 1990; 12 995 DALYs per million population would be avoided (towards sustainable transport scenarios)
Lindsay et al. (2011) [12] Auckland, New Zealand	Moving short urban trips (<7 km) from cars to bicycles by 1%, 5%, 10%, and 30%	VEPM version 2.3	vehicle emissions per km for CO, CO_2, NO_X, VOC, and PM_{10}	HAPiNZ study	HEAT	Annual reduction in deaths Energy expenditure	New Zealand Household Travel Survey HAPiNZ study	HEAT	Value of Statistical Life Fuel savings ($NZ)	HAPiNZ study Ministry of Transport's Value of Statistical Life	Shifting 5% of vehicle kilometers to cycling would save 22 million liters of fuel; reduce transport-related GHGs by 0.4%; avoide 122 deaths annually due to increased physical activity and local air pollution reduction; save $200 million per year from health effect

Table 1: Continued.

Reference Author, year, study sites	Study design Scenarios	Methodological of modeling Environment impact assessment Method/ tools	Indicators	Key parameters resource	Health impact assessment Method/ tools	Indicators	Key parameters resource	Economic impact assessment Method/ tools	Indicators	Key parameters resource	Results Main finding
Rojas-Rueda et al. (2012) [13] Greater Barcelona metropolitan area	BAU Replacing car trips (20%, 40%) by bicycle Replacing car trips (20%, 40%) by public transport (bus, tram, train, and metro) Replacing car trips (20%, 40%) by bicycle and public transport	Barcelona Air-Dispersion Model	$PM_{2.5}$ concentration CO_2 emission	Barcelona City council report 2009 Local trans-portation departments	RR functions in PM2.5 HEAT	All-cause mortality	Daily Mobility Survey of Catalonia Daily Mobility Survey of Catalonia Statistical Institute of Catalonia Published literature				A shifting of 40% car trips to cycling and public transport would avoid 98.5 deaths in total; reduce 203, 251 t/CO_2 emissions per year
Grabow et al. (2012) [14] Midwestern United States	Replacing short car trips (≤8 km round trip) in urban areas by bicycle	Community Multiscale Air Quality Model version 4.6 BenMAP version 4.0.35	Mean annual $PM_{2.5}$ and O_3 concentration	2001 National Emissions Inventory US EPA	BenMAP HEAT	Mortalities of asthma, chronic bronchitis, respiratory problems, cardiovascular problems, work-loss days, acute respiratory symptoms, ER visits, mortality, HA (respiratory school-loss days worker productivity), (air pollution reduction), All-cause mortality (increased physical activity)	1996 National Health Interview Survey Published literature US EPA	BenMAP HEAT	Cost savings	US EPA	Eliminating short car trips and completing 50% of them by bicycle would decline mean annual $PM_{2.5}$ by 0.1 $\mu g/m^3$; decline mortality by 1,295 deaths/year in 31.3 million people because of improved air quality and increased exercise; combine benefits of improved air quality and physical fitness would exceed $8 billion/year

Table 1: Continued.

Reference Author, year, study sites	Study design Scenarios	Methodological of modeling Environment impact assessment Method/ tools	Indicators	Key parameters resource	Health impact assessment Method/ tools	Indicators	Key parameters resource	Economic impact assessment Method/ tools	Indicators	Key parameters resource	Results Main finding
Maizlish et al. (2013) [15] San Francisco Bay Area	BAU 2035 Low-carbon driving (increased hybrid vehicles and light-duty diesel, biofuel, and electric vehicles) Active transport (50% of BAU miles travelled in car trips less than 1.5 miles are walked and 50% of BAU miles travelled in car trips 1.5 to 5 miles are by bicycle)	EMFAC2007 BAAQMD air shed model	CO_2 emissions Annual PM2.5 concentration	California Air Resources Board Bay Area Air Quality Manage-ment District	CRA	Lung cancer, respiratory disease, (air pollution reduction) Annual preventable DALYs of cardiovascular diseases, colon cancer, breast cancer, diabetes, dementia (increased physical activity)	Global Burden of Disease Database 2000 Bay Area Travel Survey Meta-analyses				Increasing active transport scenario would reduce 5952 DALYs per million people in total; increase the traffic injury burden by 39% (5907 DALYs); decrease GHGE by 14% Low-carbon driving scenario would reduce 31 DALYs per million people in total; reduce GHGE by 33.5%

BAU: business as usual.
ERG: Environmental Research Group.
ADMS: Atmospheric Dispersion Modelling System.
OSPM: operational Street Pollution Model.
SIM-air: Simple Interactive Models for better air quality.
LAEI: The London Atmospheric Emissions Inventory.
DALY: The disability-adjusted life year.
VEPM: Vehicle Emissions Prediction Model.
HAPiNZ: Application of Health and Pollution in New Zealand.
HEAT: Health Economic Assessment Tool.
BenMAP: Environmental Benefits Mapping and Analysis Program.
EPA: Environmental Protection Agency.
EMFAC: Emission Factors model.
BAAQMD: Bay Area Air Quality Management District.

an instance, 20% of all trips made on an average weekday are less than 1 km, 35% are less than 2 km, and 60% are less than 5 km, which has been considered to be a suitable distant for walking or cycling [26]. However, the number of trips made by walking and cycling has declined significantly over the last 20 years [28]. It has been reported that cycling only occupies less than 3% of the total travel trips in some cities in UK, USA, and Australia [26, 27, 29]. This decline in cycling strongly reflects a high reliance on motor cars in modern society.

Despite the significant decline in the number of trips made by active transport, government efforts can play a considerable role in active transport promotion. It is estimated that a 52% increase in bicycle trips could be achieved in Australia by 2016, and a 71% rise by 2026 under a collaboration among the Australian Local Government Associations [30]. Given growing environmental concerns, many developed countries have conducted cycling promotion programmes to encourage active transportation. Countries like the Netherlands, Denmark, and Germany have been very successful in this endeavour. From 1950 to 1975, the percentage of trips using cycling decreased significantly by two-thirds in the Netherlands (from 50% to 85% of trips in 1950 to only 14–35% of trips in 1975) and Germany (fell by 78% from 1950 to 1975), as car ownership surged and cities started spreading out [27]. However, during that 25-year period, the governments of these countries focused on improving their cycling infrastructure, whilst imposing restrictions on car use; subsequently, the cycling share of trips increased by 25%. Currently, over 30% of trips to work or school are made by bicycle in the Netherlands and Denmark, whilst this percentage in Germany is 28% [27].

3. Evidence of Potential Benefits of Promoting Alternative Transport

3.1. Environmental Benefits. More than half of the world's population live in urban areas, and it has been estimated that the global urbanised population will reach five billion by 2030 [31]. Accordingly, air quality will be significantly affected due to increasing travel demands and related motor vehicle usage. However, air quality could be largely improved by implementing appropriate traffic controlling strategies especially in urban areas. During the 2008 Beijing Olympic Games [32], for instance, most Beijing residents chose public transit or cycling as their dominant mode of transport because a large portion of private and business cars were restricted in use according to Olympic traffic management. Consequently, a noteworthy reduction of traffic flow was noticed during the Olympic traffic control days and on-road air quality improved significantly: the average reduction rates of PM_{10}, CO, NO_2, and O_3 reached 28%, 19.3%, 12.3%, and 25.2%, respectively [32]. Similarly, a three-month traffic restriction implemented during the Sino-African Summit was a remarkable success in air pollution control, reducing 40% NO_x emissions in Beijing [33]. Throughout the period of the 1996 Atlanta Olympic Games, as a result of traffic restrictions, peak daily ambient ozone concentrations dropped by 30% from the baseline measure, which led to a significant decrease of asthma cases [31]. Therefore, reducing motor vehicle usage can improve air quality with immediate short-term effect.

3.2. Health Benefits

3.2.1. Health Benefit from Mitigation of Vehicle Emission Reduction. On one hand, transportation has been identified as being partly responsible for GHG effects, given that the emissions from motor vehicles contain large amounts of CO_2, NO_x, and CH_4. Furthermore, it has been proven that GHG effect is the main cause of global warming. Cross-sectional studies conducted in different regions have shown that thousands of excess deaths could be caused with the increased frequency and intensity of extreme weather [34–36]. On the other hand, according to a recent WHO report, approximately 1.3 million premature deaths worldwide are attributed to outdoor air pollution in 2009 [37]. Recently, health impacts of vehicular air pollution have also attracted more and more public attention and academic research, with an increasing number of studies investigating the association between proximity to roads and population health. They reported that pollutant concentrations are higher in areas closer to motorways and decline gradually with distance from motorways [38, 39] and increasing mortality and morbidity have been observed in populations living near major roads [40–42]. Particularly, a Dutch cohort study enrolling 12,852 subjects with a 10-year followup illustrated that traffic intensity on the nearest road would increase mortality of natural causes, cardiovascular, respiratory, and lung cancer by 5%, 4%, 22%, and 3%, respectively [43]. Similarly, people living close to major roadways have an increased risk of coronary mortality [44]. In contrast, the risk has been found to decrease gradually when people move away from major roadways.

Transport-specific behavioural change programmes, including increasing mass transit use and active travel, are essential in relieving these adverse health effects. Woodcock and colleagues [11] evaluated the environmental and health benefits of various alternative transport scenarios by 2030 in London, UK, and Delhi, India. Their research indicated that about 122,000 premature deaths and thousands of disability-adjusted life-years (DALYs) caused by air pollution could be saved under alternative transport scenarios by 2030. Another study conducted in Mexico City evaluated five control options for the Program to Improve Air Quality in the Valley of Mexico: taxi fleet renovation, metro expansion, hybrid buses, liquefied petroleum gas (LPG), and cogeneration. The results showed that these five measures together could reduce approximately 1% PM10 exposure, 3% maximum ozone exposure, and more than 1.5 Mton (Metric Ton) CO_2 equivalent emissions. Additional to the environmental benefits, these measures could also save nearly 100 lives and reduce 700 cases of chronic bronchitis each year.

3.2.2. Health Benefit from Active Transport. Another potential health cobenefit comes from increased physical activity associated with active transport. According to Global Recommendations [45], adults aged 18–64 should do at least

150 minutes of moderate intensity aerobic activity per week. A person who walks or cycles 150 minutes a week or 30 minutes per week day could be grouped in the population conducting regular physical exercise on the basis of the World Health Organization (WHO) recommendation. Although such guidelines for physical activity have been provided for a long time, sedentary lifestyles still remain a global public health problem. To date, physical inactivity has been regarded as one of the most risky behavioural factors contributing to disease burden, especially in developed countries [46].

Active Transport, Physical Activity, and Health Benefits Overall. Active transport such as walking and cycling provides an opportunity to incorporate frequent physical activity into daily living, which could help people achieve recommended levels of physical activity. Moreover, various evidence of a positive association between active transport and health outcomes has been published [20, 47–51]. For example, a recent systematic review [52] summarised evidence of the health benefits of cycling and reported a strong inverse relationship between commuter cycling and all-cause mortality, cardiorespiratory fitness, cancer mortality and morbidity, and a clear positive dose-response relationship between the amount of cycling and body fitness, and incidence of overweight and obesity decrease.

A systematic review conducted by Woodcock et al. [47] reported a reduction in mortality risk of 19% in populations who have 30 minutes daily of moderate intensity activity 5 days per week, compared with those people with no activity. A longitudinal study among Scandinavian adults, for example, found that all-cause mortality rates in moderately and highly active persons decreased by 50% when compared to a sedentary group of people [53]. In addition, this study suggested that cycling to work would reduce the risks of all-cause mortality by approximately 40%. A study conducted in Copenhagen followed up a health cohort including 13,375 women and 17,265 men for nearly 15 years. The main finding of this study suggested that cycling to work can decrease the risk of all-cause mortality by 40%, including leisure time physical activity [53]. A similar result was reported in a Chinese cross-sectional study showing that women who regularly did physical exercise or used a bicycle as transportation could attain a 20–50% lower risk of premature mortality [54]. Further, Australian research revealed that a 5% increase in the proportion of people doing 30 minutes moderate activity each day could save around 600 lives per year, which could significantly reduce health expenditure to the health system [55].

Active Transport, Physical Activity, and Benefits Relating to Specific Conditions. Moderate intensity physical activities, including walking and cycling, have also been demonstrated to decrease the morbidity of many chronic diseases such as diabetes, cardiovascular disease, breast cancer, colon cancer, and dementia [11, 56–59]. Jeon and colleagues [57] reviewed 10 prospective cohort studies to estimate the effect of physical activity of moderate intensity on type II diabetes. They found that the risk of type II diabetes was 31% less for participants who engaged in regular moderate intensity physical activity, with 30% less risk among a regular walking population compared with almost no walking [57]. Xu et al. [60] systematically examined the relationship between active transport to work or school and cardiovascular health. A significantly positive association between active transport to work or school and cardiovascular health has been found in this review. Furthermore, another systematic review conducted by Monninkhof and colleagues reported that regular exercise might reduce the risk of postmenopausal breast cancer by 20%–80%, with each additional hour of physical activity per week potentially resulting in a further 6% reduction in breast cancer risk [58].

Active Transport, Physical Activity, and Benefits Relating to Fitness and Weight. Body fitness can also be strengthened by prompting active transport. A British study compared the physical condition of children who walked or cycled to school compared with those who travelled by bus or car. Their finding revealed that the former group was fitter than the latter one, with 30% higher vigour in boys who took active transport and seven times higher in girls [61]. It is estimated that approximately 40 million children and 1.4 billion adults are either overweight or obese worldwide [62]. Active travelling may be regarded as an efficient approach to combat obesity. Indeed, a synthesised result from the systematic review conducted by Xu et al. also reported that more active transport to work or school has been found associated with lower body weight [60]. Moreover, an Australian study conducted by Ming Wen and Rissel suggested that men who drove to work were more likely to be obese or overweight compared with those who chose cycling [49]. Recent research investigating the obesity levels in Europe, North America, and Australia established an inverse relationship between active transport levels and obesity levels in the population [63]. The results suggested that active transport might be one of the important factors contributing to international differences in obesity rates [63].

3.3. Economic Cobenefits. In addition to environmental and health benefits, economic benefits can also be obtained through alternative transport promotion. At the moment, the majority of motorised vehicles are highly dependent on fossil oil and consume almost 50% of total fossil oil usage [64]. The overreliance of motorised vehicles on petroleum not only causes concern regarding GHG emissions but also leads to nonrenewable energy sources diminishing. Apparently, the fossil oil cost would be reduced with the reductions of vehicle kilometres travelled and the increase of alternative transport [65]. In addition, with the decrease in the vehicle travelled kilometres and fuel use, the costs of air pollution control would also be reduced correspondingly. Although the costs per kilometre air pollution and climate change of public transport are higher when compared with private transport, the costs per passenger of public transport are significantly less than that of private transport due to the large number of private cars [66].

A New Zealand case study estimated the total costs of private and public transport in Auckland, with particulate

matter as the vehicle-related air pollution indicator. Their finding demonstrated that a PM_{10} value of 16 mg/m^3 caused by motor vehicle exhaust led to additional illnesses and amounted to a cost of $422 million in 2001, which was equal to 57% of the total health cost arising from PM_{10} in the Auckland region [66]. Further analysis on these additional costs revealed that $211.6 million (of the $422 million) came from private transport, whereas only $17.2 million was contributed by public transport. A similar trend was also observed when the authors calculated the total climate change costs from private cars and public transport using a unit cost per tonne CO_2. By this standard, the total costs from transport were $58.4 million, with $0.67 million coming from public transport and $57.8 million from private transport [66]. In addition to the cost reduction in fossil oil usage and air pollution control, economic benefits of alternative transportation may also be achieved by reducing motor vehicle-related mortality and morbidity. In Australia, it has been reported that the combined economic cost of motor vehicle-related mortality and morbidity was approximately $2.7 billion in 2000. More than 85% of this cost was incurred in capital cities, which covered 80% of Australian populations [67].

Previous studies have also suggested that negative health outcomes caused by physical inactivity (related to car travel, rather than alternative transport) might lead to increased medical expenditure as well. Recent estimates indicate that the direct and indirect costs are $13.8 billion for physical inactivity [55] and $21 billion for obesity and overweight in Australian [68]. To investigate the economic benefit from active transport, Grabow and Colleagues [14] modelled the impact on the health budget of eliminating short motor vehicle trips in 11 metropolitan areas in the upper mid-western United States. They estimated that the combined benefits of improved air quality and physical fitness would exceed $8 billion/year.

4. Methodology Issues in Cobenefit Analysis

4.1. Scenarios. To predict the cobenefits of alternative transportation modes, it is fundamental to set up alternative GHGs emission/active transportation scenarios for analysis. Alternative scenarios are designed not only based on the researcher's assumptions but also in relation to local transport circumstances. Although there are a variety of alternative transport choices, such as bus, taxi, hybrid vehicle, and bicycle, most researchers tend to choose ecofriendly and healthy modes to evaluate the cobenefit effects. In current cobenefit studies (as seen in Table 1), the alternative transport scenarios were built from different perspectives, and different assumptions were made with a consideration of uncertainties. However, those assumptions must be reliable, practical, and achievable. For instance, in a US study [14], all short car trips (≤8 km) were assumed to be eliminated and they made this scenario based on a census-tract level travel. Similarly, Woodcock et al. [11] compared a BAU with alternative scenarios in 2030 in London, UK, and Delhi, India, for their cobenefit analysis. In their study, because of the different traffic structure, they then modelled different alternative transport scenarios for each city. Obviously, it is not practical to assume that 100% of car trips will be made by cycling or public transport. It would be preferable, instead, to base scenarios on an understanding of local traffic conditions and future transport plans or policies of local authorities, although the challenges in doing this are acknowledged.

4.2. Modelling Method and Tool

4.2.1. Environmental Benefit Assessment. In transport related cobenefit studies, the estimation of the emissions change from motor vehicle reduction is a vital component of the environmental impact assessment. There are various vehicle emission models which could be used in cobenefit analysis appropriately. However, data requirements and modelling approaches may vary for each model, and it is difficult to judge which one is the best. Generally, the ideal model should be adapted to the target application and the changing demand. In addition, the model should be used either to examine relative changes from different scenarios or to predict absolute levels of emissions under a given period and location [69]. Furthermore, it is also vital for researchers to model emissions with tools corresponding to local traffic situations. For example, a UK study [11] modelled the vehicle emissions in London by using the Emissions Toolkit developed by the Environmental Research Group from King's College, which provided detailed transport emission data for over 6,000 roads in London. In a New Zealand study [70], the researchers used the Vehicle Emissions Prediction Model (VEPM), which was developed by Auckland Regional Council as their own emission model, to calculate the average light vehicle emissions [10]. Rojas-Rueda et al. [13] and Grabow et al. [14] also used local air pollution model to assess the health impacts of changing in PM concentrations in Barcelona and midwestern United States under the car trips reduction scenario. PM is a complex mixture of extremely small particles and liquid droplets. It can be of organic or inorganic origin and includes airborne dust particles, soot and hydrocarbons from combustion processes, metal residues, fibres, and sulphate or nitrate compounds [71]. Meanwhile, there have been much strong lines of evidence, relating to proving the dose-response relationship between PM and health outcomes [44, 72–74]. Thus, to avoid double counting, the WHO suggests using PM_{10} and $PM_{2.5}$ as the indicators of air pollution exposure. All the cobenefit studies we reviewed in this review chose PM_{10} or $PM_{2.5}$ concentration as the major air pollution exposure indicator in their health impact assessment section.

Other general tools could be used to estimate the change in emissions if there is a lack of local air pollution modelling tools. A new generation of emission models, including The Vehicle Air Pollution Information System (VAPIS) model and The Simple Interactive Models for better air quality (SIM-air), have been developed recently [75] as user friendly spreadsheet based tools. One of the advantages of these models is that only basic local traffic parameters are required, such as baseline vehicular numbers, average annual vehicle growth rates, average vehicle travelled kilometres, and emission factors. Therefore, these models can still be applied when

available data are limited. For example, the SIM-air Model was used to estimate $PM_{2.5}$ for Delhi where local traffic data were incomplete in the UK study [11]. Although the emission trends analysis can be performed easily, the estimations generated from these tools are relatively crude. It is also impossible for the SIM-air Model to assess the impact on emissions induced by traffic-management schemes, such as speed restriction, roundabouts, signal coordination, or road widening. Despite the limitations, however, these tools still remain a substitute when detailed local traffic information is not available for cobenefit analyses.

In cobenefit studies, the selection of an air pollutant index related to vehicles should have a close association with population health impact. Although air pollutants are various, it is not necessary to model all the vehicle pollutant emissions since air pollution-related diseases are often caused by one or two dominated pollutants [76]. PM is a complex mixture of extremely small particles and liquid droplets. It can be of organic or inorganic origin and includes airborne dust particles, soot and hydrocarbons from combustion processes, metal residues, fibres, and sulphate or nitrate compounds [71]. Moreover, there have been much strong lines of evidence, relating to proving the dose-response relationship between PM and health outcomes [44, 72–74]. Thus, to avoid double counting, the WHO suggests using PM_{10} and $PM_{2.5}$ as the indicators of air pollution exposure. All the cobenefit studies we reviewed in this review chose PM_{10} or $PM_{2.5}$ concentration as the major air pollution exposure indicator in their health impact assessment section.

4.2.2. Health Benefit Assessment. Health benefit assessment is another critical element in cobenefit studies. A scoping method was recently developed by the IPCC and WHO, in conjunction with other international organizations, to estimate the health impact from greenhouse mitigation strategies [77]. This method was then modified slightly by Smith and Haigler to remain consistent within energy cobenefit studies [78]. The development of these scoping methods has made it possible to extend cobenefits analyses to more sophisticated assessments. In the scoping methods, Comparative Risk Assessment (CRA) plays an essential role in evaluating the health benefits of interventions in the energy sector. Developed by WHO, CRA is defined as the systematic evaluation of the changes in population health which result from modifying the population distribution of exposure to a risk factor or a group of risk factors [79]. In simple terms, this parameter could be used to evaluate the change of attributable fractions (AF) of risk factors and translate the changed AF into burdens of disease which can be applied to the projection by the researchers. Therefore, this approach cannot only be used to assess the health benefits from enhanced physical activity by increasing active transport but also can be adapted to evaluate the change in disease burden of air pollution reduction. As we can see from Table 1, both the UK study [11] and the Bay Area study [15] used this approach to comprehensively estimate health impacts of alternative transport scenarios. In addition, the CRA has been used to evaluate the health cobenefits of many mitigation activities for GHG emissions and air pollution [11, 80–82]. However, it is notable that assumptions and values of key parameters have an important effect on the model outcomes. For example, it is necessary to obtain the values of RR of risk factor like air pollution or physical inactivity. If there is no local statistical data available, the *RR* could be estimated by doing meta-analysis like the UK [11], and Bay Area studies [15]. As seen in Table 1, other studies used an indirect approach with the Health Economic Assessment Tool (HEAT) to evaluate the health impact. We will discuss this tool in the following section.

The respiratory and cardiovascular systems appear to be the most affected by urban air pollution. The WHO estimates the disease burden of air pollution based on the contributions of three health outcomes: mortality from cardiopulmonary disease in adults, mortality from lung cancer, and mortality from acute respiratory infections (ARI) in children aged 0–4 [83]. According to the global burden of disease calculated by the WHO, diseases having the most significant association with physical inactivity include diabetes, dementia, hypertensive heart disease, ischemic heart disease, cerebrovascular disease, breast cancer, colorectal cancer, and depression. Therefore, as shown in Table 1, most of the studies reviewed conducted the health impact assessment on air pollution reduction based on the cardiopulmonary disease and lung cancer health outcomes, and the health impact assessment on active transport based on major chronic diseases outcomes. Health outcomes could be considered in terms of the number of deaths, mortality and morbidity rates, and the Disability Adjusted Life Years (DALY). DALY is a metric that combines premature mortality and morbidity, which can provide an overall picture of burden of disease.

One issue in health benefit assessment is that enhanced physical activity improves health effects gradually over time and those effects will be maintained in a certain time period. Therefore, how quickly the health benefit of increasing an individual's active transport level appears remains uncertain. As such, current cobenefit studies only projected the health cobenefits that occurred in one "accounting year."

Another controversial issue concerns whether active transport is associated with more physical activity in reality. One systemic review conducted by Faulkner et al. suggested that children and youth who actively travel to school tend to be more physically active than passive commuters [48]. However, another recent systematic review concluded that evidence that active transport users necessarily have more physical activity than others is limited due to a lack of longitudinal studies [84]. Therefore, it remains uncertain whether active transport commuters gain health benefits solely from their active transport use.

Furthermore, the UK and Bay Area studies [11, 15] assumed everyone in the population aged over 15 would possibly use active transport as an alternative; a goal very hard to achieve because older people constitute a group that may find it difficult to start cycling for various reasons. In Denmark, cycling trips declined with age, but even among 70–74 years old people, cycling still accounts for 12% of all their trips, double that percentage has been found in Dutch elderly [27]. Thus, it is worth considering whether elder people should be included in the health impact model. On

the other hand, considering those people already achieved the criteria of sufficient physical activity, they may not gain more health benefit from active transport since physical inactivity was no longer a risk factor of some diseases for them. Accordingly, largest health benefits from active transport may be gained from those people who are completely sedentary but become active travellers.

4.3. Economic Benefit Assessment. Economic benefit assessment in a cobenefits study can be conducted from different perspectives, such as investment cost on environmental protection, fuel savings, and cost of medical expenditure. A standard "value of a statistical life" approach is commonly used in transport appraisals, which reflects the willingness of a middle-aged person to pay to avoid sudden death (willingness-to-pay) [85]. The value of willingness-to-pay could vary considerably between different regions. Alternatively, Smith and Haigler [78] recommended a simpler way to assess the cost effectiveness of possible interventions by comparing local gross domestic product (GDP) with DALYs. If the health-related investment is less than local $GDP/capita per DALY, the intervention is considered to be very cost effective and should be promoted quickly and widely [78]. The intervention is cost-effective if the health-related investment is between one and three times of the local $GDP/capita per DALY. When an investment is over three times of the local $GDP/capita per DALY, the intervention is not considered to be cost effective.

WHO has developed a specific Health Economic Assessment Tool (HEAT) to evaluate the health effects related to increased cycling [86]. This Excel-based tool sets the relative risk as 0.72 for all-cause mortality of regular adult commuter cyclists. The HEAT also contains a default value of a statistical life, based on the Copenhagen Centre for Prospective Population studies which controlled gender, smoking, education, leisure time physical activity, body mass index, and other risk factors for chronic disease [53]. Therefore, reduced mortality could be used as an indicator to estimate the mean annual benefit from cycling. The total value of economic savings due to the reductions in all-cause mortality among these cyclists could also be calculated with the data entered by the user. Those studies [12–14] that conducted the health impact assessment by the HEAT have not considered the age issue of beneficiaries, because HEAT is only designed for adult population (aged approximately 20–64 years) and it is generally accepted that this group of people is most suitable for cycling. However, the HEAT is not suitable for assessing the economic benefits of other alternative transport, such as walking, as the Copenhagen study only compared the relative risk of all-cause mortality between cyclists and noncyclists. In addition, the HEAT only investigates the impact on mortality but not on morbidity and it does not consider mental health issues. It also cannot be applied to children.

4.4. Data Issues. One of the challenges in conducting a cobenefit study is the establishment of a series of modelling work to project the multiple benefits. To establish effective modelling relies on multiple high quality datasets. For instance, to estimate environmental benefit, it is essential to collect transport data, such as annual vehicle kilometres travelled, emission factors of vehicle types, and public travel patterns. For health benefit estimations, various health data are needed, such as prevalence of insufficient physical activity, local mortality and morbidity of relevant diseases, and relative risks of air pollution and physical inactivity. When projecting long-term effects of alternative transport plans, baseline data quality is crucial. To date, data between different countries have shown heterogeneity. In addition, transferability between diverse populations has not been established yet. In addition, transferability between diverse populations is challenging for researchers, who need to consider the comparability and differences between populations and regions. Theoretically, it is ideal to use local data as the baseline when calculating the estimations. However, the available local databases of transport, emissions, and health system are updated in different years, and it would be acceptable to use databases in different years to build the baseline scenario. For studies which tend to make projective model, researchers also need to consider the development trend in the study population. Like the UK and Bay Area studies [11, 15], they took into account population growth and changes in emission standards when they designed the 2030 scenarios. Moreover, vehicular emission factor, a key parameter for air pollution modelling, varies with ageing vehicle fleets, engine types, or on the cold start/driving/brake, which should be considered in order to adjust the model.

4.5. Summary and Recommendations. It is well known that alternative transportation can bring cost-effective benefits to environmental protection and population health. However, current analyses of transport mitigation strategies in terms of health and economic aspects are still at an early stage. Most of the previous research regarding the transport sector has only focused on one of those possible benefits and has rarely quantified the overall cobenefits of alternative transportation planning. Additionally, most of the current cobenefit studies are more interested in the long-term effect of alternative transportation, while the short-term effect has not been considered adequately. Some other benefits, such as social benefits from alternative transport are also valuable for further investigation. For example, both cycling and walking could enhance social/neighbourhood interaction. It has been shown that active transport can increase activity in local neighbourhoods and the passive surveillance of private and community infrastructure [87].

The health effects of active transport could involve physical, mental, and psychological aspects. At the moment, studies thoroughly investigating all these aspects are relatively rare. The majority of the conclusions from existing cobenefit studies only indicate that active transport has positive influences on preventing chronic disease. It is still uncertain how much mental and psychological health benefit could be achieved by the alternative transport. Moreover, the benefits of noise mitigation have also been commonly neglected, which is a particular effect induced by motor vehicle reduction. There are also some gaps in health benefit research when taking different age groups into consideration. Although researchers could assume that people of all the ages

would be affected by air pollution reduction and increased physical activity due to reduced usage of motor vehicles, such hypotheses may lead to inaccurate conclusions for certain population, such as children, for which few studies have considered the health benefits.

At the moment, the investigation of economic benefits of transport strategies, especially for active transport, is still at an early stage. The assessment tools currently available for economic benefits analyses can be limited when applied to different scenarios. For example, WHO has provided HEAT, which is a specific economic assessment tool for cycling. However, how to apply it to other active transport modes (such as walking) still needs to be explored. The range of current economic benefit assessment is also somewhat incomplete. Fuel saving, decreasing investment in environmental protection, and medical expenditure reduction are the aspects which have been most commonly studied. Beyond these, other economic benefits related to reducing traffic congestion, such as car space requirements and oil demands, should also be taken into account in the future.

To date, most of the cobenefits research has been conducted in developed societies. Relevant studies in underdeveloped societies are insufficient, especially in countries such as China and India where motor vehicle emissions have become a significant source of air pollution due to the recent sharp increase in vehicle numbers. As different types of cities have dissimilar populations, traffic situations, transportation modes, weather types, and infrastructures, cobenefit studies specific to individual regions are essential, and further research should be applied to cities with different characters. Furthermore, as well as considering alternative transport, cobenefits of mitigation strategies in other energy consuming sectors, such as industry, agriculture, and electricity generation, are also significant and warrant further exploration.

In addition to study design, choice of methods may also cause bias in the research of cobenefits. While quantitative methods are the most frequently used, qualitative methods have been rarely used in studying cobenefits. Although public behaviour and stakeholder attitudes may influence transport choice and policy making, little information has been provided in this area, which is well suited to in-depth qualitative analysis. Thus, further investigation should adopt qualitative methods, such as interviews and focus group discussions, in order to address these gaps in knowledge. Findings from the combination of both quantitative and qualitative methods will provide stronger evidence to assist policy makers in decision making and policy implementation.

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Research Article

Measuring Workplace Travel Behaviour: Validity and Reliability of Survey Questions

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Background. The purpose of this study was to assess the (previously untested) reliability and validity of survey questions commonly used to assess travel mode and travel time. *Methods.* Sixty-five respondents from a staff survey of travel behaviour conducted in a south-western Sydney hospital agreed to complete a travel diary for a week, wear an accelerometer over the same period, and twice complete an online travel survey an average of 21 days apart. The agreement in travel modes between the self-reported online survey and travel diary was examined with the kappa statistic. Spearman's correlation coefficient was used to examine agreement of travel time from home to workplace measured between the self-reported online survey and four-day travel diary. Moderate-to-vigorous physical activity (MVPA) time of active and nonactive travellers was compared by t-test. *Results*. There was substantial agreement between travel modes ($K = 0.62$, $P < 0.0001$) and a moderate correlation for travel time ($\rho = 0.75$, $P < 0.0001$) reported in the travel diary and online survey. There was a high level of agreement for travel mode ($K = 0.82$, $P < 0.0001$) and travel time ($\rho = 0.83$, $P < 0.0001$) between the two travel surveys. Accelerometer data indicated that for active travellers, 16% of the journey-to-work time is MVPA, compared with 6% for car drivers. Active travellers were significantly more active across the whole workday. *Conclusions*. The survey question "How did you travel to work this week? If you used more than one transport mode specify the one you used for the longest (distance) portion of your journey" is reliable over 21 days and agrees well with a travel diary.

1. Background

Evidence suggests that reducing car use and increasing use of active travel (public transport, walking, and cycling) to travel to work have benefits for public health [1–5]. There is interest from both transport and public health practitioners in promoting active and sustainable travel. Workplace travel plans are a promising way of addressing this, although the evidence that they may improve employee health is equivocal [6].

Workplace travel plans are strategies for managing travel to, from, and during work. Most travel plans are implemented to alter the transport profile of an organisation. Government websites and reports provide guidance on developing workplace travel plans [7]. They outline a process for developing a travel plan which involves an assessment of the transport modes of employees of the organisation at baseline, which can be used to inform the development of the plan and measure the impacts of the plan over time. Since travel time to work is an important determinant of choice of transport mode, it is also measured.

Many travel plans implemented in various countries [6, 8, 9] have used similar questions to assess transport profiles.

Whilst there are published studies assessing the validity and reliability of survey questions assessing travel mode to school [10, 11], a literature search did not identify published studies assessing the validity and reliability of survey questions on travel mode and travel time to work. The purpose of this study was to examine the validity and reliability of a question to assess travel mode over the past week that is commonly used in surveys for developing workplace travel plans [12], as well as a question used to assess travel time.

The specific research questions of this study are the following.

(1) What is the level of agreement between online survey-reported travel mode and time compared with the self-report travel diary?

(2) How stable are the self-report survey questions on travel mode and travel time on average over a two-to four-week test-retest period?

(3) How physically active are people who have been classified as active or inactive commuters by the travel survey during their journey to work and over an entire day?

2. Methods

2.1. Study Design. This study was part of a workplace travel survey conducted whilst developing a travel plan for Liverpool Hospital in 2011. A subsample of respondents to the workplace survey of travel behaviour were invited to complete a travel diary for four working days, receiving SMS reminders to complete these each morning and evening. Throughout this period participants wore an accelerometer on their right hip, only taking it off during sleep and water-based activities. Participants then repeated the travel survey online when returning their diary and accelerometer one week later. Twenty participants were unable to recomplete the survey since the survey site was down at the time they returned.

Approval to conduct the research was provided by the Royal Prince Alfred Hospital Ethics committee, and site-specific assessment and governance approval was provided by Research Ethics and Governance at South Western Sydney Local Health District. All participating staff provided written consent following an explanation of the study.

2.2. Geographical Context and Travel Mode of Study Participants. Liverpool is a major centre in an outer metropolitan area of south-western Sydney, Australia. The Hospital is a principal referral teaching hospital. At the time of conducting the study, Liverpool Hospital was well serviced by trains, with two railway stations within ten-minute easy-walking distance. Hospital staff also had access to a bus network close to the main entrance of the Hospital and at a large bus interchange. The interchange at Liverpool train station serviced areas throughout south-western Sydney and beyond this area.

Although the off-road cycling network in the area did have off-road routes in all directions in a 10 km radius of the Hospital, apart from the route to the north along the railway, there were significant gaps in the cycling network in the immediate surrounds of the Hospital. Most of the surrounding area within a 10 km radius of the hospital is flat. There were 800 car spaces for 3700 FTE staff, and there was significant parking overspill in the surrounds. This overspill had the potential to create significant walking distances for some staff choosing to drive to the Hospital who did not have an on-site parking space.

The online all staff survey was conducted in late September of 2011, and the weather was fine on most days in both weeks the survey was conducted. The weather was typical of Spring in Sydney, being fine with moderate temperatures on most days throughout the study period. The survey found that 83% ($n = 605$) of staff drove alone to work, whilst 11% ($n = 83$) used public transport and 4 ($n = 28$) used active transport modes (walking and cycling) to travel to work. The baseline survey results are described in detail elsewhere [13].

2.3. Study Participants. From 804 staff who had completed an online all-staff ($n = 3222$) survey, 392 volunteered to participate in additional research and provided their contact details after reading an explanation of what the follow-up would involve and being offered an incentive of entering a prize draw. The list of 392 volunteers was printed in order of time and date of completing the survey. Volunteers were called in the order of this list until a total of 65 participants were recruited with an aim of achieving a sample size of at least 50 for this validation study. Since volunteers were called during work hours and a high proportion were clinical staff ($n = 109$, 60%), many could not be contacted by telephone after reaching number 183 on the list. Of 74 staff who answered the telephone, 87% agreed to participate, and the sample was achieved after reaching volunteer 183 of the list of 392.

2.4. Measures. Participants completed the question: "How did you travel to work this week? (If you used more than one form of transport, show the method used for the longest (distance) part of the journey)." The 13 response options for each day of the week were walked, cycled, drove a car, car passenger, bus, ferry, train, taxi, truck, motorbike or scooter, worked at home, other, and I did not go to work. See http://www.activetravel.net.au/professionals/tools for survey. The survey also asked staff to indicate the time in minutes for the longest portion of their trip for each of these working days. Participants were also asked how long their daily trip to work was from their front door to their workplace. This was assessed by an online staff survey.

Public transport, walking, and cycling categories were considered "active travellers" since the public transport commute also included an approximate 10-minute walk to major bus and train interchanges in this location. Car categories were considered "nonactive travellers" since for the majority of car drivers their commute was likely to be inactive.

Participants were categorised as "active travellers" overall if they travelled using an active travel mode on half or more of the working days recorded in their travel diary.

Participants were instructed on how to complete a four-day travel diary which itemised each trip they made, what travel mode they used, and how long it took.

Participants were also asked to wear an accelerometer for the same four days they kept their travel diary. The Actigraph GT1M accelerometer (Actigraph, LLC, Fort Walton Beach, FL) is an objective measure of the physical activity and sedentary behaviour and was used as the criterion measure.

The Actigraph is a single axis accelerometer that records activity counts and steps taken, which were stored every 15 seconds. This enabled the accelerometers to capture short and intermittent bursts of activity, which may be expected during stop-start journeys to work by train, bus, walking, or bike.

Moderate-vigorous physical activity time was calculated using the accelerometer data. The travel diary was used to determine the start and finish of the journey to work for which the MVPA attributed to this trip could then be calculated.

After one week these participants returned their travel diary and accelerometer and redid the online survey before leaving.

2.5. Analysis. Data were analysed using SPSS V20.0 (Chicago, Illinois). Travel modes were categorised to car, walking/cycling and public transport. Car included travel mode categories of "I drove alone," "I was a car passenger," "truck," "motorbike or scooter," and "taxi". Public transport included "bus," "ferry," and "train". Response categories of "I worked at home," "other," and "I did not go to work" were excluded.

To assess the validity of the self-report online survey, the agreement in travel modes between self-reported survey and travel diary was examined with the Kappa statistic. Spearman's correlation coefficient was used to examine agreement of travel time from home to workplace measured between the self-reported online survey and four-day travel diary.

The test-retest reliability of the survey questions on travel mode and travel time between the two online surveys over the average 21-day period was assessed using the Kappa statistic. The test-retest reliability of travel time from home to workplace between two self-reported online surveys was determined with Spearman's correlation coefficient.

Statistical analysis of validity and reliability excluded weekends for individual days since there were small numbers of weekend workers. Data for weekend workers were included for the overall statistical analysis.

The comparison of the proportion of the time travelling to work that was spent in MVPA (from the accelerometer data) between active and nonactive travellers was assessed using a two-sample proportion test. The comparison of the mean MVPA time for the whole day between nonactive travellers and active travellers was assessed by t-test. Public transport users were grouped with walkers and cyclists as active travellers because the number of public transport users was very small. Moreover, this was also considered appropriate since in this geographical context the journey of public transport users included a substantial amount of walking from a rail or bus interchange to their workplace.

Table 1: Characteristics of participants in validity study and MVPA time assessment.

	Validation study survey completers n (%)	MVPA time assessment completers n (%)
Total	45 (100)	65 (100)
Occupational group		
Administration	11 (24)	19 (29)
Medical	3 (7)	4 (6)
Nursing	12 (27)	17 (26)
Allied Health	6 (13)	11 (16)
Commercial	13 (29)	15 (23)
Occupational type		
Clinical	21 (47)	32 (48)
Nonclinical	24 (53)	34 (52)
Age		
18–34	19 (43)	24 (37)
35–54	23 (52)	36 (55)
≥55	2 (5)	5 (8)
Gender		
Female	37 (82)	55 (83)
Male	8 (18)	11 (17)
Distance from home to work*		
<5 km	8 (18)	12 (18)
5–10 km	9 (20)	12 (18)
>10 km	28 (62)	42 (64)
Main travel mode to work		
Car user	33 (73)	52 (80)
Public transport	7 (16)	8 (12)
Walked or cycled	5 (11)	5 (8)
Shift work		
No	36 (80)	55 (83)
Yes	9 (20)	11 (17)

*Based on postcode of residence.

3. Results

Data for all 65 participants was used to assess MVPA time. Data for 45 participants was used for the validity and reliability study since the survey site was down when some participants returned to redo the survey.

There was a high proportion (80%) of car users among study participants, and two-thirds of participants lived more than 10 km from their workplace. Table 1 shows the demographic and transport profiles of the 45 validation study survey recompleters and the 65 study participants whose data was used for assessments of MVPA time. The characteristics of the twenty missed participants were compared to other study participants, and there were no significant differences for any of the demographic variables presented in Table 1.

Table 2: Spearman's and Kappa correlations for travel mode and travel time comparing online survey retest to travel diary and initial all-staff online survey.

	Travel mode		Travel time	
	K (95% CI)	P	ρ	P
Validity				
Overall	0.62 (0.35–0.89)	<0.0001	0.75	<0.0001
Monday	0.77 (0.45–1.0)	<0.0001		
Tuesday	0.79 (0.56–1.0)	<0.0001		
Wednesday	0.89 (0.68–1.0)	<0.0001		
Thursday	0.63 (0.31–0.94)	<0.0001		
Friday	0.38 (−0.05–0.80)	<0.007		
Reliability				
Overall	0.82 (0.57–1)	<0.0001	0.83	<0.0001
Monday	0.37 (−0.15–0.9)	<0.004		
Tuesday	0.81 (0.56–1)	<0.0001		
Wednesday	0.57 (0.24–0.90)	<0.0001		
Thursday	0.69 (0.37–1.0)	<0.0001		
Friday	0.79 (0.39–1.0)	<0.0001		

The validity and test-retest reliability of the self-reported travel survey are presented in Table 2. Overall, there were a substantial agreement for travel mode between self-reported survey question and the travel diary ($K = 0.62$, 95% CI 0.35–0.89) and moderate correlation between the survey and diary for travel time ($\rho = 0.75$, $P < 0.0001$).

When comparing the survey responses overall at two time points, travel mode from home to work had good reliability ($K = 0.82$, 95% CI 0.57–1, $P < 0.0001$), as did travel time from home to work (Spearman's $\rho = 0.83$, $P < 0.0001$). When comparing travel mode day by day, most results for both validity and reliability study showed moderate-to-good agreement, with only one day each for validity and reliability reaching fair agreement.

The mean MVPA time assessed by the accelerometer during commute time (travel from home to work) for all active travellers was 6.1 minutes (SD 3.0), which is 16% of commute time, compared to 2.6 minutes (SD 2.1), which is 6% of commute time for nonactive travellers. This represented a difference of 4 minutes (95% CI 2.32–5.59). The mean MVPA time for the whole day for active travellers was 62.0 minutes (SD 8.7) versus 37.9 (SD 19.3) for inactive travellers, representing a difference of 24.1 minutes between the two means (95% CI 6.5–41.7). On separating public transport users from walked and cycled, this group travelled for the longest period to work and achieved 14% of their daily moderate-vigorous physical activity during their commute. Table 3 presents mean travel time from survey, travel diary, and MVPA time from accelerometer by three travel modes.

4. Discussion

There were moderate-to-substantial correlations between the online survey questions and the travel diary travel mode and travel time measures. These are meaningful levels of agreement for these statistical tests [14, 15].

The difference in the travel diary responses to travel mode across the week compared with the self-report response to the online survey retest may be explained by recall bias. Participants presented on a Thursday commenced their diary on the next working day and then recompleted the online survey the following Thursday. The survey question asks respondents to recall their travel modes for the past week. Therefore, for most participants Thursday and Friday were the furthest days to recall, and these days showed the weakest association with the travel diary response.

The discrepancy between travel mode in test and retest survey responses may also be explained by recall bias creating inconsistency in responses. Monday shows the weakest association, and in the test survey Monday would have been the farthest day to recall for most respondents since the survey was delivered on a Thursday. For the retest, Thursday or Friday would have been the furthest, and this may have created some inconsistencies that further exacerbated the poor association. In the test survey, this was done to maximise response rate since a significant proportion of staff did not attend work on Fridays. In the retest, participants were asked to fill in the travel diary for the next four working days, and on returning this diary they were asked to redo the survey and recall the week gone by.

Accelerometers are the "gold standard" objective measure for physical activity in population health research [16]. The accelerometer data used to calculate MVPA time showed that active travellers (defined as walkers, cyclists, and public transport commuters in this study) were significantly more active in their morning commute. This activity represented a significantly greater proportion of their total physical activity for the day, and they were more active overall. It is noteworthy that a high proportion of the participants defined as active travellers in this study were public transport users. These results are highly consistent with a recent review of the literature [1], and they do suggest that promoting use of public transport in medium and large workplaces may be an effective population health strategy for increasing physical activity levels.

Considering the small sample of walkers, cyclists, and public transport users in the study, we compared their results for MVPA time measure by accelerometers to the results for MVPA time for all staff that were measured using survey questions that have been validated previously [17]. For cyclists the average journey time to work in the survey sample was much shorter than MVPA time overall in the all-staff survey; therefore, these results are unlikely to be reflective of active commuting by bicycle generally and may have biased our results for research question 3 towards the null. However, for public transport users, the MVPA times of study participants were similar to those of all staff. This is logical since the major bus interchange and train stations are located at similar distances of about 10-minute easy-walking distance from the Hospital and most public transport users are likely to walk this distance. Further, many workplaces are located at walking distances from train or bus services that could make significant contributions to physical activity for health, and many have parking close to the door or lifts. Therefore, the comparison for MVPA time between public transport commuters and car drivers is likely to be generalisable to many workplaces.

Table 3: Mean survey, travel diary, and accelerometer outcomes by travel mode.

Mode	Survey		Travel diary		Accelerometer	
	n (%)	Time (minutes)	*n* (%)	Time (minutes)	% MVPA*	MVPA time** (minutes)
Car	37 (82)	43	33 (73)	46	6	2.6
Public transport	3 (7)	67	7 (16)	60	14	8.3
Walked/cycled	5 (11)	25	5 (11)	16	24	3.8

*% MVPA is the MVPA time for the journey to work from accelerometer data divided by the total time for the journey to work from travel diary.
**MVPA time in minutes for the journey to work calculated for all 65 participants.

The Hospital had large parking overspill at the time of the study, and there was potential for drivers to walk similar distances to public transport users from their parking spot to work. However, the average MVPA for drivers in the study was approximately two minutes; therefore, their journey did not include significant amounts of physical activity as they must have parked close to their workplace.

Accelerometers measure activity in the vertical plane; therefore, they can underestimate physical activity from cycling. Due to the small number of cyclists, it is unlikely to have changed the results relating to the difference in physical activity levels of active and nonactive commuters.

A limitation of the study was the small number of public transport commuters and participants who walked or cycled to work. In future research, the limited number of active commuters and public transport users could be overcome by oversampling these groups on recruitment into the study and recruiting more participants overall. However, the strength of the correlations in the tests of reliability and validity, and the simplicity of the questions on travel mode and travel time do provide confidence that the questions are stable and measure what they are trying to measure.

5. Conclusions

Whilst the evidence for organisational travel plans improving health is equivocal, they have been described as a promising intervention for increasing employee physical activity levels that are worthy of further research. Although guides exist for conducting workplace surveys for developing travel plans, to our knowledge, none of these questions had been assessed for validity or reliability at the time this study was published. The questions on travel mode and time tested in this study were found to be valid and reliable. Therefore, this study makes a significant contribution to the literature for a promising public health intervention. Whilst the sample size is small, the finding that public transport users accrued significant physical activity levels in their morning commute is consistent with a growing body of research on this topic and does indicate that promoting public transport use shows promise for increasing population physical activity levels [1].

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Research Article

Joy, Exercise, Enjoyment, Getting out: A Qualitative Study of Older People's Experience of Cycling in Sydney, Australia

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Introduction. Cycling can be an enjoyable way to meet physical activity recommendations and is suitable for older people; however cycling participation by older Australians is low. This qualitative study explored motivators, enablers, and barriers to cycling among older people through an age-targeted cycling promotion program. *Methods*. Seventeen adults who aged 50–75 years participated in a 12-week cycling promotion program which included a cycling skills course, mentor, and resource pack. Semistructured interviews at the beginning and end of the program explored motivators, enablers, and barriers to cycling. *Results*. Fitness and recreation were the primary motivators for cycling. The biggest barrier was fear of cars and traffic, and the cycling skills course was the most important enabler for improving participants' confidence. Reported outcomes from cycling included improved quality of life (better mental health, social benefit, and empowerment) and improved physical health. *Conclusions*. A simple cycling program increased cycling participation among older people. This work confirms the importance of improving confidence in this age group through a skills course, mentors, and maps and highlights additional strategies for promoting cycling, such as ongoing improvement to infrastructure and advertising.

1. Introduction

Maintaining the health of Australia's ageing population is a priority for governments and healthcare providers, not only to improve quality of life but also to minimise the burden of ill health on existing resources [1]. Ensuring that older people get the recommended amount of daily physical activity is a key way to improve and maintain health in this important group.

Just 40% of Australian adults who aged 55–74 years achieve the recommended amount of physical activity each week, and after 75 years, the proportion falls to 24% [2]; however identifying physical activities that are enjoyable and accessible for older people can be challenging. Many older adults prefer to exercise alone or with others of their own age [3], and more than half of older Australians undertake their physical activity in unstructured forms such as walking to local shops [4]. Barriers to exercise for older people can include cost, time, and difficulty, travelling to group programs [5].

Cycling is a form of physical activity with particular benefits for older people. It is nonweight bearing and therefore has less impact on the joints than jogging or other running sports [6], and several longitudinal epidemiological studies have shown significant risk reduction for all-cause and cancer mortality, cardiovascular disease, colon and breast cancer, and obesity morbidity in middle-aged and elderly cyclists [7–9]. Cycling may also contribute to improved quality of life for

older people [10], by enhancing social networks and building empowerment, and can be incorporated easily into a daily routine [11].

Despite these benefits, cycling participation by older adults in Australia is low [12]. In contrast to many European cities where older people continue to cycle [13], in Australia just 18% of those who aged over 50 cycled in the past year, compared with 50% of those aged 10–29 and 39% of those aged 30–49 years [12].

A small number of published studies have investigated the barriers and facilitators of adult cycling in Australia, but none have looked specifically at the important and growing population of older people. These studies found that poor confidence and cycling ability are concerns for inexperienced riders [14, 15]. Lack of cycle paths is often cited as a barrier to regular cycling, as is fear of cars and negative attitudes from motorists [14, 16, 17].

This study investigated the motivators, barriers and facilitators of cycling in older people who participated in a pilot cycling program. Feedback on the program itself was also sought.

2. Methods

This qualitative study was part of a cycling promotion study among older people, looking at improvements in leg strength and balance as risk factors for falls [18]. Adults who aged 50–75 years, who were willing to cycle for two or more hours per week over a 12-week period, were recruited through local advertising and word of mouth in a discrete geographic area of Sydney (Canada Bay), Australia. Canada Bay is an innerwest suburb of Sydney, located around 8 km west of the city. The area scores 1,076.5 on the SEIFA index of disadvantage, indicating that it is less disadvantaged that the national average, and the median/average age of the population is 39 years of age, 2 years above the Australian average [19]. The site was chosen for this study to build on existing relationships between one of the researchers (CM) and the community centre and Bicycle User Group in that area.

We aimed to recruit around 20 participants for the pilot study because it was feasible to support this quantity with the resources available, and the researchers felt that around 20 participants would be sufficient for the purposes of this trial.

2.1. Qualitative Methods. Semistructured interviews were conducted one-on-one before participants attended a cycling skills course and 12-weeks later. The study's chief investigator conducted baseline interviews, and follow-up interviews were conducted by another author. The chief investigator was experienced in qualitative interviewing techniques, is personally within the age bracket for participation in the study, and is an experienced cyclist who rides to work daily. The second interviewer has less experience in qualitative interviewing techniques, is younger than the study participants, and cycles to work often.

Five themes were investigated; motivators and barriers were the focus of the baseline interview, while the follow-up interview focused on benefits/outcomes, enablers, and cycling promotion.

Interviews were audio-recorded but not transcribed, and analysed by an individual researcher using thematic analysis. Interviews were coded and then data linked by codes were collated into potential themes. In this way, the researcher generated a thematic map of the entire analysis. Themes were further refined in an ongoing analysis. The person conducting the analysis was younger than the study participants, is female, and cycles to work occasionally.

2.2. Program Components. Participants were supported to complete their 2 hr/week of cycling by providing cycling skills training, mentors, and a resource pack.

2.2.1. Cycling Skills Course. The program commenced with a cycling skills course to develop participants' cycling ability, safety knowledge, and confidence, as poor skills and confidence are known barriers to taking up cycling across all ages. The course was delivered by accredited trainers "Bikewise," and funded by the City of Sydney Council (see http://www.bikewise.com.au/). The course lasted 4.5 hours and covered basic bicycle control skills (starting, braking, and turning), route planning, and on-road riding skills.

2.2.2. Mentors. Participants were matched with mentors from their local area, who were experienced cyclists and could be contacted either directly or via a google group. Each mentor/participant pair was free to meet and/or interact as they chose. The research team also made brief informal phone calls to participants at one and six weeks to maintain participant engagement and identify any additional support required. Strong social support and encouragement have been shown to enable and motivate people to take up and sustain physical activity, and these interventions targeted these constructs.

2.2.3. Resource Pack. Participants received a resource pack which included local cycling maps, information about local Bicycle User Groups, and where and when local group rides were held. These interventions targeted the potential barrier of participants not knowing where to ride and also encouraged participants and supported social connectedness.

3. Ethical Approval

This study received ethical approval on September 7, 2011 from the University of Sydney Research Integrity Human Research Ethics Committee (Protocol no.: 09-2011/14065). The approval was ratified by the University of NSW HREC (HREC Ref. # HC12587) on October 25, 2012.

4. Results

Seventeen participants were recruited, ranging from 49 to 72 years of age (mean 61 years). The majority (twelve) were female. Most (twelve) had not ridden in the past year, but fifteen were undertaking some form of physical activity; however the amount varied widely, ranging from "a little bit of walking" to one woman running 50 km per week.

Two participants withdrew from the program for personal reasons after the baseline interview, and researchers were unable to schedule a suitable time for a followup interview with four participants. All available interviews were included in this analysis—17 at baseline and 11 at followup.

The four participants who were unable to attend a followup interview were at the younger end of the age bracket (more likely to be in their 50s) and more likely to be working.

Nine participants successfully met the 2 hr per week cycling target.

4.1. Before the Program. As the sample was self-selected, all enrolled participants were highly motivated to start cycling. The main reason for wanting to cycle was for exercise, and the biggest perceived barrier was fear of cars and traffic.

This study was advertised as a way to potentially improve balance and leg strength, and this should be considered a motivator for people to take part.

4.1.1. Why Cycle? (Motivators). All participants cited exercise as a major reason to take up cycling, as many did not like gyms and thought that cycling would be a more fun way to exercise, and would fit more easily into their lifestyle.

> *"I'm not fantastic on the discipline. If it fits into my lifestyle, then I'll do it and love it ... but if I have to ... go to the gym ... then I'm not very good at following through" (59yo female).*

Some participants added that cycling is a form of exercise that they can continue to do now that they are older.

> *"We [my wife and I] used to run ... but I can't run anymore because I damaged one of my knees so I'm past running, so that's why we're thinking well bikes will be good" (62yo male).*

All participants also mentioned enjoyment as a reason to cycle, but this was not as strong a motivator as exercise. Cycling was perceived as a fun way to spend time with family or make new friends. Participants expected to enjoy being outdoors and anticipated the feeling of freedom that cycling brings.

> *"I think it's quite nice because I see my husband going off and it's like he has a social group and ... they always seem to stop somewhere nice for coffee ... I think that would be quite nice to be in a similar sort of social group" (67yo female).*

> *"Joy, exercise, enjoyment, getting out, you know? Getting out and getting about" (59yo female).*

Around a third intended to use the bicycle for local utility trips. Motivators included convenience, exercise, enjoyment, and the environment.

> *"I drive to work, I drive to dad, I drive back from dad, I drive to church, I drive... even to the shops now ... I'm just driving all the time and I'm hating it ... I'd love to ... just jump on my bike to go and get the milk" (59yo female).*

Several participants had plans to go on a cycling holiday with family members and were building their confidence and fitness.

> *"I said to my son ... next year, why don't you meet me in Copenhagen and we can cycle up the east coast?" (71yo female).*

4.1.2. Barriers. The primary barrier to cycling for all participants was fear of cars and riding on streets. Most would only consider riding on cycle paths and very quiet roads, and many mentioned friends who had had a "close call" while cycling on roads.

> *"I've got a lot of friends ... and I can't find a single friend who thinks that it's safe enough for them to be on the road" (67yo male).*

Many were not confident in their riding ability, mentioning they might be "a bit wobbly" on the bike to begin with because they had not ridden in years and had never ridden a bicycle with gears. Many were relying on the cycling skills course to practice and to build confidence.

> *"I feel very nervous about riding a bike because I don't feel I can have adequate control over it ... in terms of wobbling where there's traffic" (67yo female).*

Interestingly, participants did not feel particularly concerned about falling off their bikes as older people. Participants were certainly aware that they may fall, but they reported that their fear was no worse than when they were younger. Even when asked about being frail or having brittle bones, this group were not particularly concerned with this aspect of cycling.

4.2. After the Program. Eleven participants completed an interview after the program. Of these, one had been unable to cycle due to an unrelated injury, and one found she lacked the skill to cycle so she gave up on her 2 hours/week target.

All of the remaining nine participants had met their 2 hr per week target and many had done much more. Most were cycling for recreation and fitness, and just over half had also used the bicycle to travel locally to work, the gym, or local shops and events. All who had met their target reported a very positive experience from cycling.

> *"you enjoy it, you're getting to work, you're missing the traffic, it makes you feel more healthy in your mind ... and you end up stronger!" (59-year-old female).*

4.2.1. Benefits/Outcomes. Overwhelmingly, taking up cycling was a liberating, fun experience, and many participants reported that it felt lovely to be outdoors, exercising in nature. Many recalled cycling in childhood and recaptured a sense of joy and freedom.

"I loved the wind blowing through your hair, that was lovely! ... That was the exhilarating part of it" (71-year-old female).

The exception was the one participant who found she was unable to cycle. This was a distressing realisation for this participant and she expressed disappointment in herself. At baseline, this participant explained that she had fallen from her bike recently and had lost her riding confidence. She hoped that participating in this program would give her the resources and motivation that she needed to get back on the bicycle.

Many participants also enjoyed a benefit to their social life as a result of cycling. They had a new experience to talk about with friends and inspired others to take up cycling themselves. In addition, cycling "plugged participants into" a new community, allowing them to interact with people outside their usual social group. The best example of this was one local cycling group, where two participants rode on weekends with a father and his two daughters. Participants loved interacting with the two young girls, as well as strengthening their own friendship.

Finally, most of the women expressed a strong sense of pride at their cycling achievements and felt empowered by overcoming their fear of cycling and improving their skills, especially as an older person. Friends told them they were an "inspiration," which heightened the positive association.

"some of my friends, they're amazed that I've gone out (well, I am too!) ... she said 'I admire you now for what you've done'" (71yo female).

Participants were not asked about this feeling specifically; it came up spontaneously in their interviews. Feeling proud and/or empowerment was not mentioned by any of the male participants in their interviews.

Participants reported feeling more energetic, having a better mood, and being able to relax and sleep better after a bike ride. This improvement in mental health was the most commonly reported health-related benefit of cycling; however they also reported improved cardiovascular fitness and feeling stronger, especially in the legs. One individual's diabetic control had improved so much that he was using less insulin.

4.2.2. Enablers. Improving the participants' confidence was key to them for cycling more. Practicing reinforced their skills, and their confidence gradually improved. The strongest determinants of confidence were bike-handling skills and knowing their intended route. The majority began cycling in parks, before moving to cycle paths, and eventually backroads as confidence increased.

While finding the confidence to cycle was a struggle for some, the cycling skills course was a hugely positive experience for all participants, and for many it was the main factor in getting them "back on a bike".

"Fantastic! If it wasn't for that, I wouldn't be cycling now" (67yo female).

Participants were the happiest when they were grouped with other older riders or riders with a similar level of skill, as they did not feel they were holding the group back and did not feel embarrassed.

"I did not want to be the duffer in the class" (71yo female).

Three participants attended the course a second time, and two more asked whether they were allowed to attend again, emphasising the importance of repetition and reinforcement for older riders. They valued the safety knowledge they gained through the course, such as road positioning and how to approach intersections, and practicing basic skills, which improved their confidence. Many had recommended the course to friends and colleagues and could not speak about it more highly.

"It's probably the best course I've ever done in my life" (66yo male).

Due to low confidence, participants needed to feel secure about where they were riding. Mentors played a big role by either providing cycle maps or showing the way. For example, one participant's mentor rode with her to work one day, and after that she was able to ride to work a few times a week, always along that same route.

Local cycle maps were also highly valued, but one participant could not use the map given because she could not locate her house on it. Participants were impressed with the well-maintained cycling facilities available in local parks, and some had not known such facilities existed until they saw them on the map.

"Well, I was amazed [when I saw the map] at the extent of bike paths and cycle ways in Sydney" (71yo female).

4.2.3. How Can We Encourage Older Adults to Cycle? (Cycling Promotion). Everyone noted the need for more safe cycle ways, away from traffic.

"I'm more concerned about traffic than anything, so if anyone in Sydney wants to build more cycle-ways, I think that's wonderful!" (62yo female).

Many participants felt that a media campaign about the benefits of cycling would encourage more older people to cycle, but that campaign would need to be backed-up with more cycle ways. Other suggestions included advertising in seniors magazines and at seniors groups and word of mouth or presentations from other older cyclists. They felt the messages needed to be that cycling is achievable, fun, and beneficial for health and that it could be done safely. Despite this, participants noted that many older people would never be responsive to this type of encouragement as cycling is perceived as too dangerous and some older people simply will not undertake physical activity.

5. Discussion

The strategies used to promote cycling in this study were simple and inexpensive, mainly linking motivated people to existing resources, but had a high success rate for increasing cycling participation. This work explored motivators, barriers, and outcomes to taking up or increasing cycling and highlighted successful strategies for promoting cycling in older people. Key findings included that cycling promotion for this age group must focus on improving confidence and must consider the need for reinforcement and repetition.

An age-targeted cycling skills course is a very successful strategy. Encouragement for Bicycle User Groups to reach out to older people, widespread availability of cycling maps, and advertising the multiple benefits of cycling are also helpful.

Continued improvement to cycle paths was strongly supported by participants. Fear of cars and traffic is a strong barrier to cycling across all age groups [20] so investment in infrastructure should also have benefits across the population.

The participant who found she was unable to cycle adds weight to the theory that confidence is extremely important in cycling promotion. This participant was given additional time, resources, and encouragement (she was lent a bike to use and strongly encouraged by her mentor); however even with these additional resources she was not able to overcome her fear of falling off her bike again although she persisted in trying. None of the other participants mentioned previous bad experiences with cycling, indicating that a previous bad experience may well cause a significant loss of confidence which would need additional, tailored strategies to overcome.

Another interesting finding is that the sense of empowerment and pride was felt very strongly by female participants but not even mentioned by men. It is possible that men may be inherently more physically confident and assume that they will be able to ride without problems while for women this is a realisation rather than an assumption. It could also be that both sexes felt empowered and proud of cycling but that women were more likely to talk about it at interview, especially as the topic was not specifically discussed or explored.

Contrary to our own preconceived ideas and that of colleagues who we spoke to informally, the participants themselves did not express concerns about being frail and bicycle riding. There may be a feeling among the general population that older people need to be physically cautious that is not held by older people themselves, or worse that older people participating in physical activity are being "reckless". If this view is held widely, it may partly explain why older people are not routinely targeted and encouraged in physical activity campaigns, despite the many benefits that physical activity provides in older age.

Our study showed that exercise is a strong initial motivator when encouraging older people to cycle, as are sociability and fun, but the best outcomes are empowerment and improved quality of life.

The cycling skills course was an important factor in improving cycling confidence. Participants preferred to be in a group with others like themselves and some needed the reinforcement and repetition of attending the cycling skills course a second time. Following our program, the City of Sydney has set up a cycling skills course specifically for older people, called "Rusty Riders" [21]. Having a mentor for support and encouragement and to ride with a participant along a new route was another effective method to support new riders, and for some new riders, group rides were a fun way to experience the social aspect of riding, gain confidence, and learn about where to ride while getting their physical activity. A public health campaign focusing on the health benefits of cycling and showing personal stories of other older cyclists might be effective and is worthy of further research.

Local cycle maps were highly valued and might be improved if someone (perhaps a mentor) could interpret the map and highlight a route for an older person to take.

As with all qualitative work, our findings are specific to the older people in our study group and not necessarily representative of the broad older population in Sydney. However, the broad themes identified in this group of older adults appear to be readily applicable to older adults generally.

Similarly as with all qualitative work, differences between interviewers may have influenced the way the interviews were conducted and the way participants related to the interviewers.

Interview data were analysed by one researcher, which may be seen as a weakness to the study; however analysis of qualitative data involves interpretation of study findings, and this process is inherently subjective. It is well accepted in qualitative research that a definitive, objective view of social reality does not exist and different researchers may well interpret the same data differently. Therefore validation by an additional researcher would not necessarily give a "correct" interpretation, simply another, equally valid one.

The participants who were lost to followup were all contacted multiple times, but the researchers were unable to schedule a time which was convenient for them for their followup interview. On reflection, these participants were more likely to be younger and working, meaning they were probably busy and had less time to devote to the study. Unfortunately, we are unable to say whether these participants had actually increased their cycling behaviour but an area for further research may be investigating the differences for cycling promotion in working, compared with nonworking older adults.

Other areas for further research could expand on our finding that empowerment, pride, and external feedback (admiration from peers) were very important positive outcomes for female participants but not mentioned by men. Another relevant topic would be looking at the use of electric bikes (ebikes) as enablers (or perhaps deterrents) to cycling in this age group.

6. Conclusions

This study suggests that cycling can have a positive influence on the quality of life of older adults, especially through a sense of empowerment and pride, broadening and invigoration of social networks, and simple pleasure. Older people could successfully be encouraged to cycle relatively cheaply and

easily by linking them with existing resources in an age-targeted way. While additional cycling infrastructure remains an important goal, in the meantime, more can be done to enable people to use the existing infrastructure. Programs such as the one used here are simple and low-cost to implement. Cycling promotion should centre around improving older people's cycling confidence through improving skills and practice and repetition, promoting existing cycle paths, increasing safe cycle paths, and promoting cycling to older adults for its health, social, and well-being benefits.

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Conflict of Interests

The authors declare no conflict of interests in publishing this work.

Authors' Contribution

All authors made a substantial contribution to the conception and design or analysis and interpretation of data, the drafting of the paper or revising it critically for important intellectual content and approval of the version to be published.

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Research Article

A Population Approach to Transportation Planning: Reducing Exposure to Motor-Vehicles

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Transportation planning and public health have important historical roots. To address common challenges, including road traffic fatalities, integration of theories and methods from both disciplines is required. This paper presents an overview of Geoffrey Rose's strategy of preventive medicine applied to road traffic fatalities. One of the basic principles of Rose's strategy is that a large number of people exposed to a small risk can generate more cases than a small number exposed to a high risk. Thus, interventions should address the large number of people exposed to the fundamental causes of diseases. Exposure to moving vehicles could be considered a fundamental cause of road traffic deaths and injuries. A global reduction in the amount of kilometers driven would result in a reduction of the likelihood of collisions for all road users. Public health and transportation research must critically appraise their practice and engage in informed dialogue with the objective of improving mobility and productivity while simultaneously reducing the public health burden of road deaths and injuries.

1. Introduction

Transportation planning and public health have important historical connections [1]. In the early 20th century transportation planning and public health held similar objectives. In 1909 Marsh wrote, "city planning is the adaptation of a city to its proper function. This conception can be indefinitely expanded but its significance will be appreciated if we admit that no city is more healthy than the highest death rate in any ward or block and that no city is more beautiful than its most unsightly tenement (p.27)" [2]. Since the early 20th century, the relationship between transportation planning and public health has waxed and waned [1, 3]. There is growing recognition that integration of theories and methods from each discipline is beneficial for advancing research and practice [4].

Of particular relevance to both transportation planning and public health are injuries due to traffic collisions. Worldwide, traffic collisions are one of the leading causes of death among youth and young adults [5]. A number of intervention strategies including black spot analyses are used in transportation planning to reduce road fatalities. There is ongoing debate in the transportation planning literature that this type of intervention may have limited effectiveness in reducing road fatalities [6–8]. New approaches are needed to reduce the burden of road traffic fatalities.

Given the need to reconnect transportation planning and public health, this paper will present Rose's strategy of preventive medicine [9, 10], a promising intervention approach from public health. The approach is applied to the analysis and prevention of road traffic fatalities.

2. The Prevention Paradox

The prevention paradox states that "a preventive measure which brings much benefit to the population offers little to each participating individual (p.38)" [10]. The prevention paradox is the basis for Rose's strategy of preventive medicine.

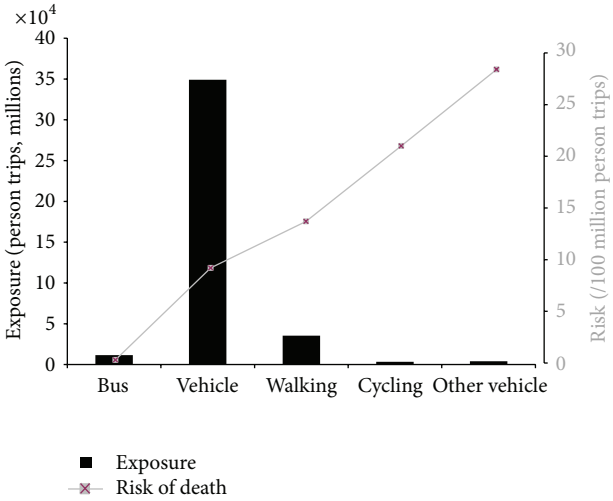


Figure 1: Theoretical distribution of the continuum of risk for all road traffic users. Note: figure adapted from Beck et al. [12].

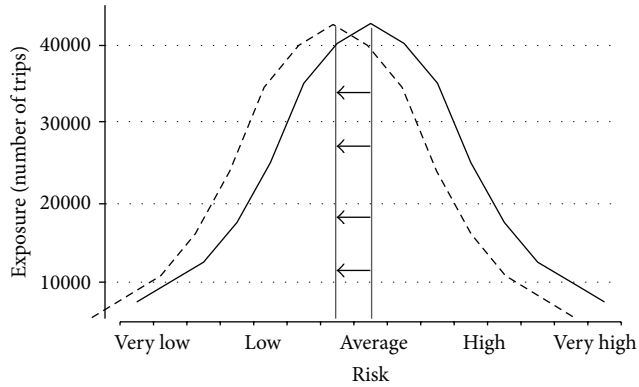


Figure 2: Theoretical distribution of the exposure to risk of road death and injury, showing a reduction in the average exposure for the entire continuum of risk (dotted line). Note: although this figure is theoretical, recent researches estimated the potential reduction in injury risk at intersections following reduction in traffic volume [17, 38] or a modal shift toward walking and cycling [18].

The prevention paradox is based on an important distinction between an individual case and the incidence of cases in a population. A case is defined as an episode of disorder, illness, or injury affecting an individual, while incidence is defined as "the number of cases of a disease that come into being during a specific time period (p.44)" [11]. The basic principle of Geoffrey Rose's strategy of preventive medicine is that the causes of cases (i.e., why a specific individual is involved in a collision) are different from the causes of population incidence (i.e., why there are over 3 million collisions per year in the United States) [9].

3. The Majority of Cases Occur in Individuals at Average Risk

Building from the prevention paradox, the primary concept of Rose's strategy is that the majority of cases do not occur in individuals at high risk. Thus, "a large number of people exposed to a small risk may generate many more cases than a small number exposed to a high risk (p.59)" [9]. The recent study by Beck [12] provides an example of this principle related to road traffic fatalities.

Beck et al. show that pedestrians (13.7 deaths per 100,000 person trips), cyclists (21.0 deaths per 100,000 person trips), and motorcyclists (536.6 deaths per 100,000 person trips) are at higher risk of a fatal collision than motor vehicle users. Despite their higher risk, pedestrians, cyclists, and motorcyclists represent only 20.5% of those killed in traffic collisions. Figure 1 shows that in the USA the majority of trips (86%) and therefore exposure to causes of collisions are greater for motor vehicle users. Thus, the majority of those killed (76.6%) are motor vehicle users who are, on average, at a lower risk (9.2 deaths per 100,000 person trips) than other road users except public transit users.

4. Acting on Causes of Incidence

For interventions to be effective in reducing the total number of road deaths and injury, they must target fundamental causes [13] (i.e., causes of incidence), which would result in a global reduction in exposure to a fundamental cause for the entire population. According to the strategy of preventive medicine road traffic fatalities can be neither understood nor properly controlled if high-risk road users are thought to constitute the entire problem. Policies and practices that attempt to prevent traffic fatalities must consider all modes of transportation because they all contribute to the total number of deaths (Figure 1) [14, 15].

In transportation research, the volume and speed of motor vehicle traffic could be considered two of the fundamental causes of collisions, for all road users [16, 17]. Throughout the paper, we consider exposure to moving vehicles as a fundamental cause of road traffic deaths and injuries. In this example, a global reduction in the amount of kilometers driven would result in a reduction of the likelihood of collisions for all road users, a left shift in the risk of road death and injury (Figure 2) [18, 19]. For all road users, including pedestrians and cyclists, a reduction in traffic volume contributes to a lower risk of injury and death. Significant public health benefits could be achieved through macrolevel interventions that influence the level of exposure to traffic volumes for all road users, for example, land use and transportation policies that encourage using safer transportation modes (e.g., public transit) and area-wide traffic calming schemes covering whole metropolitan areas, among others. In the USA, recent reductions of traffic volume were associated with a reduction in the total number of road fatalities [20]. Potential mechanisms for this reduction include an economic recession and higher gas prices.

5. Acceptability of Change

Rose's perspective is one way to critically appraise the challenge of reducing the overall burden of collisions while maintaining the benefits of effective mobility. However, it remains theoretical. The implementation of interventions supported by Rose's strategy requires a dialogue

Table 1: Estimated reduction in risk resulting from a 15%, 10% and 4% shift in the risk distribution for motor vehicle crash injury rates for all modes in the United States*.

	Person Trips (million)	Fatal risk per 100 million person trips	Number of fatal injuries			
			Status quo	Scenario of risk reduction		
				−15%	−10%	−4%
Vehicle	349125	9.25	32283	−4842	−3228	−1291
Walking	35366	13.7	4846	−727	−485	−194
Bus	11458	0.35	40	−6	−4	−2
Other vehicle	4068	28.42	1156	−173	−116	−46
Cycling	3314	20.97	695	−104	−70	−28
Motorcycle	580	536.55	3112	−467	−311	−124
Total	403,911	10.43	42132	−6320	−4213	−1685

*Note. Table adapted from [12].

between researchers, planners, policy makers, and the public. Throughout this discussion we must recall that the primary function of roadways is not to cause collisions but rather the mobility and productivity of the population [21]. Because roadways have multiple functions, policy makers, planners, health officials, and the public may disagree on how to balance road safety with other competing functions. As Rose states, "if a problem is common and has been around for a long time, then people come to accept it even if it is large: it is the exceptional or new which causes alarm. The toll of deaths from road traffic accidents vastly exceeds that from crashing aero planes, but only the latter lead to public health inquiries (p.57)" [9]. As the previous quote suggests, researchers must critically appraise their work and dialogue with policy makers and the public about complex transportation challenges in order to achieve an acceptable balance between the need for mobility and its consequences [22–24]. Ideally, interventions will both improve mobility and reduce the public health burden of road traffic injuries. In particular researchers must be conscious of the potential influence of structural global economic forces lead by major car and oil companies in influencing road collisions research and discourse [21, 25–27].

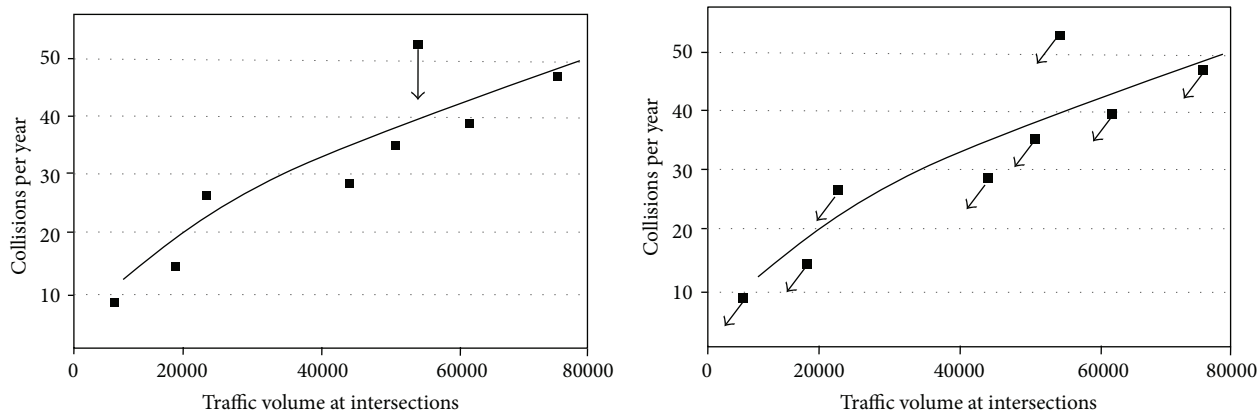
6. An Example: Road Traffic Collisions, Injuries, and Deaths

Beck et al. state, "our findings suggest that a shift from passenger vehicle travel (lower risk) to nonmotorized travel (higher risk) could result in an overall increase in the numbers of people killed in traffic... measures that prevent crashes and injuries for pedestrians and bicyclists are needed, especially given the recent focus on increasing physical activity through active travel (p.216)" [12]. The discussion by Beck et al. suggests that the high-risk approach is a more acceptable intervention than a population approach, which would reduce exposure to fundamental causes, volume of motor vehicles in our example, for all road users. However, in general, interventions targeting high-risk groups (e.g., walkers and cyclists) have limited population wide benefit for injury prevention. Targeting the causes of incidence to reduce exposure to motor vehicle volume for all road users, the population approach, has the potential for a greater reduction in the total number of transportation fatalities in a population than the high-risk approach.

Reanalyzing the data from Beck et al. compares a population approach and a high-risk approach targeting pedestrians and cyclists. In the USA, between 1999 and 2003, a 25% reduction in the number of pedestrian and cyclist fatalities would have resulted in 1386 fewer deaths (1212 for pedestrians, 174 for cyclists). A greater number of lives would have been saved by a 4% reduction in the fatal risk for all road users (Table 1). Table 1 estimates the hypothesized effect of decreasing fatal risk over the entire population of road users. It shows that a 10% and 15% reduction in the fatality risk for all road users would result in a reduction of 4213 and 6320 cases, respectively. These scenarios would benefit motor vehicle occupants but also pedestrians and cyclists. In urban settings, a risk reduction of 15% could be achieved through area-wide traffic calming interventions [28].

Reducing the risk of road death and injury by intervening to reduce the level of exposure to traffic volumes, or other fundamental causes, has many consequences. First, the potential reduction in road injuries and deaths is much larger than with high-risk approaches. Second, a population-wide prevention strategy is of benefit to high-risk road users, whatever the criteria used to define "high risk" (e.g., transportation mode, alcohol consumption, age group). Third, it may also reduce other externalities including pollution, noise, physical inactivity of fundamental causes such as traffic volume [21, 29].

For decades, the strong relationship between traffic volume and road traffic injuries or death has been reported, at the street, city, region, or country levels [30, 31]. For all intersections from a road network, Safety Performance Functions show that the expected number of collisions at intersections increases as traffic volume increases, though this relationship is not linear (Figure 3). The traditional intervention strategy, recommended by the US Department of Transportation [32] is to return deviant intersections to within an acceptable range of the average collisions rate at comparable intersections. As seen in Figure 3(a), this targeted intervention approach aims to move the deviant intersections closer to the best fit regression line. This is



(a) Potential effect of reducing collisions rate at targeted "deviant" intersections

(b) Potential effect of a global reduction in exposure to traffic volume at intersections

Figure 3: Approaches to address safety at intersections using the traditional high-risk approach (a) and the population approach (b). Note: the figure is adapted from: US Department of transportation, Federal Highway Administration [32]. Signalized intersection: Informational guide. Publication no. FHWA-HRT-04-091. Arrows represent the hypothetical change in the number of collisions per year associated with high-risk (a) and population (b) approaches.

an example of a high-risk approach that does not address the entire population of intersections or injured individuals. In Montreal, for example, only 4% of pedestrian injuries occurred at 22 identified black spot intersections, whereas the remaining 96% of pedestrians were injured at more than 3500 different crash sites, none of which were "black spots" [8].

The population strategy acknowledges that interventions should address the fundamental causes of road deaths and injuries, in our example, the level of exposure to moving vehicles over the entire population, and for all intersections. The population approach would ask whether it was possible to globally reduce the exposure to traffic volume (Figure 3(b)) and subsequently reduce the risk of death and injury at any given intersection for all road users. As the arrows show in Figure 3(b), the traffic volume and subsequent risk are reduced at every intersection. In theory, it would result in a greater reduction of the number of injured road users than targeting deviant streets and intersections.

7. A Caveat

This paper presents a simplified version of Rose's strategy applied to road collisions. The intent was not to present the theory in its entirety. Rather we present a promising approach to think about road traffic fatalities. A detailed reading of Rose's work [9, 10] will provide more precision and help clarify interested readers understanding. It should be noted that Rose's ideas are not without considerable debate in public health [33–35]. For example, modeling studies suggest that Rose's approach is generally more cost effective; however, in certain cases a high risk approach can have better cost/benefit ratios [33]. For example, recent studies suggest that when compared with other roads, streets with cycle tracks have a lower risk of injury for cyclists [36, 37]. As well, the potential of Rose's strategy for reducing social inequities in health in general [34, 35] and in particular road fatalities for those residing in low income areas is still debated. A vulnerable population approach may be the most acceptable when attempting to act on social inequities; however, a recent study has shown that reducing traffic volume at all intersections of a Canadian city would be most beneficial in poorer neighborhoods [38].

8. Conclusion

Transportation planning and public health have important historical roots. To address common challenges, including road traffic fatalities, integration of theories and methods from both disciplines is required. Geoffrey Rose's strategy of preventive medicine made an important theoretical contribution to public health and has applications to transportation. The present paper demonstrated Rose's theory and provided examples drawn from transportation research. This paper allowed for both public health and transportation research to critically appraise their practice and engage in informed dialogue with the objective of improving mobility and productivity while simultaneously reducing the public health burden of road deaths and injuries.

Conflict of Interests

All authors declare no conflict of interests.

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Research Article

Association between Physical Activity and Neighborhood Environment among Middle-Aged Adults in Shanghai

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Objective. To determine the perceived neighborhood environment (NE) variables that are associated with physical activity (PA) in urban areas in China. *Methods*. Parents of students at two junior high schools in Shanghai, one downtown and the other in the suburbs, were recruited to participate in the study. They completed an International Physical Activity Questionnaire (IPAQ) and Neighborhood Environment Walkability Scale-Abbreviated (NEWS-A) survey. Participant physical activity was also objectively measured using accelerometers. *Results*. Participants from downtown areas were more positively associated with transportation PA and leisure-time PA than respondents living in the suburbs. Residential density was found to be a significant positive predictor of recreational or leisure-based PA. Street connectivity was negatively associated with leisure time PA for respondents. Moderate-vigorous PA was found to be negatively associated with traffic safety. There were no significant associations between environmental factors and transportation PA. Women had higher levels of moderate-vigorous PA than men. *Conclusions*. The results of this study demonstrate that residential density, street connectivity, and traffic safety have a significant impact on Chinese middle-aged adults' PA, suggesting urban planning strategies for promoting positive public health outcomes.

1. Introduction

Much research has identified and quantified the health benefits of physical activity (PA) [1]. For example, increased PA has been found to reduce the risk of cardiovascular diseases, diabetes, cancers, osteoporosis, and depression [2]. One interesting trend found in countries with emergent economies is a consistent decline of PA associated with economic development [3]. China is experiencing a process of transition from a developing country to a developed one, with increases in urbanization/urban living and associated increases of physical inactivity [4, 5]. For example, average weekly physical activity among adults in China fell by 32% between 1991 and 2006 [5] and car ownership increased from 0.5% to 13.1% between 2000 and 2010 [6]. Some variation with age has been identified: participation in exercise by all Chinese residents was 14.1% but was the lowest amongst the 18–44 age group at 5.9%. The U-shape trend of PA with age is also reflected locally and data from 2005 [7] showed that participation in exercise by Shanghai residents was the least at around 40 years of age. These data and trends indicate an urgent need to consider factors influencing middle-age adults' PA in China.

Many studies have considered the impact on PA of the local environment in terms of its residential density, land use configuration, street connectivity, walking or cycling facilities, and aesthetics [8–11]. A number of interesting associations specifically have been identified including the relationships between residential density with walking behaviors [12, 13], increased transportation PA in areas of greater land use diversity [14], and access to recreational facilities positively associated with leisure time PA [15]. A number of literature reviews have summarized the evidence from many studies that have been published in this area [16, 17].

Some previous studies in China have examined individual behavior in relation to PA [18], but only a few examples have considered how the environment affects PA [19, 20]. However, the application of standard (Western) methodologies in China may not be appropriate due to both cultural differences and differences in the built environment. Some studies have examined subjective perceptions of PA with measured PA behaviors and how they relate to environmental factors and typical analyses assess transportation PA, leisure time PA, or moderate-vigorous physical activity (MVPA) [21–24].

In this study, subjective and objective methods were used to investigate the association between PA and neighborhood environment (NE) among middle-aged adults in Shanghai and to analyze the relative contributions of environmental variables in explaining PA in different NE contexts. The need for such research relates to urbanization in China now exceeding 50% to provide evidence relating to NE impacts on PA and inform urban policy making in China.

2. Methods

2.1. Study Design. Research was conducted as part of a cross-sectional study to investigate the spatial patterns of PA in Shanghai (the Evaluation of Spatial-Patterns of Physical Activity—ESPA project). Two typical junior high schools in Shanghai were selected as case studies: one in the downtown area (Changning district) and another in the suburbs (Pudong district). The parents of the grade-2 students in junior high school were recruited as subjects. Data were collected between October 2010 and June 2011. The study was approved by Ethics Committee of Fudan University, and the University of Tokyo and the participants had given written informed consent.

2.2. Study Procedure. Parents were asked to fill a structured questionnaire of their individual characteristics (age, gender, weight, height, educational background, family income), a Chinese version of the NEWS-A (Neighborhood Environment Walkability Scale-Abbreviated) survey and the IPAQ (International Physical Activity Questionnaire-Long) survey.

With the purpose of finding the household effect, plus the lack of the accelerometer devices, adults in two-parent families were selected to wear the accelerometer (Lifecorder EX (Suzuken Co., Ltd, Nagoya, Japan)) in order to evaluate their physical activity levels. However, there were still a few adults in one-parent families who were included into the accelerometer survey due to the operational reasons. Participants were instructed to attach the accelerometer to an adjustable belt and to wear it firmly around their waist, positioned just above the right hip. Participants were instructed to wear the accelerometer consecutively for 7 days except when sleeping or engaged in water-related activities such as swimming and showering. Class teachers reminded the participants of the correct way to wear the accelerometer and encouraged them to continue to wear it for the direction of the study.

2.3. Measures. The NEWS-A questionnaire captures measures of respondent perceptions of their neighborhood environment using a four-point scale. From this data standard measures are generated to describe residential density, the diversity of land use, facility access, street connectivity, walking and cycling facilities, the aesthetics of the environment, pedestrian safety, and crime safety [25]. IPAQ-long form is designed to measure cross-national PA in adults and considers work-related PA, transport PA, domestic and gardening PA, and leisure PA. It asks respondents to describe their time spent on walking, moderate PA and vigorous PA within each domain. The reliability and validity of the Chinese version of NEWS-A and IPAQ have been demonstrated in previous studies [25, 26].

Objective PA data for individuals can be obtained using an accelerometer. This study used the Lifecorder EXwhich has been shown to measure PA and energy expenditure at a range of different activity levels [27, 28].

In order to obtain valid PA measurements [29], wear and nonwear times were defined as follows: nonwear time as a period of at least 60 consecutive minutes of zero PA level; any period of less than 60 consecutive minutes not recorded as nonwear time. Wear time as a minimum period of 10 hours (8:00–18:00) with an absence of nonwear time during that period was defined as a valid day. Data for participants with at least 1 valid day were included in the analysis.

In order to ensure data quality and completeness, questionnaires with missing data were returned to the participants and any questionnaires that were still incomplete after this were excluded from the final analysis. Double data entry was used. Epidata 3.1 was used to enter the questionnaire data and Predictive Analytics Software (PASW) 18.0 was used for data editing and analysis.

2.4. Analysis. The analysis sought to investigate the relationships between perceived transportation and leisure time physical activity, as captured by the IPAQ survey, and environmental and demographic variables. The data on self-reported transportation PA (i.e., physical activity related to "getting somewhere") and self-reported leisure time PA (i.e., recreational physical activity) were modeled against NEWS-A attributes such as residential density, land use diversity, facility access, street connectivity, walking and cycling facilities, the aesthetics of the environment, pedestrian traffic safety, and crime safety (Model A), and then this analysis was extended by considering participant demographics (Model B). Work-related PA and domestic and gardening PA were not included in this analysis because these two domains of PA were affected by lots of social and individual factors, and there were few studies showing their significant association with neighborhood environment. Actual physical activity data as captured by the accelerometer was also compared with environmental variables (Model A) and environmental variables plus demographic attributes (Model B).

Unadjusted and multivariate-adjusted odds ratios (OR) and 95% confidence intervals (CI) were calculated from logistic regressions to examine the association between NE and PA. Eight environmental variables were used as the

Table 1: Demographics of the participants in the questionnaire-based survey and accelerometer-based survey.

	Questionnaires-based survey	Accelerometer-based survey
Participants number	478	235
Age[a]	39.8 ± 6.29	39.6 ± 5.64
Gender[b]		
Male	231 (48.3)	113 (48.1)
Female	247 (51.7)	122 (51.9)
Area[b]		
Suburb	231 (48.3)	117 (49.8)
Downtown	247 (51.7)	118 (50.2)
BMI[b]		
<18	16 (3.4)	3 (1.3)
≥18, <24	300 (63.2)	154 (66.1)
≥24, <28	127 (26.7)	61 (26.2)
28≤	32 (6.7)	15 (6.4)
Family income[b]		
<20,000 RMB	99 (20.8)	43 (18.5)
2–40000 RMB	150 (31.6)	74 (31.8)
40000 RMB<	226 (47.6)	116 (49.8)
Educational background[b]		
Primary school	18 (3.8)	8 (3.4)
Junior high school	250 (52.7)	121 (51.7)
High school	93 (19.6)	46 (19.7)
College	89 (18.8)	44 (18.8)
University and above	24 (5.1)	15 (6.4)

[a]data presented as means ± SD; [b]data presented as *N* (%).

independent variables to estimate dependent variables of transportation, leisure time PA, and moderate-vigorous physical activity. The models were adjusted for area, gender, educational background, and family income level. For self-reported transportation and leisure time PA, participants were divided into two groups (low active and active) depending on whether they met the recommendations of the IPAQ international criterion. For the accelerometer measured PA, MVPA was divided into two groups based around the median value for all participants: >=36 minutes/day and <36 minutes/day.

3. Results

Of the 515 questionnaires sent out, 478 (92.8%) valid ones were collected and analyzed. Of these, 327 respondents from two-parent families were asked to wear the accelerometer, with 235 having valid accelerometer data.

Table 1 presents a breakdown of the demographics of the participants in the questionnaire and accelerometer-based surveys. The sample for each survey included 48% of male, mean age (SD) was 40 (6) years, and 33% of participants were overweight or obese (body mass index was greater than or equal to 24). Almost half of the questionnaire participants had a family income of more than 40,000 RMB per year (47.6%), with the national average being 42,500, and had an educational background of at least high school level (43.5%). Of the participants in the accelerometer survey, 49.8% had an income greater than 40,000 RMB per year and 44.9% had an educational background of at least high school level.

The attributes of the respondent PA and NE are presented in Table 2. This shows that the transportation PA active group included 42.5% of the participants and that the leisure time PA active group included 25.3% of the participants. No significant differences were found between genders in the perception of transportation PA, leisure time PA, and neighborhood environment, but a difference was found in MVPA between male and female respondents with female having significantly higher levels of MVPA than male.

Logistic regression was used to identify the factors influencing PA (Table 3). For Model A, respondents' transportation PA was not found to be associated with any of the neighborhood environmental variables. When demographic variables were considered alongside environmental ones (Model B), the associations between transportation PA and the environmental variables were still not present, but participants from the downtown area were found to be more positively associated with transportation PA than respondents living in the suburbs.

For both the unadjusted and adjusted models, higher levels of leisure-time PA were positively associated with perceived residential density and with poorer neighborhood street connectivity. In the demographically adjusted model (Model B), participants from the downtown area were more positively associated with leisure time PA than those living in the suburbs. Residential density was a significant positive predictor, while street connectivity was a negative predictor of recreational or leisure-based physical activity in both the unadjusted and demographic adjusted models.

MVPA was found to be negatively associated with traffic safety in Model A. After adjusting for demographic variables, the results indicated that women were more strongly associated with increased levels of MVPA than men; however, there was no association between MVPA and traffic safety in the adjusted model.

4. Discussion

The results indicate possible associations between traffic safety and MVPA among Chinese adults (parents) and that two neighborhood environmental variables (residential density, street connectivity) are significantly associated with leisure time PA after adjusting the demographic variables. The impacts of environmental factors vary depending on the nature of the PA. Leisure time PA was found to be positively associated with residential density but negatively associated with street connectivity, and MVPA was found to be negatively associated with traffic safety.

Although many people (more than 20%) in China walk to work (transportation PA) compared to less than 5% in western countries [30], with the improvement of public transportation and the growth of private motor vehicles, it is

Table 2: Comparison of physical activity and neighborhood environment of participants using IPAQ, NEWS-A, and accelerometers by sex.

	Male	Female	Overall
IPAQ-based physical activity indicators[a]			
Transportation PA			
Active group	99 (42.9)	104 (42.1)	203 (42.5)
Low active group	132 (57.1)	143 (57.9)	275 (57.5)
Leisure time PA			
Active group	57 (24.7)	64 (25.9)	121 (25.3)
Low active group	174 (75.3)	183 (74.1)	357 (74.7)
Accelerometer-based physical activity indicators[a]			
MVPA (minutes per day)*			
36-	49 (43.4)	71 (58.2)	120 (51.1)
-35	64 (56.6)	51 (41.8)	115 (48.9)
Perception of neighborhood environment using the NEWS-A[b]			
Residential density	348.8 ± 130.6	352.1 ± 130.9	350.5 ± 130.6
Land use mix diversity	2.88 ± 0.81	2.85 ± 0.81	2.86 ± 0.81
Land use mix access	2.88 ± 0.60	2.88 ± 0.58	2.88 ± 0.59
Street connectivity	2.82 ± 0.53	2.80 ± 0.51	2.81 ± 0.52
Walking/cycling facilities	2.68 ± 0.72	2.65 ± 0.70	2.67 ± 0.71
Aesthetics	2.69 ± 0.78	2.70 ± 0.75	2.69 ± 0.76
Traffic safety	2.85 ± 0.52	2.86 ± 0.52	2.86 ± 0.52
Crime safety	3.05 ± 0.91	2.98 ± 0.90	3.01 ± 0.90

* $P < 0.05$ MVPA, moderate-vigorous physical activity; [a]data presented as N (%); [b]data presented as means ± SD.

likely that less people in the future will walk or cycle to work. Other studies have suggested that physical environment may have a greater effect on transportation PA than leisure time PA. Learnihan et al. [31] found land use diversity to be the most critical factor influencing transportation PA. However, land use diversity and other environmental variables were not found to be associated with transportation PA in this study. This may be due to the different effects in suburb and downtown cancelling each other out as exemplified by land use diversity which was positively associated with suburban participants' transportation PA but negatively associated with downtown participants' transportation PA.

In urban China, the per capita living space is 31.6 m^2, with a population density of 2209 people per km^2, whilst in Shanghai, the population density is 3630 people per km^2 [6]. In this study, the higher levels of residential density in the participant neighborhood environments were associated with higher levels of leisure time PA (with or without demographic adjustment). This is consistent with other studies [32] which have also found higher housing density to be positively associated with physical activity. However, a Japanese study [12] has shown that high residential density is associated with reduced leisure PA for women, indicating that the correlates may be due to gender or cultural differences. This study found that women did more MVPA than men, yet in other studies women have been found to be less active with less MVPA than men in global studies [30], suggesting that further studies may be needed to unpick these differences.

Van Dyck et al. [9] found perceived street connectivity to be negatively associated with recreational walking. This is consistent with the findings of this research, which showed poorer street connectivity to be associated with more leisure-time PA. This suggests for neighborhoods with better street connectivity that greater consideration should be given to interventions for improving the opportunities for leisure-time PA.

The results of previous studies investigating the relationships between traffic safety and PA are not consistent. Some studies have variously shown traffic safety to not be related to PA [33], others has shown that it is positively associated [12, 34] and yet further studies have found it to be negatively associated [23]. This research found that higher perceptions of traffic safety problems were associated with less MVPA, although this association was not found when the model was adjusted for socioeconomic variables (Model B). That is, high perceptions of traffic safety issues resulted in less PA, which may be due to a dependence between perceptions of traffic safety and environmental attributes with, for example, areas with heavy traffic often having a greater diversity of land uses.

There were differences in the associations with PA between respondents from different areas. For example, respondents from downtown areas were found to be more positively associated with transportation PA and leisure time PA than respondents living in the suburbs. It should be noted that parents of children from only one school were selected in each area and the results may be not representative, especially as some of the effect sizes are small. This may limit their practical relevance, but they do indicate possible interventions in relation to improving PA especially in relation to active commuting to work and leisure time in the suburbs. Future studies will be conducted in more schools to verify the results.

Table 3: Association between physical activity and neighborhood environment measures.

Correlates of PA	Self-reported PA (IPAQ)				Accelerometer-measured PA	
	Transportation PA (low active group and active group)		Leisure time PA (low active group and active group)		MVPA (≥36 minutes/day group and <36 minutes/day group)	
	Model A[a] OR (95% CI)	Model B[b] OR (95% CI)	Model A OR (95% CI)	Model B OR (95% CI)	Model A OR (95% CI)	Model B OR (95% CI)
Area						
Suburb		Reference		Reference		Reference
Downtown		**2.127 (1.212, 3.734)****		**2.110 (1.100, 4.048)***		1.224 (0.516, 2.900)
Sex						
Male		Reference		Reference		Reference
Female		0.960 (0.654, 1.411)		1.054 (0.676, 1.643)		**2.111 (1.182, 3.771)***
Family income per year						
<20,000 RMB		Reference		Reference		Reference
2–40000 RMB		1.129 (0.643, 1.983)		1.453 (0.753, 2.805)		0.679 (0.284, 1.623)
40000 RMB<		0.678 (0.389, 1.182)		1.111 (0.585, 2.110)		0.770 (0.324, 1.830)
Educational background						
Primary school		Reference		Reference		Reference
Junior high school		0.661 (0.223, 1.961)		6.350 (0.793, 50.814)		0.864 (0.160, 4.663)
High school		0.780 (0.243, 2.502)		3.884 (0.463, 32.611)		2.296 (0.362, 14.580)
College		0.581 (0.178, 1.897)		3.493 (0.408, 29.876)		5.157 (0.784, 33.907)
University and above		0.665 (0.163, 2.712)		2.054 (0.192, 22.007)		1.502 (0.175, 12.876)
Residential density	1.001 (1.000, 1.003)	1.001 (0.999, 1.002)	**1.003 (1.001, 1.005)****	**1.003 (1.000, 1.005)****	0.999 (0.997, 1.002)	0.997 (0.995, 1.000)
Land use mix diversity	1.117 (0.848, 1.470)	0.967 (0.708, 1.321)	0.986 (0.718, 1.354)	0.932 (0.654, 1.330)	1.124 (0.727, 1.737)	0.935 (0.556, 1.573)
Land use mix access	0.965 (0.629, 1.480)	1.042 (0.670, 1.621)	0.981 (0.596, 1.615)	1.000 (0.601, 1.663)	1.117 (0.586, 2.129)	1.356 (0.671, 2.740)
Street connectivity	0.791 (0.522, 1.198)	0.797 (0.516, 1.232)	**0.599 (0.366, 0.980)***	**0.598 (0.359, 0.995)***	1.207 (0.712, 2.046)	1.147 (0.652, 2.017)
Walking/cycling facilities	1.131 (0.825, 1.551)	1.008 (0.724, 1.402)	0.990 (0.688, 1.425)	0.951 (0.650, 1.391)	1.117 (0.720, 1.733)	0.892 (0.552, 1.441)
Aesthetics	1.156 (0.867, 1.540)	1.103 (0.819, 1.486)	0.986 (0.707, 1.375)	0.945 (0.669, 1.334)	1.145 (0.758, 1.730)	1.040 (0.668, 1.618)
Traffic safety	0.648 (0.416, 1.009)	0.714 (0.444, 1.146)	0.962 (0.576, 1.608)	0.980 (0.569, 1.687)	**0.428 (0.226, 0.811)****	0.514 (0.257, 1.030)
Crime safety	0.987 (0.785, 1.240)	1.012 (0.799, 1.283)	1.044 (0.800, 1.362)	1.061 (0.806, 1.398)	1.397 (0.970, 2.013)	1.350 (0.912, 1.998)

[a] Model A only includes neighborhood environment. [b] Model B also includes area, sex, family level, and educational background besides all the factors in Model A. $^{*}P < 0.05$; $^{**}P < 0.01$.

There are several limitations in this study. First, the study was cross-sectional and the direction of causality could not be evaluated, suggesting the need for longitudinal or intervention studies in the future. Second, the environmental attribute measures were derived from subjective questionnaires rather than objective measures from a GIS or remote sensing analysis [35]. Third, the age range of the participants was narrow, which limits the extrapolation of the findings to other age groups. Fourth, the participants were selected from the parents of children at only one school in each area, which may not fully represent the population of Shanghai and may limit the generalization of the results to other areas.

5. Conclusions

This study confirms the relationship between residential density, street connectivity, and traffic safety with a range of PA behavior in middle-aged Chinese adults. No significant associations were detected between transportation PA and environmental variables. Leisure time PA was found to be positively associated with residential density but negatively with street connectivity. The perceptions of traffic safety were strongly associated with MVPA, although this association disappeared after the model was adjusted for socioeconomic variables. The results suggest a number of ways that urban planning could increase the physical activity level of the middle-aged adults in China, for example, by centralizing the residence in the neighborhood, especially in downtown areas.

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Research Article

Two Pilot Studies of the Effect of Bicycling on Balance and Leg Strength among Older Adults

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Objectives. Study 1 examines whether age-related declines in balance are moderated by bicycling. Study 2 tests whether regular cycling can increase leg strength and improve balance. *Methods*. *Study 1*: a cross-sectional survey of 43 adults aged 44–79 was conducted. Leg strength was measured, and Balance was measured using the choice stepping reaction time (CSRT) test (decision time and response time), leg strength and timed single leg standing. *Study 2*: 18 older adults aged 49–72 were recruited into a 12-week cycling program. The same pre- and postmeasures as used in Study 1 were collected. *Results*. *Study 1*: participants who had cycled in the last month performed significantly better on measures of decision time and response time. *Study 2*: cycling at least one hour a week was associated with significant improvements in balance (decision time and response time) and timed single leg standing. *Conclusions*. Cycling by healthy older adults appears promising for improving risk factors for falls.

1. Introduction

Falls in older people represent a significant health burden. One-third of adults aged over 65 years fall at least once each year [1]. Falls can result in injuries (e.g., fractures), loss of confidence, and restriction of physical activity [2]. Physiological risk factors have been found to be associated with greater risk of falling, include gait instability, leg weakness, and poor balance [3].

The deterioration of balance with age has been well documented [4], and physical activities that increase balance and strength are recommended for falls prevention for older adults [5]. A recent meta-analysis found that the most effective physical interventions for falls prevention involve a challenge to balance [6].

The majority of physical activity interventions for falls prevention are structured, supervised group training programs. However, participation in these programs is variable, and more than half of older Australians undertake their physical activity in unstructured forms [7]. Studies from the USA and Europe suggest that many older adults prefer to exercise alone rather than in organised group classes [8], and that the cost, time, and difficulty of travel to group programs can be barriers to participation [9]. Identifying activities that are enjoyable and accessible for older people that have a benefit in contributing to falls prevention is the challenge, and there is currently limited evidence about the effect of recreational leisure time or daily physical activity on falls risk factors [10]. To date, Tai Chi is the only single physical activity that has been tested and shown to prevent falls through its positive effect on strength and dynamic balance [11, 12].

Riding a bicycle is an example of an increasingly popular physical activity for older adults; in Australia, increasing numbers of older adults cycled for recreation and transport in the past decade [7, 13]. Cycling is a healthy form of physical activity [14] and a non-weight bearing activity that is less stressful on the body than jogging or other running sports. A recent systematic review found a consistent positive relationship between cycling and cardiorespiratory fitness, functional abilities, and disease risk factor profiles [15]. Several longitudinal epidemiological studies have shown significant risk reduction for all-cause and cancer mortality and for

cardiovascular disease, colon and breast cancer, and obesity morbidity in middle-aged and elderly men and women [15]. Cycling may also have other benefits for older people, such as providing opportunities for recreation and socialising, and as an affordable form of transport.

There are risks associated with cycling, especially traumatic injuries. However, a recent analysis has compared the risks and benefits of shifting from a car to bicycle commuting in urban settings and estimated that the life expectancy gained due to increased physical activity (3–14 months gained) was far greater than the life expectancy lost due to increased air pollution (0.8–40 days lost) and traffic injury (5–9 days lost) [16].

It is not known if cycling prevents falls. However, there is some evidence that cycling is associated with increased leg strength and balance, important risk factors for falling. Indoor stationary cycling has been found to increase leg strength, muscle endurance, balance, and functional abilities in healthy middle-aged and older adults [17–19]. Although the impact of nonstationary cycling has not been tested in older adults, we expect that nonstationary cycling would also increase leg strength and balance, and it may have additional benefits such as increased social activity.

This paper reports on two pilot studies exploring the relationship between cycling participation and leg strength and balance in healthy older adults. The first pilot study examines the cross-sectional association of recent cycling with leg strength and balance, and the second pilot study examines whether an older adult noncyclist riding a bicycle will increase leg strength and improve balance.

2. Study 1 Methods

The design of this pilot study is a cross-sectional study. Participants were recruited by invitations circulated through existing cycling and social networks. Eligible participants were healthy adults aged over 40 years and gave informed consent. Both Study 1 and Study 2 were approved by the University of Sydney Ethics Review Committee.

2.1. Measures

2.1.1. Questionnaire. A short questionnaire was administered orally by one of the investigators. Participants were asked when they last rode a bicycle, and how often they usually cycled. Recent cycling (in the past month) was considered the key independent variable. Participants were also asked to describe their regular physical activities. The investigators then assigned a crude rating of physical activity on a scale from 1 to 10 (1 = no physical activity, 10 = frequent, intense physical activity). Demographic details were also collected.

2.1.2. Physical Measures

Seated Leg Strength. The strength of three leg muscle groups (knee flexors and extensors and ankle dorsiflexors) was measured, while participants were seated. An electronic force gauge (Checkline Model Series 4) was attached to the participant's leg and secured to the back of the chair. Participants were then asked to straighten their leg out from the chair as far as possible. There were three trials on each leg. For each trial, the greatest force was recorded (to a maximum of 50 kg). Quadriceps strength using a spring gauge to measure knee extension has been shown to have a good intra-rater reliability (ICC = 0.76) [20].

Dynamic Balance. Dynamic balance was measured using the choice step reaction time (CSRT) test.

The CSRT test uses a plastic mat marked with two central footprints and four arrows (one in front of each foot and one to the side of each foot). The participant stands facing a computer screen displaying a diagram of the mat. On the screen, arrows are illuminated in random order, and participants step on the corresponding arrow on the mat as quickly as possible. Two measures were collected: decision time (time between arrow being illuminated on screen and participant raising foot from centre footprint) and response time (time between raising the foot from centre footprint to placing foot on correct arrow). The Choice Step Reaction Time test is associated with a range of sensorimotor and balance measures important in preventing falls, and is also effective at differentiating fallers from nonfallers [21].

Standing Balance. Standing balance was measured using the timed single leg standing test [22]. Participants were asked to stand on one leg with eyes open for as long as possible up to a maximum of 5 minutes. There was one trial on each leg.

Statistical Analysis. Participants' best trials for standing balance and leg strength were included in analyses. For the Choice Step Reaction Time test, mean decision time and response time were calculated. Regression models were created with four separate outcome measures: standing balance, leg strength, dynamic balance decision time, and dynamic balance response time. The main variable of interest was cycling activity in previous month (yes/no). Three other potentially confounding variables were also included in the regression models: age, sex, physical activity rating (0–10). The data were analysed using SPSS Version 19.

3. Study 1 Results

There were 43 participants; 67% were female. Participants ranged in age from 44 to 79 years (mean = 57.2, standard deviation = 7.9). Twelve participants (28%) rated their current health status as excellent, 20 (47%) as very good, 9 (21%) as good, and 2 (5%) as poor.

Current participants physical activity ratings ranged from 1 to 10 (mean = 5.4, standard deviation = 2.5). Forty percent of participants ($n = 17$) had cycled within the past month, a further 15% within the last year, and the rest longer than a year.

As expected, performance on two of the four measures of strength and balance significantly declined with age. These were leg strength (regression coefficient = −0.592, $P = 0.008$)

and standing balance (regression coefficient = −6.58, P = 0.001). Decision times increased marginally (regression coefficient = 0.005, P = 0.009), and response time was not associated with age (regression coefficient = 0.007, P = 0.187). In contrast, performance on all four measures improved significantly with increasing physical activity. After adjusting for age, sex, and physical activity rating, participants who had cycled in the last month ("cyclists") performed significantly better on measures of decision time (P = 0.008) and response time (P = 0.050) compared to those who had not cycled in the last month ("noncyclists") (see Table 1). There was a borderline significant difference in standing balance between cyclists and noncyclists (P = 0.063).

Cycling was not a statistically significant independent predictor of timed one leg standing balance; however, the 62 seconds difference in standing balance between cyclists and noncyclists is potentially clinically significant. Cycling was negatively associated with leg strength, with noncyclist's average leg strength significantly greater than cyclists.

4. Study 2 Methods

The design of study two was a pre-post program evaluation. We sought to recruit adults aged from 50 to 75 years who were willing to cycle for two or more hours per week over a 12-week period. This amount of activity has been assessed as the minimum amount necessary for an intervention effect for preventing falls [5]. Eligible participants were healthy adults who were able to cycle, had cycled previously but were currently not cycling (average of less than 30 minutes a week), and gave informed consent.

4.1. Program Components. The program was initially situated in a discrete geographic area of Sydney (Canada Bay) and commenced with a cycling skills course to develop participants cycling ability and confidence. The course was delivered by accredited trainers "Bikewise," and funded by City of Sydney Council. The course duration was 4.5 hours, and it covered the basic bicycle control skills (starting, braking, and turning), route planning, and practiced on-road group and individual riding skills. Participants were then encouraged to cycle for at least two hours a week over 12 weeks.

Participants were also supported by mentors in their local area over the 12 weeks of their participation and received a resource pack with information about cycling. The research team made brief informal phone calls to participants at one and six weeks after the cycle skills course to maintain participant engagement with the project and identify any additional support required. The project timeline is shown in Table 2.

Measures of leg strength and balance were collected, as described for Pilot Study 1. These were taken before the cycling skills course and at 12 weeks. Participants were also asked to keep a diary recording their cycling. At the end of the project, participants were asked a series of open-ended questions about their experiences of cycling, with the interviews being recoded and analysed qualitatively for major themes.

4.2. Statistical Analysis. Quantitative outcome measures were single leg standing balance time (seconds), leg strength (kilograms), and decision time and response time on the Choice Step Reaction Time test (seconds). Analysis was a pre-post comparison of leg strength and balance using paired sample t-tests. Participants' best trial for standing balance and leg strength was included in analysis. For the Choice Step Reaction Time test, mean decision time and response time were calculated. The data were analysed using SPSS Version 19.

5. Study 2 Results

There were 18 participants, of whom 13 were female. Participants ranged in age from 49 to 72 years, with an average age of 61. At baseline, six participants rated their current health status as excellent, seven as very good, and five as good. When asked at baseline about the time since they last cycled, eleven participants had not cycled in the last year, three had cycled in the last year, three in the last month, and one in the last week, with recent cyclists riding less than 30 minutes a week.

(1) Cycling Participation. Two participants withdrew from the study (for personal reasons), one was unable to participate due to injury, a fourth could not be contacted for timely followup, and two more participants had only done a very small amount of cycling (less than 10 minutes a week). All withdrawals were female. This left 12 participants (66%) who had on average cycled an hour or more a week for the past 12 weeks (including six who cycled for more than two hours a week), and for whom baseline and follow-up information was available. Five of these remaining participants were male, and seven were female. The average age (SD) was 62.2 (4.6) years and ranged from 53 to 68 years.

(2) Physical Measures. Pre- and postintervention results for the twelve participants who cycled for at least an hour per week are presented in Table 3. Overall, participants significantly improved their performance on measures of one leg standing balance (P = 0.028), and response time (P = 0.031), and borderline significance for decision time (P = 0.058). Leg strength increased over the 12 weeks, but not significantly.

(3) Qualitative Feedback. From participant feedback during the follow-up data collection, the program appears to have been successful in supporting most participants to start cycling regularly. Several participants described the program as a "life-changing" experience that made it possible to achieve their goal of cycling. Participants described health benefits including increased fitness, increased leg strength, weight loss, and improved performance in other physical activities such as walking and running. Cycling was also considered beneficial for participants' mental health, as a form of relaxation. Participants identified social benefits of cycling, reporting that group rides had expanded their social network, or that cycling was an activity they could enjoy with their partner and friends.

Almost all participants said the skills course was essential in developing their cycling skills and confidence, especially

Table 1: Mean leg strength and balance outcome measures of participants who had cycled in the past month (cyclists) and those who had not (noncyclists) ($n = 43$).

Measure	Noncyclist ($n = 26$) mean (SD)	Cyclist ($n = 17$) mean (SD)	$P^{\dagger}$
Leg strength (kg)	37.4 (11.8)	31.9 (11.0)	0.012
Standing balance (sec)	156.3 (113.7)	218.3 (89.1)	0.063
Dynamic balance decision time (sec)	0.67 (0.12)	0.58 (0.05)	0.008
Dynamic balance response time (sec)	0.97 (0.31)	0.79 (0.09)	0.050

†Adjusting for age, sex, and other physical activity.

Table 2: Timeline for Older People Cycling Project.

Dates	Activities
Oct-Nov 2011	Promotion of project in Canada Bay Council area through Drummoyne Community Centre, City of Canada Bay Council, Canada Bay Bicycle User Group, and inviting people to volunteer as mentors and participants
Dec 2011–March 2012	Enrolment of mentors and participants
Jan–April 2012	Baseline interview, questionnaire, and physical measures. Participation in cycling skills course
12 weeks	Participants ride two hours a week over at least two days, recording rides in diary
April–June 2012	Follow-up interview and physical measures

for riding in groups and on roads. Participants also found it helpful to have "mentoring" from another local cyclist who was able to provide tips, support, and encouragement.

6. Discussion

We found that older adults who had cycled recently and those who cycled for over an hour a week performed better than nonriders or infrequent cyclists on measures of static and dynamic balance, important predictors of falls risk. After adjusting for age, sex, and physical activity, cycling was a significant predictor of decision time and response time on a dynamic balance task.

Although cycling was not a statistically significant independent predictor of standing balance time, this may reflect the limited power of the study due to the small sample size. Cyclists balanced on one leg for 62 seconds longer on average than noncyclists, a large and potentially clinically significant difference. The clinical significance of this finding is difficult to judge as methods for administration of the one-legged standing test vary greatly between studies; however, many studies have found that decreased one-legged standing time is associated with increased falls risk and declines in activities of daily living [23].

Our finding of no association between cycling and leg strength in Study 1 was unexpected, although may be due to the way leg strength was measured. Gains in strength are in part specific to the type of muscle action used in training [24]. Cycling involves using several leg muscle groups at relatively low force over a long period of time, whereas the leg strength test involved exerting maximum force for a short period using mainly quadriceps muscles. Despite a small increase in leg strength as a consequence of regular cycling, other studies also have found that stationary cycling does not improve seated leg strength in healthy middle-aged women [19] or stroke patients [25]. In addition, although leg weakness is a risk factor for falls, there is no evidence that leg strength training reduces falls risk [6]. It is possible that once a person has sufficient leg strength to avoid falling, further strength training has no additional benefit [6].

In addition to the measured balance improvements, participants also reported a range of other benefits from cycling, including improved health and wellbeing, increased confidence, and expanded social opportunities. Most project participants were reasonably physically active before they started the program, and the benefits of cycling may be even greater for people with lower baseline levels of physical activity.

Overall, the results suggest that cycling is a potential falls prevention strategy for healthy older adults who are able to ride a bicycle. Previous research indicates that exercise can protect against age-related decline in strength and balance and reduce the risk of falls [5]. However, this is one of the first studies to specifically examine the relationship between outdoor bicycling and leg strength and balance in healthy older adults and to have demonstrated improvements related to regular cycling. These preliminary results suggest that cycling has an additional impact on balance, over and above what is gained through other physical activity. Thus, cycling may further reduce falls risk even among adults who are already physically active.

The main limitations of these pilot studies are the small sample sizes in both studies, the lack of a comparison group for Study 2, lack of sensitivity to cycling of the leg strength measure, and the use of a nonvalidated measure of physical activity. However, with the effect sizes shown, sample size calculations can be made for future research to replicate these results in a larger sample. Further research is required to verify the findings of this pilot program. Larger-scale trials over a longer time period are required to replicate these findings and examine whether the observed improvements in balance translate to reduced rates of falls.

Given the many benefits of cycling, we recommend that cycling programs for older people become more widely available. Our program provides a successful model for supporting older adults to cycle that could be easily replicated

Table 3: Pre-and postintervention leg strength and balance for participants cycling one hour or more per week over 12 weeks ($n = 12$).

Measure	Preprogram mean (SD)	Postprogram mean (SD)	P
Leg strength (kg)	31.4 (11.6)	36.2 (10.3)	0.141
Standing balance (sec)	145.7 (90.7)	175.2 (98.5)	0.028
Dynamic balance decision time (sec)	0.62 (0.04)	0.59 (0.04)	0.058
Dynamic balance response time (sec)	0.86 (0.05)	0.81 (0.05)	0.031

elsewhere, and it was delivered at low cost by making use of existing resources (i.e., local Bicycle User Group and a free cycling skills course) plus a coordinating role. Key elements of our program that participants identified as helpful were the skills course and mentoring, and we suggest future initiatives to promote cycling for older adults incorporate these components as a way of developing cycling skills and confidence in a supportive peer environment. Dedicated cycling courses for older adults or "rusty riders" could facilitate greater participation. Rider support through mentors, that is, being able to ride with someone else who could develop their safety and riding skills and show them safe local routes, was important for older adults. Support for local Bicycle User Groups (who organise social and community rides and participate in advocacy) is a practical way to provide this mentoring.

In addition, it is important to continue to expand cycling infrastructure such as dedicated off-road cycle paths, separated cycleways, and connectivity to other forms of public transport. This would allow new riders of all ages to access off-road cycle areas, where they feel safe to develop their skills and potentially transition to on-road riding.

Key Points

(i) Adults who had cycled in the last month performed significantly better on balance measures of decision time and response time.

(ii) Cycling at least one hour a week was associated with significant improvements in balance (decision and response times) and timed single leg standing.

(iii) Cycling by healthy older adults appears promising for improving risk factors for falls.

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Research Article

Active Transport and Health Outcomes: Findings from a Population Study in Jiangsu, China

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To investigate the prevalence of active transport (AT, defined as walking or bicycling for transport) and to explore the association between AT and health outcomes, we conducted a population-based cross-sectional study in Jiangsu, China, where walking and bicycling are still the main modes of transport. In this study, 8400 community residents aged 18 or above were interviewed following a multistage random sampling method (100% response rate). Face-to-face questionnaire survey data, anthropometric measurements, and biochemical data from blood tests were collected. Results show that 49.6% of the subjects, as part of daily transport, actively traveled on average 5.3 days per week, 53.5 minutes per day, and 300.3 minutes per week. There was an inverse correlation between AT and some health outcomes: AT respondents had a higher prevalence of cholesterol disorder; AT respondents who actively travelled every day had a higher risk of diabetes, whilst AT respondents with shorter daily or weekly duration had a lower risk of obesity, central obesity, and cholesterol disorder. Moreover, AT influences more health aspects among urban residents than among rural residents. Findings of this study do not support the notion that AT is beneficial to population health. Further research is needed in determining the negative side effects of AT.

1. Introduction

As the result of rapid economic development in recent years, many countries are experiencing a fast-growing automobile population and steadily improving public transportation infrastructure, which accelerate the transition from active to passive transport. Active transport (AT), which usually means walking, cycling, and using public transport, could have multiple health benefits by increasing physical activity, protecting people from some chronic diseases and reducing the adverse health effects of motor vehicle transport [1–3]. Many countries strongly promote a population shift from car dependency to active transport [4, 5]. In 2008, in order to promote a healthier lifestyle, the Chinese government launched a nationwide program, of which AT is an integral part [6]. However, some studies have reported that AT was related to no or even negative effects on health [7, 8].

As being the largest developing country, China has her unique characteristics concerning transport environment and residents' transport activity. However, there is little data on these aspects available at present. Jiangsu Province is one of the most economically booming areas in the southeast of China. With a population of 78.66 million, Jiangsu is witnessing the transition from AT transport mode to increased car dependency. In this study, we investigated the prevalence, frequency, and duration of AT and explored the relationship between AT and health outcomes at a population level.

2. Materials and Methods

2.1. Study Design. Jiangsu Provincial Surveillance (JPS) on chronic diseases and behavioral risk factors is a population-based cross-sectional survey carried out in every 3 years in 14 disease surveillance points (DSPs, in the unit of county) of Jiangsu Province, China. These 14 DSPs are spread across all municipal cities of Jiangsu and were shown to be representative of Jiangsu for geographic coverage and size, population, death rates, economic development level, and other characteristics [9]. In this paper, we analyzed AT data of the latest JPS carried out between August and November of 2010.

2.2. Sampling. A multistage stratified sampling method (see Figure 1) was employed. 8400 community residents aged 18 or above were selected. The response rate was 100%.

Written consent was obtained from all the participants.

2.3. Data Collection

(i) Face-to-face interviews using a structured questionnaire were conducted by trained public health practitioners. Information on frequency and duration of active transport within one typical week was collected. To assess the overall physical activity level, strength, frequency and duration of occupation, and exercise-related physical activities within one typical week were also recorded. Information on demographics and self-reported health was collected simultaneously.

(ii) Anthropometric measures on body weight were collected using an electronic scale (TANITA HD-390), height, and waist circumstance (WC) with soft tape. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were also measured by electronic blood meter (OMRON HEM-7071) three times, and the average was calculated.

(iii) Biochemical tests using fasting blood were conducted for glucose (FBG) and lipemia, including total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and triglycerides (TG).

2.4. Study Variables.

Active Transport (AT). Walking and/or bicycling for transport was accessed by the question "Do you usually have more than 10 minutes' walking and/or bicycling (includes both traditional and electric) in transport?" Walking or bicycling for occupational reasons, couriers' walking or bicycling during work time, for example, or for exercise was not included.

Obesity. Body mass index (BMI = body weight/height^2) $\geqslant 24\,\text{kg/m}^2$ [10].

Central Obesity. WC of male $\geqslant$ 90 cm or WC of female $\geqslant$ 80 cm [11].

Hypertension. Average of thrice SBP $\geqslant$ 140 mmHg and/or average of thrice DBP $\geqslant$ 90 mmHg [12].

Diabetes. FBG $\geqslant$ 7.0 mmol/L [13].

Cholesterol Disorder. TC $\geqslant$ 6.22 mmol/L and/or HDL-C $<$ 1.04 mmol/L and/or LDL-C $\geqslant$ 4.14 mmol/L and/or TG $\geqslant$ 2.26 mmol/L [14].

Overall Physical Activity Level. It was categorized into "active," "moderate," and "inactive" according to frequency and duration, total amount of transport, occupation, and exercise-related physical activity within one typical week [15]. "Active" was developed to describe higher levels of participation, which equates to approximately at least one hour per day or more, of at least moderate-intensity activity above the basal level of physical activity; "moderate" is proposed as a level of activity equivalent to half an hour of at least moderate-intensity PA on most days; "inactive" is simply defined as not meeting any of the criteria for either of the previous categories.

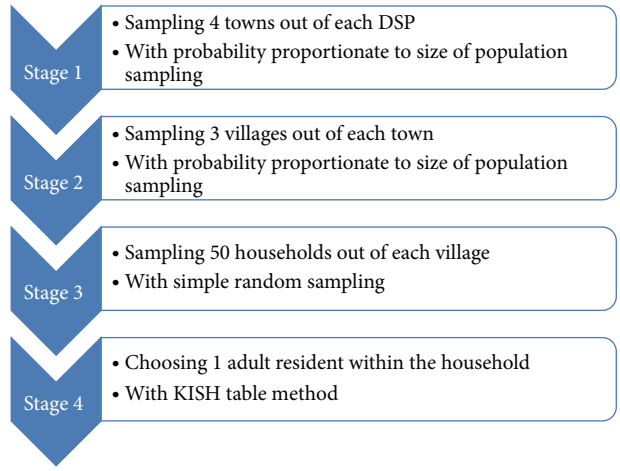

Figure 1: Sample assignment and sampling methods.

Educational Level Category. Illiterate or finishing primary education as "low," finishing university or above education as "high," all others as "medium."

Household Income Level Category. Lower than the Q_{25} of household income as "low," upper than the Q_{75} as "high," and all others as "medium."

2.5. Statistical Analysis. Survey responses were entered into EpiData3.1 with double-check method. All the analyses in this paper were performed with SPSS Statistics 19.0. Independent-samples t-test, one-way ANOVA, and Chi-square tests were used to compare differences in variables. The association was analyzed using logistic regression models, 0 for non-AT or no-disease, 1 for AT or disease, 0.05 for probability of entry, and 0.10 for removal. Statistical significance was considered when $P < 0.05$ (two sided).

3. Results

Females account for 54.7% of all the 8400 participants aged 18–94 (mean age: 52.5 years). AT respondents are significantly different to non-AT respondents in the composition of gender, age group, educational level, and household income level.

3.1. Prevalence, Frequency, and Duration of AT

3.1.1. Prevalence. The prevalence of AT was 49.6% (n = 4166) in general, while it was higher among females (52.8%), the middle-aged or the aged (57.0% for 55–64 age group and 55.3% for 65 or above age group), people of low or high educational level (53.0%), and people of low household income level (54.4%). Results of Chi-square test showed that, compared with non-AT respondents, AT respondents have lower percentages of inactive level of physical activity and higher percentages of active level of physical activity. There is no significant difference between urban residents (49.2%)

and rural residents (49.8%) on the prevalence of AT. The prevalence of AT among different groups of subjects was shown in Table 1.

3.1.2. Frequency and Duration of AT. For the 4166 subjects with AT, on average, they actively traveled for transport on 5.3 days per week, for 53.5 minutes per day, and 300.3 minutes per week. Males had more days (5.4) and longer duration (54.2 min/day, 308.6 min/week) of AT than those of females. Compared with rural residents, urban residents were more frequently on AT (5.5 days/week, $P < 0.01$) but with shorter daily duration (48.5 minutes, $P < 0.01$). On the whole, both daily duration and weekly duration of AT increased with age (59.9 min/day and 340.7 min/week for 65 or above age group). With the increase of household income level, AT also increased in frequency but with shorter duration. Daily and weekly duration of AT decreased with the increase of educational level as well (data not shown).

3.2. Health Outcomes Difference with AT

3.2.1. Health Outcomes Difference between AT and Non-AT Respondents. Compared with non-AT respondents, subjects with AT had a higher prevalence of central obesity, hypertension, and cholesterol disorder. Through further analysis of health indices, we found that the difference in the prevalence of hypertension mainly comes from SBP, while difference in the prevalence of cholesterol disorder is mainly from TC and HDL-C. Differences on prevalence of chronic disease and means of health indices between AT and non-AT respondents are shown in Table 2.

3.2.2. Health Outcomes/Indices with Frequency and Duration of AT. Among AT responds, the prevalence of hypertension and average level of WC increased with both frequency and daily duration of AT ($P < 0.05$). Meanwhile, the prevalence of cholesterol disorder and average level of SBP and HDL-C increased with daily duration of AT ($P < 0.05$). The prevalence of health outcomes/the mean level of health indices among different groups of AT frequency and AT duration were shown in Table 3.

3.3. Multinomial Analysis

3.3.1. Association between AT and Health Outcomes. Results of the logistic regression models show that, after being adjusted for age, gender, educational level, household income level, and overall physical activity level, the odds ratio (OR) of cholesterol disorder for AT respondents compared with non-AT respondents is 1.26 (95% C.I 1.13–1.41, $P < 0.01$). The association between central obesity/hypertension and AT disappeared after adjustment in the logistic regression models (see Table 4).

3.3.2. Association between Frequency, Daily Duration, Weekly Duration of AT, and Health Outcomes. Taking frequency and daily duration of AT into logistic regression simultaneously, results reveal that, among AT respondents, people who have AT 3–6 days per week have lower risk of diabetes than those who have AT every day (OR = 0.73, 95% CI 0.53–0.92, $P < 0.05$). Between people who have AT less than 30 minutes per day and people who have AT more than 60 minutes per day, the ORs of obesity, central obesity, and cholesterol disorder are 0.63 (95% CI 0.48–0.83, $P < 0.01$), 0.82 (95% CI 0.68–0.99, $P < 0.05$), and 0.68 (95% CI 0.56–0.82, $P < 0.01$), respectively (see Table 4). By analyzing urban residents and rural residents separately, we found that, among urban residents, less frequent AT was associated with lower prevalence of central obesity (OR = 0.66, $P < 0.05$), diabetes (OR = 0.57, $P < 0.05$), and cholesterol disorder (OR = 0.67, $P < 0.01$); shorter daily duration of AT was associated with lower prevalence of central obesity (OR = 0.67, $P < 0.01$), obesity (OR = 0.61, $P < 0.05$), and cholesterol disorder (OR = 0.61, $P < 0.01$) whereas, among rural residents, only shorter daily duration of AT was association with lower prevalence of obesity (OR = 0.66, $P < 0.05$) and cholesterol disorder (OR = 0.73, $P < 0.05$). No significant difference was found among different age groups.

Logistic regression results also show that, after adjustment, risks of listed chronic diseases increased with weekly duration of AT. Differences on obesity, central obesity, and cholesterol disorder were statistically significant (see Table 5).

Table 1: Characteristics of study participants (%).

	AT	Non-AT	Total
Gender*			
Male	41.72	48.82	45.30
Female	58.28	51.18	54.70
Residence			
Urban	35.45	35.97	35.71
Rural	64.55	64.03	64.29
Age*			
18–34	10.01	14.10	12.07
35–44	17.28	23.64	20.49
45–54	22.18	23.59	22.89
55–64	27.72	20.55	24.11
~65	22.80	18.12	20.44
Educational level*			
Low	51.15	44.71	47.90
Medium	42.22	49.50	45.89
High	6.63	5.79	6.20
Household income level*			
Low	41.67	35.16	38.42
Medium	32.82	34.84	33.83
High	25.51	30.01	27.75
Overall physical activity level*			
Inactive	7.42	21.15	13.28
Moderate	34.66	33.07	33.98
Active	57.92	45.78	52.74

*$P < 0.01$.

Table 2: Health indices/outcomes differences between AT and non-AT respondents.

	AT respondents			Non-AT respondents		
	Prevalence /mean	95% CI Lower	Upper	Prevalence /mean	95% CI Lower	Upper
Obesity (%)	13.88	12.83	14.93	13.40	12.38	14.43
Central obesity (%)**	42.95	41.44	44.45	40.79	39.31	42.27
Hypertension (%)*	50.97	49.45	52.49	47.34	45.84	48.85
Diabetes (%)	8.76	7.90	9.62	8.22	7.39	9.05
Cholesterol disorder (%)*	34.36	32.92	35.80	29.69	28.32	31.07
BMI (cm)	24.35	24.24	24.45	24.35	24.24	24.45
WC (cm)*	82.50	82.21	82.79	82.44	82.15	82.74
SBP (mmHg)*	139.21	138.53	139.88	137.66	136.98	138.34
DBP (mmHg)	84.83	84.49	85.18	84.92	84.58	85.27
FBG (mmol/L)	5.63	5.59	5.67	5.57	5.53	5.62
TC (mmol/L)*	4.37	4.33	4.40	4.49	4.46	4.52
HDL-C (mmol/L)*	1.32	1.31	1.33	1.38	1.36	1.39
LDL-C (mmol/L)	2.27	2.25	2.29	2.28	2.26	2.31
TG (mmol/L)	1.53	1.48	1.57	1.49	1.45	1.53

* $P < 0.01$; ** $P < 0.05$.

Table 3: Health outcomes/indices and frequency and duration of AT.

	Frequency (days/week)			Daily duration (minutes/day)		
	1-2	3–6	7	<30	30–60	>60
Obesity (%)	13.63	12.85	14.58	10.70	14.53	15.12
Central obesity (%)	41.43	41.08	44.50	41.09	42.32	44.68
Hypertension (%)*†	48.02	48.99	53.02	45.81	50.19	54.84
Diabetes (%)	7.61	7.21	10.03	7.34	9.50	8.86
Cholesterol disorder (%)†	31.38	33.81	35.55	29.66	35.01	36.50
BMI (cm)	24.11	24.31	24.44	24.06	24.43	24.44
WC (cm)*	81.96	82.07	82.92	81.67	82.59	82.91
SBP (mmHg)†	138.97	138.78	139.53	135.70	139.86	140.64
DBP (mmHg)	84.42	84.78	84.98	83.87	85.35	84.89
FBG (mmol/L)	5.55	5.53	5.72	5.60	5.62	5.66
TC (mmol/L)*	4.38	4.36	4.37	4.39	4.40	4.32
HDL-C (mmol/L)†	1.35	1.32	1.31	1.35	1.31	1.31
LDL-C (mmol/L)	2.22	2.25	2.30	2.26	2.30	2.25
TG (mmol/L)	1.44	1.42	1.61	1.48	1.55	1.53

* $P < 0.05$ between different groups of frequency; † $P < 0.05$ between different groups of daily duration.

4. Discussion

Against the background of people increasingly using passive transport, as much as 49.6% of subjects from different groups of age, educational level, and household income level were walking and/or bicycling in their daily transport, which illustrates that walking and bicycling are still one of the main modes of transport for Jiangsu residents. Additionally, data of average frequency (5.3 days/week), daily duration (53.5 minutes), weekly duration (300.3 minutes) of AT, and higher percentages of active level of physical activity among AT respondents demonstrate that AT contributes much toward physical activity, which is consistent with existing evidence about active travel [16, 17].

Although it is widely believed that, from a societal point of view, the shift from car to walking and bicycling may have beneficial health effects due to increased levels of physical activity and decreased air pollution emissions [18–22], in this research, we found that having AT is related with higher prevalence of cholesterol disorder. We also found that, higher frequency, longer daily duration, and weekly duration of AT were associated with chronic diseases, such as obesity, central obesity, and cholesterol disorder, even after adjustments for age, gender, educational level, household income level, and overall physical activity level. To exclude the possible confounding effect of diet and life style, we analyzed the consumption amount of oil (gram/per capita/day within households) and daily sedentary time of each subject; results

Table 4: Logistic regression results with AT and prevalence of health outcomes.

	Category	OR	95% CI	
			Lower	Upper
Obesity				
AT or Non-AT		1.04	0.90	1.21
Frequency (days/week)$	1-2	0.98	0.73	1.30
	3–6	0.88	0.71	1.10
	7			
Daily duration (minutes/day)#	<30*	0.63	0.48	0.83
	30–60	0.92	0.75	1.14
	>60			
Central obesity				
AT or Non-AT		0.98	0.88	1.09
Frequency (days/week)	1-2*	0.81	0.66	1.00
	3–6	0.87	0.74	1.01
	7			
Daily duration (minutes/day)	<30*	0.82	0.68	0.99
	30–60	0.91	0.78	1.06
	>60			
Hypertension				
AT or Non-AT		0.98	0.88	1.10
Frequency (days/week)	1-2	0.86	0.70	1.07
	3–6	0.91	0.78	1.07
	7			
Daily duration (minutes/day)	<30	0.87	0.72	1.06
	30–60	0.93	0.79	1.10
	>60			
Diabetes				
AT or Non-AT		1.04	0.86	1.25
Frequency (days/week)	1-2	0.72	0.50	1.04
	3–6*	0.70	0.53	0.92
	7			
Daily duration (minutes/day)	<30	0.93	0.67	1.30
	30–60	1.11	0.85	1.45
	>60			
Cholesterol disorder				
AT or Non-AT		1.26	1.13	1.41
Frequency (days/week)	1-2	0.81	0.66	1.00
	3–6	0.91	0.78	1.06
	7			
Daily duration (minutes/day)	<30*	0.68	0.56	0.82
	30–60	0.91	0.78	1.06
	>60			

(1) All adjusted by age, gender, educational level, household income level, and overall physical activity level.
(2) Probability for entry 0.05, for removal 0.10.
(3) 0 for non-AT or nodisease, 1 for AT or disease.
(4) $Taking "7 days/week" as control; #taking ">60 min/day" as control.
(5) $^{*}P < 0.05$.

Table 5: Logistic regression results with AT weekly duration and health outcomes.

Weekly duration (minutes/week)$	OR	95% CI	
		Lower	Upper
Obesity			
<105*	0.72	0.54	0.95
105–420*	0.79	0.63	0.99
>420			
Central obesity			
<105*	0.76	0.62	0.94
105–420	0.85	0.72	1
>420			
Hypertension			
<105	0.83	0.68	1.03
105–420	0.87	0.73	1.03
>420			
Diabetes			
<105	0.75	0.53	1.06
105–420	0.9	0.69	1.19
>420			
Cholesterol disorder			
<105*	0.64	0.52	0.79
105–420	0.86	0.73	1.01
>420			

(1) All adjusted by age, gender, educational level, household income level, and overall physical activity level.
(2) Probability for entry 0.05, for removal 0.10.
(3) 0 for non-AT or nodisease, 1 for AT or disease.
(4) $Taking ">420" as control.
(5) $^{*}P < 0.05$.

showed that AT respondents intake less oil ($d = 0.9$ gram, $P < 0.01$) and have shorter sedentary time ($d = 22$ minutes, $P < 0.01$) compared with non-AT respondents. Yet, we have no idea whether there is any other diet pattern or behavior among AT respondents which may affect the metabolism of fat.

Although there were some studies reported that walking or bicycling is not associated with benefit on health indices or body fitness before [23, 24], this finding runs counter to nearly all previous research, except that Hu et al. found that commuting or leisure-time physical activity was inversely related to mean BMI and the highest mean blood pressure in a cross-sectional survey [25]. Jiangsu Province of China is at a stage of fast economic development and transition. Thus, it is allocated increasingly more financial and material resources to the building of motor-vehicle-oriented transport infrastructure in the province. However, this consistently reduces space left for pedestrians and riders. It is supposed that the health effect of AT could be undermined by negative side effects of AT, such as more absorption of polluted air, and stress and tension from unsafe road conditions [26, 27]. In this study, we found that AT influences more health aspects among urban residents than among rural residents. Further information is needed concerning whether this is related to

possible pressure from the more complex traffic situation in cities.

Although the underlying reason for this inverse correlation needs further study, this research highlights the need for the decision to promote AT to be discussed in depth from the health-related aspect. Jiangsu Province is a typical area with fast economic development and a big population; therefore, the research findings will be readily applicable to other similar areas.

For limitations of this research, walking and bicycling were not distinguished, which may induce confoundation in the health effect, because it is reported that health effects of walking and bicycling are not identical for their different intensities [28]. Traditional bicycling and electric bicycling were measured together as well. At present, there is little evidence on the health effect difference between traditional and electric bicycling, though electric bikes shoot up and by far compose slightly less than half of the entire bicycle population in China [29]. Moreover, some of these differences are close, though these results are statistically different. Clinical meaning of these differences needs further discussion as well.

5. Conclusions

Walking and bicycling are still the main modes of transport for Jiangsu residents and they contribute much toward physical activity. The findings of this study did not support the notion that AT is beneficial to health at a population level. Further research is needed in determining the negative side effects of AT.

Conflict of Interests

The authors have declared that no conflict of interests exists.

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Research Article

A Pilot Study of Increasing Nonpurposeful Movement Breaks at Work as a Means of Reducing Prolonged Sitting

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There is a plethora of workplace physical activity interventions designed to increase purposeful movement, yet few are designed to alleviate prolonged occupational sitting time. A pilot study was conducted to test the feasibility of a workplace e-health intervention based on a passive approach to increase nonpurposeful movement as a means of reducing sitting time. The study was trialled in a professional workplace with forty-six participants (33 females and 13 males) for a period of twenty-six weeks. Participants in the first thirteen weeks received a passive prompt every 45 minutes on their computer screen reminding them to stand and engage in nonpurposeful activity throughout their workday. After thirteen weeks, the prompt was disabled, and participants were then free to voluntary engage the software. Results demonstrated that when employees were exposed to a passive prompt, as opposed to an active prompt, they were five times more likely to fully adhere to completing a movement break every hour of the workday. Based on this pilot study, we suggest that the notion that people are willing to participate in a coercive workplace e-health intervention is promising, and there is a need for further investigation.

1. Introduction

Increasing purposeful, or voluntary, physical activity both during leisure and work time is advocated as a means of reducing the risk of cardiovascular disease (CVD) [1–3]. In response workplace physical activity interventions have been designed to increase participation in purposeful physical activity programs during scheduled breaks in work time [4]. Yet the effectiveness of such interventions is mixed because of problems with sustainability and adherence [5]. Moreover, it appears that an increase in purposeful physical activity does not alleviate the CVD risk associated with prolonged periods of sitting (>4 hrs) [6–11]. Changes to the built environment, such as increases in technology, have resulted in prolonged occupational sitting time in excess of 6 hours [12], with concomitant decreases in energy expenditure for desk-based workers (>300 calories/per/day) [13, 14]. Guidelines for increasing cardiorespiratory fitness have changed over the years to reflect a growing understanding of the role of dose and frequency [15]. Recent evidence suggests short bouts of physical activity both purposeful and nonpurposeful (i.e., chores, standing up) are positively associated with cardiorespiratory fitness [15] and may buffer against issues of adherence to workplace health and wellbeing programs [4]. Moreover increasing nonpurposeful activity as part of an intervention may also ameliorate the health risks posed by prolonged sitting.

Research shows that short bursts of physical activity (<10 minutes) result in a reduction of CVD risk factors [16, 17]. For example, a cross-sectional analysis of the Framingham Heart Study Third Generation participants showed that accruing physical activity bouts of <10 minutes resulted in favourable changes to CVD risk [17]. There is evidence of the feasibility of these results being transferred to workplace interventions. For example, successful interventions may include a 10-minute flexibility and strength program [18], a single 10-minute bout of physical activity [19], mixed program for 30 minutes [20], or group physical activity classes [4]. Moreover, it appears that sustainability and adherence rates may be superior to those reported for purpose-based exercise interventions. In one study, average monthly attendance ranged from 76 to 86 percent over six months [4]. Given these results it would appear that short bursts of nonpurposeful activity may be suitable for worksites interventions.

Purposeful activities are effective in improving cardiorespiratory fitness, but increases may not ameliorate the risks associated with prolonged sitting because the activities only occur once a day [21], and the seated position needs to be regularly interrupted throughout the day. A number of studies have shown that regularly breaking a seated position results in positive changes to glucose and lipid profiles [16], lipoprotein lipase [22], and metabolic risk [23]. Consequently, there is support for an increase in nonpurposeful movement into desk-based work [14, 24, 25]. One strategy for increasing nonpurposeful activity is changing the built environment by including ergonomic equipment that affords movement [13, 14]. In one study [26] middle-aged men who were either overweight or obese participated in three separate daily sitting schedules with a break of six days between each of the days. In the first trial condition, each participant sat for five hours with no break. In the second experiment, they walked on a treadmill desk at a light-intensity pace for two minutes every 20 minutes, and in the third trial condition they walked on a treadmill desk at moderate-intensity pace for 2 minutes every 20 minutes. Results revealed that light-intensity movement, such as standing up and moving regularly throughout the workday yielded health benefits. Nonetheless, despite promising results there is little data to suggest that installation of treadmill desks will result in people changing their prolonged sitting periods because their use reflects planned behaviour, and subsequently such a strategy may suffer from the same problems as other purposive movement interventions. Moreover, sitting for desk-based work reflects a habit rather than a planned behaviour, and therefore interventions may be better informed by theory of habits [27].

Sitting for desk-based work is a habit because it is a learned act that is automatically performed in the presence of situational cues [27, 28]. Initially, the decision to sit at work is likely to be under the control of constructs as described by the theory of planned behaviour [29]. Within the workplace employees are faced with a limited choice of built environment (i.e., chairs and fixed height desks), prevailing workplace attitudes towards what is required to complete the daily tasks, and social pressures to sit while working. These factors are likely to create a perception that one has little control to execute an alternative to sitting [30]. Nonetheless, developing a new habit is more complex than substituting a new behaviour for the existing behaviour, especially if the behaviour is complex such as those that require multiple decisions to be made in short periods of time.

Sitting for desk-based workers is a complex behaviour because it typically involves more than one action. For example, the worker has to turn on the computer, select an appropriate chair, acquire the necessary equipment for a job task on the desk, complete multiple tasks within short time frames, and decide upon the sequence of these tasks. The sequence of behaviours could be described as a habitual pattern [31], but it may contain semiautomatic responses [32, 33] or behavioural scripts [34], which require some level of conscious thought. Yet preexisting habits may cause a breakdown of the intention-behaviour relationship by overriding the intention to perform an alternative behaviour [27]. When an individual intends to perform a new behaviour but engages in an old behaviour it is described as a slip or action switch and is evidence of a strong habit intrusion [35]. The performance of counter-habitual goal-directed actions (e.g., standing while taking a telephone call instead of sitting) requires conscious attention to interrupt the habit. If attentional resources are absorbed by other tasks and the intention to perform an alternative course of action is not capable of "over-ruling" the activation of a habitual programme [35–37], an action slip may result. For example, a desk-based worker under a high stress load because of attending to multiple tasks in a short time frame may find that when the phone rings, rather than stand as they have been instructed to do to break prolonged occupational sitting time (alternative course of action) they find themselves maintaining the old habit of sitting. The issue for interventions designed to break prolonged sitting is how to increase the odds of people performing an alternative behaviour.

One mechanism for counteracting the effect of an existing habit on a new habit is through the use of prompts at the point of decision [27, 28, 38]. Prompts at points of decision include a wide range of mechanisms including signs, emails, text messages, or telephone calls [39]. The rationale is the prompt presents a situation whereby the individual is able to reevaluate behavioural choices [38]. There is research that supports the efficacy of prompts to help people decide to participate in alternative health behaviour. These changes typically involve the use of electronic prompts and reminders to encourage people to engage in a particular behaviour [40]. For example, one study showed that a simple message at the point of decision extoling the health benefits of taking the stairs over the escalator resulted in an increase in stair use over baseline measures [38]. In terms of the efficacy of prompting to change prolonged sitting one study [41] showed that participants who received a computer-based prompt significantly reduced their sitting times compared to their counterparts who received education only about the health effects associated with prolonged sitting. Nonetheless, the effect was observed only over a 5-day period within a clinically controlled environment.

Despite the promising results for interventions to reduce prolonged sitting thus far, there are some limitations to consider. Changes to the built environment, such as having workers use treadmill desks, may result in an increase in work errors [42]. Second, the assessment of efficacy of ergonomic posture equipment is restricted to clinical studies, with no data available from field-based research to provide an understanding of how such changes to the built environment might work or be implemented in a workplace. Thus the applicability and sustainability of such equipment in workplaces to break prolonged sitting is unknown. Moreover, the financial costs associated with ergonomic workplace equipment may be prohibitive to small organisations. Finally, the efficacy of prompts is also mixed, with numerous variables influencing their effectiveness [39, 43]. Further, no field studies have reported the sustainability of such an intervention to break prolonged sitting in the workplace.

Although prompts at points of decision alert individuals about alternative behaviours, the individual can either consciously or unconsciously (i.e., action slip) ignore the prompt. This is a common occurrence in other health habits such as

seat-belt wearing [44] and cell phone use while driving a car [45]. Thus, strategies should go beyond the usual range of education, rehabilitation, punishment, reward, and disincentive schemes to change individual attitude and belief about health behaviour [32] and environmental modifications to achieve significant behavioural changes among the target population [46]. We believe that it is timely to revisit some of the notions within a communitarian model of health promotion [47–49], in particular the active-passive approach for individual behaviour and preventative health interventions. Within this model when individuals voluntarily performing a preventative health action (e.g., regularly breaking sitting posture during the workday) it is considered an active prevention strategy. Thus, only individuals who choose to engage in the behaviour would gain the protective health benefit associated with that of regular standing, whereas passive prevention strategies remove some or all of the decision making process from the individual (e.g., only having water available in the drink machines). To assess this model we utilised a workplace e-health program that allowed us to manipulate the delivery of passive and active prompts in an effort to have desk-based employees engage in nonpurposeful movements throughout the workday as a means of reducing their prolonged occupational sitting time.

For health interventions there are a number of benefits in adopting a more passive approach. Health interventions that are passive have higher compliance levels and therefore greater efficiencies [44, 49–53]. Of note is the use of persuasive systems, which are computerised software systems designed to change or shape attitudes or behaviours [52, 53]. Noncoercive [52] and coercive [53] persuasive systems have been successful in changing health behaviours. Given the less than successful outcomes of purposeful physical activity interventions in the workplace which have relied on an active approach to preventive health [5], we hoped to learn if desk-based employees would tolerate a coercive, passive-prompting e-health intervention. We were also interested in differences between passive-based and active-based prompts for maintaining adherence to the health behaviour designed to increase nonpurposeful movement throughout the workday. We hypothesised that a passive prompt, compared to an active prompt, would significantly increase the odds of participants complying with seven periods of non-purposive movement during a workday. Noncompliance to the prompting conditions was defined as recording between one and six activities per workday. This number was based on the maximum number of prompts that a participant could receive during an eight-hour shift with a one-hour lunch break.

2. Methods

2.1. Sample. Participants were randomly selected from approximately 460 desk-based employees to take part in a field-based, sequential intervention study within a professional workplace across multiple sites (Project PAUSE). Given the lack of previous studies to guide power analysis and the pilot nature of this study, we chose a relative wide precision estimate of 28% with 95% confidence intervals, which indicated that a sample size of 50 was needed. Participants were randomly recruited through a computerised random draw. Eligibility criteria for inclusion into the study were (a) full-time desk-based employment, (b) clear of any medical health issues, and (c) daily desktop computer access to the internet.

In terms of the sample frame, the organisation's full-time desk-based workers were largely composed of females (67%); so, for parsimony, we chose a 1/3 split for our sample. Four participants withdrew from the study because of personal reasons two days before the induction and were not replaced, as replacements could not attend the induction at short notice. So the study proceeded with a reduced sample ($N = 46$). Participants had a range of work roles including receptionists, forensic analysis, administrative support, call center, sworn duties, and media/community liaison. Approximately 80 percent of participants worked in urban-based offices. Workplace configurations included open plan worksites, single offices, and shared office spaces. All participants completed the Exercise Stages of Change questionnaire [54], which assesses individual motivation to participate in exercise. Participants (females = 33, male = 13) all reported being in one of the first three stages of exercise participation (i.e., precontemplation (23%), contemplation (58%), or preparation (19%)), with no participant indicating that they had started or had been involved in a regular exercise program for the previous six months. Before data collection participants provided informed consent in accordance with granted university ethics committee procedures (H10875). Demographic characteristics of the sample are presented in Table 1.

2.2. Procedures. All participants first attended an induction session to inform them about the protocol of the study. The sequence of the session was the collection of demographic baseline data (30 minutes), an educational session on the negative health effects associated with prolonged sitting (15 minutes), general instructions on the recommended dose of movement to alleviate the adverse effects of prolonged sitting (20 minutes), and an informational session on using the e-health software (30 minutes). Participants were instructed that the length of the study would be 26 weeks and were reminded that their involvement in the study was strictly voluntary and they could withdraw at any time. At the completion of this induction session, all participants had the e-health software installed onto their computers. Participants were not blinded to other participants' involvement because of the nature of some worksites, and all attended the one induction session.

2.3. Intervention. The intervention was an e-health software program designed to passively prompt employees to break prolonged sitting periods by increasing nonpurposeful workday movement. The software has two distinct phases. It contains a set timed prompt that reminds employees to break their sitting time by engaging in nonpurposeful movement throughout the workday. The software provides employees a choice of 60 office-appropriate activities (i.e., walking, taking the stairs, and retrieving the photocopies). As the aim of the intervention was to increase nonpurposeful movement during the workday, participants were free to choose the

Table 1: Demographic characteristics of the sample. Values are means standard deviations.

Variable	Before	After
Age (years)		
Female	41.53 (12.1)	
Male	46.10 (6.3)	
Height (cm)		
Female	164.61 (6.74)	
Male	176.76 (6.85)	
Weight (kg)		
Female	71.91 (13.45)	70.87 (11.88)
Male	96.31 (17.96)	95.46 (17.28)
BMI		
Female	26.55 (4.36)	26.19 (3.96)
Male	30.81 (5.17)	30.52 (4.90)

activity, duration, and intensity. This e-health program was tested through passive and active prompting strategies.

2.4. Passive Prompt Condition. The passive prompting condition was initiated during the first 13 weeks of the study. During this period, participants were exposed to a prompt that did not allow them to ignore the request to engage in the recommended behaviour. This was achieved through two mechanisms that were occurred in the following sequence. First, a small icon appeared on the taskbar. After 45 minutes the small icon automatically enlarged into a coloured pop-up prompt (5 cm × 3 cm) onto the bottom right hand side of participants' screens. The prompt contained a message alerting participants that the movement sequence was about to start (Figure 1).

Second, after the prompt appeared, a countdown clock started, and after 60 seconds, participants' screens were deactivated, and a cover screen appeared revealing the e-health software interface. At this point of decision, participants could select to complete a movement activity. Participants had freedom of choice over which activity to perform and the frequency or duration of participation. When participants completed their chosen activities, they were then prompted to record their progress. These activities were time stamped and stored on a remote server so that we were able to calculate the total number of logged activities for each day. Logged activities served as our dependent variable of compliance. Once data were recorded, the sequence terminated, and the participants regained access to their original computer screen at the point of deactivation. The prompt would then reinitiate after 45 minutes.

The dependent variable was determined by calculating the total number of days with seven or more logged activities and the total number of days with one to six logged activities. We set the criteria for compliance at seven or more activities per day because this indicated that participants were regularly breaking their prolonged sitting every hour as indicated by the Australian national guidelines [55]. We excluded days where no activity was logged because this may have reflected

Figure 1: Prompting message seen by participants on their computer screens.

that the participant was out of their office, on leave, or working at other worksites with no computer. As this was a self-report measure, participants received a phone call from the researchers once throughout the study period to remind participants about the necessity to accurately report their activities.

2.5. Active Prompted Condition. After 13 weeks of the passive prompting condition, the researchers disabled the timed prompt for a further 13-week period. During this phase, if the participants wanted to engage with the e-health software, they needed to do so under their own volition. Participants could still view the icon on their taskbar and could still use the e-health software but had to voluntarily initiate the program by clicking on the icon. Once voluntarily initiated, the sequence remained the same as that for the passive prompting condition, and the dependent variable of logged activity frequency to determine compliance was used in the same manner.

2.6. Data Analysis. Using commercially available software [56] odds within conditions (compliance/noncompliance), odds ratio (OR), and 95 percent confidence intervals for the OR were generated using a 2 (compliance/noncompliance) × 2 (passive prompt/active prompt) contingency table. For each prompt condition, total number of days compliant and noncompliant for the 26-week experimental period were calculated and used as the frequency measure. A test of the hypothesis (OR = 1) was assessed using a chi-square statistic.

3. Results

All participants ($N = 46$) maintained the software on their desktop computers for the 26 weeks of the study and recorded activities through the study. Participants recorded a total of 2893 days out of a possible 5980 days where at least one activity was logged for the day across the 26-week study period. Participants recorded using a wide variety of movement-based activities, with the most popular activities being stair climbing, walking, and chair squats. Most days of recorded activity (Table 2) were associated with the passive prompted condition ($n = 2321$ days). Similarly, the highest number of activities recorded for a day by an individual was 23 in the passive prompt condition compared to 16 activities for the active prompt condition. For the passive prompt

Table 2: Total number of days for compliance and noncompliance in each prompt condition.

	Passive prompt	Active prompt
Compliance	1216	108
Noncompliance	1104	465

condition, nine activities in a day were the most frequent count (12%) compared to one logged activity per day for the active condition (37%).

In terms of each prompting condition, results showed that odds of compliance were greater in the passive condition (Odds = 1.1) compared to the active condition (Odds = 0.23). In terms of comparing the two conditions, a passive prompt improved the odds of desk-based workers complying to participate in nonpurposeful movement every hour seven times a day nearly five times more compared to the active condition (OR = 4.78, 95%CI = 3.78–5.93, and $P < 0.05$). Therefore, participants who were automatically reminded and forced to make a decision about moving were significantly more likely to engage in nonpurposeful physical activity seven times a day compared to when they were left to spontaneously stand throughout the workday on their own accord.

4. Discussion

The first finding of this study was that the employees in our sample were willing to accept a passive-based workplace e-health intervention [48] that was predicated on the principles of introducing nonpurposeful movement. No participant withdrew from the study during the 26-week study, although not all participants achieved our rigid criteria of full compliance by completing seven nonpurposeful movement breaks throughout the workday. Given that CVD is a major health issue [1–3] and the widening of guidelines for physical activity dose and frequency [15], these results are encouraging. Adherence to purposeful physical activity intervention are a constant problem. One cause of low adherence and compliance rates is some recruits to purposeful-based physical activity interventions cannot meet the high dose and frequency rates set for increases in cardiorespiratory fitness because of a variety of factors. Our results give an indication that people who do not exercise regularly and are willing and capable of increasing nonpurposeful movement activities that were associated with their work if regularly prompted to do so. Given the number of people who are not regularly participating in purposeful physical activity [5], CVD risk could be somewhat addressed through workplace physical activity interventions based on increasing compulsory nonpurposeful movement.

Our second finding was the enhanced benefit of using a passive prompt compared to an active prompt to achieve increase adherence to new health behaviour. A workplace e-health intervention underpinned by a passive prompt increased compliance by nearly five times to increasing nonpurposeful movement during the workday compared to when employees were left to their own free will to comply with the intervention. Within the context of passive versus active approaches to interventions [48] we believe this is the first field-based report of desk-based employees accepting a coercive persuasive system within a preventative health intervention designed to increase nonpurposeful movement at work. Given the low compliance rates for the active condition, which occurred after the passive condition for all participants, it could be assumed that the new behaviour of participating in hourly nonpurposeful movement had not become habitual. Despite the best intentions of health professionals, interventions designed to increase purposeful activity (e.g., walking, running, and strength training) have returned mixed results [5]. Our results provide preliminary evidence for the use of coercive persuasive systems to ameliorate low compliance rates may work with other health preventative initiatives.

Finally, the compliance results in the active condition, which followed the passive condition for all participants in our sample, highlight issues with sustainability of workplace physical activity-based interventions. The difficulty health professionals have in establishing new behaviours is well documented in the literature [57]. It would appear that 13 weeks of exposure to a coercive prompt is insufficient time to establish the nonpurposeful movement as a new behaviour. Sitting at work is a complex behaviour that involves many subroutines, and thus longer periods of exposure to the passive prompt may be needed to develop the new habit of regularly breaking sitting posture to move. Or as others have [58] argued, an insistent and obtrusive reminder might well be effective in the short run, but the effect reduces significantly over time. We would advocate that future research investigates a multiple strategy approach for changing workplace health behaviours to include changes to the built environment, such as treadmill or standing desks, coupled with a passive prompt to encourage workers to become less sedentary during the workday.

Our results have several possible implications. Coercing people to comply with health recommendations has the potential to reduce wastage of personal and monetary resources, help improve the efficacy of health and wellbeing interventions, and, most importantly, potentially reduce mortality and morbidity associated with preventable diseases such as CVD. Yet, the palatability of using passive approaches for individual preventative health interventions, such as increasing physical activity levels, has yet to be fully tested by researchers. Further, to date, despite the widespread knowledge of the effect of base levels of exercise (e.g., walking 30 minutes per day) on health and wellbeing, health researchers lament the low adherence rates within the population to recommended dose levels yet remain largely silent and inactive in recommending and prescribing nonpurposeful movement as an alternative or an adjunct strategy.

Nonetheless, there were several limitations to this study. This was a pilot study to test the feasibility of the e-health software and the efficacy of applying a passive persuasive system to a workplace e-health intervention. We did not measure habit strength and thus are unable to determine if participants' nonpurposeful movement habits had fully developed by the end of passive prompt condition. Hence, the

poor compliance rates during the active condition may reflect that the behaviour had not become habitual. Second, in the active condition, the small number of reports for both compliance and noncompliance may lead to an under-estimation and hence alter the final odds ratio calculation. Third, we are unable to establish if participants may have chosen to simply stand to break their sitting time and elected not to complete a period of nonpurposeful activity in either condition. Finally, the measure of compliance was based on self-report. It is possible that participants simply became annoyed with the prompts or software and chose to record a false activity or no activity because of time and work pressure. Follow-up studies should incorporate a larger sample size and use more direct measures of compliance, such as accelerometers, in conjunction with e-health, passive-prompting software programs. Moreover, there is scope to determine the saliency of the coercive approach with other health behaviours.

5. Conclusion

Results from this study found that desk-based workers who received information about the health effects of prolonged sitting and who subsequently participated in a workplace e-health intervention based on a passive approach model had significantly higher compliance levels to participate in non-purposeful movement compared to voluntary engagement in the same program. Further research is needed to rigorously test the efficacy of a such an approach in terms of sustainability, as well as what conditions employees are willing to be coerced into changing their health behaviours while at work. We plan to conduct further studies on a larger sample of desk-based workers across multiple worksites to help understand how health can be positively influenced within the workplace in an effort to reduce the risks associated with CVD.

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Research Article

A Combined Impact-Process Evaluation of a Program Promoting Active Transport to School: Understanding the Factors That Shaped Program Effectiveness

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This mixed methods study was a comprehensive impact-process evaluation of the Ride2School program in metropolitan and regional areas in Victoria, Australia. The program aimed to promote transport to school for primary school children. Qualitative and quantitative data were collected at baseline and followup from two primary schools involved in the pilot phase of the program and two matched comparison schools, and a further 13 primary schools that participated in the implementation phase of the program. Classroom surveys, structured and unstructured observations, and interviews with Ride2School program staff were used to evaluate the pilot program. For the 13 schools in the second phase of the program, parents and students completed questionnaires at baseline ($N = 889$) and followup ($N = 761$). Based on the quantitative data, there was little evidence of an overall increase in active transport to school across participating schools, although impacts varied among individual schools. Qualitative data in the form of observations, interviews, and focus group discussions with students, school staff, and program staff provided insight into the reasons for variable program impacts. This paper highlights the benefits of undertaking a mixed methods approach to evaluating active transport to school programs that enables both measurement and understanding of program impacts.

1. Introduction

Over the last 30 years, rates of children walking and cycling to school in Australia have declined substantially [1–3]. This has been accompanied by increasing rates of children being driven to and from school [4]. Factors such as the built environment making active transport modes difficult, a culture of car dependence [5], concerns about personal safety and traffic danger among parents [6, 7], and an increase in parents' working hours [4, 8] have contributed to this trend. These trends at the social, cultural, environmental, and economic levels have been linked to a decrease in physical activity [9] and an increase in overweight and obesity among Australian children [10]. While Australian data are not available at the national level, comparative international data show an inverse association between active transport and childhood obesity [11]. There is also consistent evidence of multiple benefits (e.g., health, environment, and community liveability) of active transport for young people [12–15].

Until relatively recently, programs to promote physical activity among children focused on structured exercise programs, sport, and formal physical education in schools [16]. The promotion of active transport to school is relatively recent. Evidence reviews indicate that some, but not all, programs achieve small-to-moderate increases in rates of active transport to school [17–21]. Variable program impacts occur both between programs and for individual schools within multisite programs.

Some more recent evaluations have been reported in Australia and New Zealand. The Central Sydney Walk to School Research Program, which comprised a randomised controlled trial involving 24 government primary schools in

inner suburban Sydney, reported inconsistent evidence of an impact on students' walking trips to and from school. Parent-reported data showed an increase in students' walking trips, but student-reported data showed no significant changes [22]. Evaluation of the Brisbane Active School Travel (AST) program, delivered by the Brisbane City Council, reported a 24.8-percentage point increase in active travel mode share *to* school and an 18.1-percentage point increase in active travel mode share *from* school across the 13 primary schools that participated in the 2008 AST program. Walking trips to school increased by 19.1-percentage points (from 19.0% to 38.1%) and cycling trips by 3.1-percentage points (from 3.9% to 7.0%) [23]. In New Zealand, the Auckland Regional Transport Authority's 2007 School Travel Plan evaluation, based on "roll call" data collected from 35,153 students across 68 primary and secondary schools, reported a reduction in travel by "family car" of 3.4-percentage points and a 2.4-percentage point increase in walking and cycling [24].

Much of this evaluation literature is relatively recent, and there has been little systematic assessment of the reasons for variable program impacts. Implementing active transport to school initiatives and assessing their effectiveness in participating schools are important, but it is also important to examine the program and contextual factors that shape the effectiveness of interventions. This study aimed to increase the impact of the Ride2School program in a number of school communities.

2. Methods

2.1. The Ride2School Program. The Ride2School program was conducted by Bicycle Network Victoria (a charitable institution that promotes and advocates for cycling throughout Victoria and Australia). From 2006 to 2010, the Ride2School program received $4 million funding from the Department for Victorian Communities, the Department of Human Services, the Victorian Health Promotion Foundation (VicHealth), Diabetes Australia-Victoria, and the Victorian Roads Authority (VicRoads). This study involved the first two years of the program (from 2006 to 2007).

The Ride2School program aimed at increasing the number of children using active transport to school, principally through behaviour change measures [25]. The program promoted walking and "wheeling" (cycling, scooter/skate) to school, but, in practice, placed greater emphasis on cycling.

The Ride2School program was implemented in two main phases. In the initial pilot phase, three schools were offered a number of program activities (e.g., participation in Ride2School Day, mapping of safe routes to school, and classroom surveys to track active transport rates), as well as infrastructure improvements funded through the program (e.g., bicycle storage funding and, for one of the pilot schools, raised pedestrian crossings). The second phase of the program involved customised advice, support, and resources for 13 participating schools which self-selected to join the program. For approximately nine to 12 months in the pilot schools and six months in the program schools, participating schools were given guidance and hands-on support from one of two Ride2School Coordinators to assist with the planning and promotion of the program within the school. Program schools were offered similar program activities as in the pilot program, but without the infrastructure components. Key activities included three cycling and active transport events (Ride2School Day, Walk and Wheel-a-thon, and 500-kilometre Gold Medal Challenge); mapping quiet neighbourhood routes to school; a website; monthly email newsletter; and incentives (e.g., 1000 Bikes Student Leadership Rewards). Not all activities were implemented in all participating schools. Schools were able to choose the activities they would participate in based on the time, resources, and interest they had to commit to the program. There was no minimum number of activities that schools were strictly required to implement; however they were encouraged to participate in all activities. Phase 1 of the Ride2School program focused on grades 5 to 6 students, and this was expanded to include grade 4 students in Phase 2.

Deakin University was contracted to undertake an external evaluation of the Ride2School program, and the authors were members of the Deakin University evaluation team. The findings reported here were for two schools involved in the pilot program ("pilot" schools) and 13 schools involved in the second phase of the program ("program" schools). Two comparison schools were matched to the pilot schools. The schools were all government, coeducational primary schools located in metropolitan or regional areas of Victoria. Ethical approval for the study was obtained from Deakin University Human Research Ethics Committee and the Victorian Department of Education and Early Childhood Development.

2.2. Evaluation Design. This was a mixed methods study using a sequential explanatory design [26] to assess the implementation and effectiveness of the Ride2School program. The study was quantitatively driven with a quantitative core design and analytic methods and a qualitative sequential component to provide insight into the quantitative findings [26, 27]. This design allows for the measurement and interpretation of program impacts [26]. The impact evaluation component of the study used primarily quantitative data collection methods and analysis to measure program impacts. The process evaluation component of the study used primarily qualitative data collection methods and analysis to (i) describe and analyse key aspects of the program's implementation, and (ii) provide insights and understanding of program impacts.

2.3. Phase 1: Pilot Schools

2.3.1. Study Design. A controlled pre-post design was used to measure the impacts of the program on two of the three pilot schools that joined the program in July 2006. Two comparison schools were matched to the intervention schools based on school type (i.e., government coeducational schools), size, location (distance from pilot school), and sociodemographic characteristics. One pilot school and its comparison school were located in established, neighbouring

suburbs, approximately 2 km apart and approximately 7 km from Melbourne's central business district (CBD) (inner suburban). The second pilot school and its comparison school were located 2 km apart in the same suburb, in a new, rapidly growing housing estate approximately 22 km from the CBD (outer suburban). Ensuring the matched schools were a short distance apart meant that the schools shared area-level similarities that impact on active transport such as street design features, population density, and access to public transport.

2.3.2. Data Collection Measures and Procedures. The main data collection methods in the pilot phase of the study were (i) direct observation of active transport modes to school and counts of bicycles and scooters on school premises, (ii) classroom Hands Up! surveys, and (iii) qualitative interviews with Ride2School program staff. No Ride2School events (e.g., Ride2School Day) were conducted on the days when data were collected at the four schools.

Observational counts were conducted at each of the four schools at baseline (July 2006) and followup (August 2007). An observational checklist was developed based on a number of previously developed instruments [28, 29] and on program objectives. The checklist included the number of students using each active transport mode (walking, cycling, scooting, and skating), gender, time of day, and who the student was traveling with. The checklist also included a section for counts of the number of bicycles and scooters located in the school grounds. Observations were conducted at each of the schools between 8 am and 9:15 am (school started at 9 am). A team of observers were positioned near each of the school entrances to observe the travel modes of students arriving at the school and were positioned so they could distinguish between children walking from home and walking from a car (only the former were recorded as "walking"). The weather was similar for all data collection days (cool with no rain).

Hands Up! classroom surveys of grades 5 and 6 students at each of the pilot schools and comparison schools were used to collect information about students' modes of travel to school on the day of the survey and the previous four school days. The surveys were conducted by classroom teachers. The classroom survey was developed based on a previously developed instrument [29] and on program objectives.

Qualitative data were collected with the Ride2School Coordinator working directly with the pilot schools program. The Coordinator participated in face-to-face or telephone interviews each month for the duration of the program and six months after the program, to provide information on how the program was progressing in each school, the supports and barriers to implementing the program in each school, and how barriers were being overcome.

2.3.3. Data Analysis. For the observational data, proportions of students using active modes of travel to school (walking, cycling, and scooter/skating) were calculated based on school enrolment data. Differences between proportions in travel modes were calculated using z-ratio computations. Chi-square tests of significance were used to determine differences between demographic variables. Because three different data collection methods were piloted (each with advantages and limitations), the overall pattern of findings was used as a form of "data triangulation" to make judgments about program impacts.

2.4. Phase 2: Program Schools

2.4.1. Study Design. Thirteen program schools participated in Phase 2 of the study which was an uncontrolled pre-post design. Attempts to recruit a sufficient number of matched comparison schools within the time constraints (i.e., before implementation of the program commenced) were unsuccessful. Three schools invited to participate as comparison schools subsequently joined the Ride2School program as program schools, forming part of the evaluation. Schools that declined to participate cited lack of time and frequent requests for other data collection in schools as reasons for not wishing to participate. Therefore, comparison schools were not included in this phase of the study. Of the 13 program schools, nine schools were located in regional areas of Victoria, and four were located in metropolitan Melbourne. Government primary schools in Victoria with an interest in promoting active transport were eligible to apply to be involved in the program. Being located in an area of disadvantage was also beneficial to schools applying, but not compulsory, and the 13 schools included schools from both disadvantaged and more advantaged areas.

2.4.2. Data Collection Methods and Procedures. The main data collection methods in this phase of the study were: (i) parent and student surveys, (ii) interviews with principals and Ride2School Coordinators, and (iii) focus group discussions with teachers and students.

Parents of all grades 4, 5, and 6 students were invited, via an information package sent home with students, to participate in a written survey about their child's travel to school behaviour and parents' attitudes to school travel modes. All students in grades 4, 5, and 6 were invited to participate in a written survey of how they traveled to and from school on the day of the survey and for the previous four days and about their attitudes to different ways of traveling to and from school. Written parental consent was required for student participation. The student surveys were administered by teachers and were completed in class by students who returned consent forms from their parents or guardians and who agreed to participate in the survey.

Parent and student surveys were conducted before (March 2007) and after (November 2007) the implementation of the Ride2School program in the program schools. The program was implemented over two school terms from March to September (from Autumn to Spring).

Because student and parent surveys were anonymous, parent and student data were not matched and were analysed separately. For similar reasons and also to maximize response rates, study participants (students and parents) were not matched at baseline and followup.

Across the 13 schools, participants in individual interviews and focus group discussions included 11 school principals, 21 teachers, 70 students (across grades 4, 5, and 6), and two Ride2School Coordinators. School principals were invited directly to participate in an interview, and they were asked to nominate approximately three teachers who might be interested in participating in a focus group. The teachers needed to have had some involvement with the program (e.g., the "cycling champion" or a grade 4, 5, or 6 teacher) to participate. Principals, teachers, and program staff provided written consent to participate in an interview or focus group, and parents provided written consent for their child to participate in a focus group.

Data collection instruments were developed based on program and evaluation objectives. Student and parent surveys were pilot tested with 10 grade 4–6 students and parents, and minor amendments were made. Each of the interviews and focus groups was semistructured, with an interview schedule that outlined the main topics and issues to be covered in the interview or focus group [30].

Individual qualitative interviews were conducted with principals via telephone to provide insight into the reasons for the school participating in the Ride2School program, their views on how the program was implemented in their school, and suggestions on how the program could be improved. Focus group discussions were conducted with teachers to determine their observations of the program, the supports and barriers to implementing the program, and how they thought the program was received by students. Focus group discussions were conducted with students to gain an understanding of their attitudes to active transport and general feedback on the program. The two Ride2School Coordinators who worked directly with the schools participated in monthly, face-to-face or telephone interviews and provided information on how the program was progressing in schools, the supports and barriers to implementing the program in each school, and how barriers were being overcome.

2.4.3. Data Analysis. Analysis of quantitative data was conducted with SPSS version 14.0.1 and Stata version 10.1. Descriptive statistics were generated for all quantitative study variables. Differences between proportions in travel modes were calculated using z-ratio computations. Chi-square tests of significance were used to determine differences between demographic variables, and independent t-tests were used to compare the differences in means for child age. In Phase 2 of the study, logistic regression models were computed to examine the impact of the Ride2School program, including adjustment for possible correlates of active transport to school. Details are included in the results section.

Analysis of the qualitative data from the interviews and focus groups in each school involved a number of steps, as described by Green and colleagues [31]: immersion in the data, coding, creating categories and identifying key themes. Categories and themes were then compared for the 13 program schools, to identify patterns in the data across schools.

3. Results

3.1. Phase 1: Pilot Schools

3.1.1. Quantitative Data. Based on the observational counts of students using active modes of travel to school in 2006, active transport was more common in the two inner suburban schools (pilot and comparison schools) (36.1% of trips) compared with the two outer suburban schools (pilot and comparison schools) (22.3%; $P < 0.0002$). Data for 2007 were similar.

In the inner suburban schools, observational data for all active transport modes combined showed an increase in rates of active transport from 2006 to 2007 in the pilot school (+7.6%; $P = 0.033$) and a decrease in the comparison school that was not statistically significant (−4.0%; $P = 0.256$) (Table 1). Although there were small increases in rates of active transport to school in both of the outer suburban schools from 2006 to 2007, the increase was significant for the comparison school only (+5.2%; $P = 0.025$).

Active transport rates based on the classroom Hands Up! surveys of grades 5 and 6 students were generally higher than for the observational counts, and this is likely due to the older sample, as older children are more likely to use active transport to school [13, 32, 33]. For the inner suburban schools, Hands Up! survey data showed an increase in walking and cycling trips to school for the school week in the pilot school (+8.8%; $P \leq 0.0002$) and no significant change in these trips to school in the comparison school (−4.3%; $P = 0.200$) from 2006 to 2007 (Table 1). In both of these schools, bicycle counts in the school grounds identified more bicycles in 2007 than in 2006, but in neither school was the change in the number of bicycles significant (Table 1).

In both of the outer suburban schools, classroom Hands Up! surveys of grades 5 and 6 students showed no significant changes in walking and cycling to school from 2006 to 2007 (see Table 1). In the pilot school, the number of bicycles counted in the school grounds declined between 2006 and 2007 (−4; $P = 0.015$) (see Table 1).

Overall, based on data from the three sources, there is reasonably consistent evidence of an increase in rates of active transport to school from 2006 to 2007 in the inner suburban pilot school, relative to the comparison school. However, in the outer suburban schools, the picture is not as consistent. The observational counts showed small nonsignificant increases in rates of active transport in both the pilot and comparison schools, while the classroom Hands Up! surveys showed small nonsignificant decreases in active transport, and bicycle counts showed a decrease in the number of bicycles in the school grounds at the pilot school, indicating less cycling to school. The three data sources therefore provide little evidence of a program impact in the outer suburban pilot school.

3.1.2. Qualitative Data. Qualitative data collected as part of the process evaluation can assist in explaining the impact evaluation data described above. Environmental characteristics of the study areas provide information about school contexts and implementation factors, based on qualitative

Table 1: Active transport at pilot and comparison schools.

Year	Inner suburban		Outer suburban	
	Pilot	Comparison	Pilot	Comparison
	n (%)	*n* (%)	*n* (%)	*n* (%)
All active transport modes combined, observational counts				
2006	113 (31.4)	157 (40.8)	96 (18.9)	179 (24.6)
2007	140 (39.0)	142 (36.8)	167 (19.7)	231 (29.8)
Change	+7.6%	−4.0%	+0.8%	+5.2%
P value	**0.033**	0.256	0.717	**0.025**
Walking and cycling trips to school, grade 5 and 6 students, classroom Hands Up! surveys				
2006	131 (43.2)	206 (50.1)	104 (26.6)	164 (34.6)
2007	208 (52.0)	226 (45.8)	118 (25.0)	217 (31.2)
Change	+8.8%	−4.3%	−1.6%	−3.4%
P value	**<0.0002**	0.200	0.593	0.220
Number of bicycles observed in school grounds				
2006	8	6	26	N/A*
2007	14	7	22	11
Change	+6	+1	−4	N/A
P value	0.192	0.783	**0.015**	N/A

*Bike storage could not be located at this school at baseline.
Bold: $P < 0.05$.

data collected from the Ride2School Coordinator, and provide insight into the program's implementation in the pilot schools.

Both of the inner suburban schools (pilot and comparison schools) were in neighbourhoods of relatively high dwelling density and street connectivity, environmental characteristics that have been associated with walking and cycling for transport [34–38]. Both schools were serviced by train stations within 500 meters.

The two outer suburban schools (pilot and comparison) were in areas of lower dwelling density with streets of lower connectivity, when compared with the inner suburban areas. Personal observations showed that the outer suburban pilot school was not located within easy or safe access of much of the residential areas. To access the school, students needed to travel on a busy arterial road, cross the creek over a bridge with a narrow shared pedestrian/cyclist footpath, cross the main road at the school crossing and travel past heavy machinery on a large commercial building site next to the school. Accessing the outer suburban comparison school appeared to be easier and safer, with housing located closer to the school and wider footpaths for pedestrians and cyclists, although streets were of fairly low connectivity. There was a school bus traveling to each of the schools.

Factors that both enabled and constrained the program's implementation in the two pilot schools occurred at the program level, school community level, and the environmental level. These factors varied for the two program schools and were identified through semistructured interviews with the Ride2School Coordinator.

Supports for Program Implementation. The Ride2School Coordinator undertook more intensive work with the pilot school in the inner suburban area than in the outer suburban area. He was more "hands-on" with this school, and therefore the teacher "cycling champion" was not expected to do too much work. There were a number of challenges (e.g., developmental stage of the school, priorities, and environmental factors) in working with the outer suburban pilot school.

Infrastructure improvements were made in the inner suburban pilot school as part of the program, which were not made to the same extent in the outer suburban school. Both schools received $4000 funding to improve their bike storage; however in the inner suburban pilot school a bike shed was erected quickly, and, in the outer suburban school, a temporary bike shed was provided for the first year until a more permanent shed could be built. In addition, two raised pedestrian crossings were built next to the inner suburban school, as part of the program, which were not provided to the outer suburban school.

As much as the environmental characteristics of the school areas were important, further qualitative data suggest that the culture in inner suburban communities (e.g., higher levels of walking and cycling and less car-dependence, in the general community) could make it easier to increase rates of active transport in these areas, as well as working with middle-smaller sized schools, such as the inner suburban pilot school. The school community was important in the implementation and acceptance of the program. At the inner suburban pilot school, the evidence suggested an enthusiastic and committed school community that made good use of resources available through the Ride2School program. In contrast, the outer suburban pilot school was in the process of establishing itself in a rapidly developing area and faced a number of competing priorities requiring considerable attention, resources, and staff time.

In summary, the program appeared to have greater impact in the inner suburban pilot school than in the outer suburban pilot school. Qualitative data suggest that the program was easier to implement and promote within a school that was smaller, more established, with a culture that was accepting and enthusiastic about active transport, in an area of higher density and lower car use, with greater use of infrastructure improvements and a more "hands-on" approach from the program Coordinator.

3.2. Phase 2: Program Schools

3.2.1. Quantitative Data

Parent Surveys. Surveys were completed by 410 parents at baseline (28.7% response rate), and 358 parents at followup (25.1% response rate). The majority of parents completing the surveys were female (89.0%, $P = 0.920$), and more than half of parents were in the 40–49 years age range (Table 2). Approximately two-thirds of respondents had completed some qualification since leaving school. There was a significant difference for parents' educational attainment at

Table 2: Parent characteristics at baseline and followup.

Demographic variable	Baseline		Followup		P value
	n	%	n	%	
Gender					
Female	365	89.0	315	89.0	0.920
Male	45	11.0	39	11.0	
Age					
18–29 years	11	2.7	3	0.8	
30–39 years	150	36.8	118	33.1	0.098
40–49 years	223	54.7	205	57.6	
50 years and over	24	5.8	30	8.4	
Country of birth					
Australia	347	84.6	299	83.8	0.823
Overseas	63	15.4	58	16.2	
Highest educational level achieved since leaving school					
No qualification	143	35.3	113	31.8	
Vocational qualification*	92	22.9	53	17.9	**0.042**
Diploma/associate diploma	48	11.7	46	12.8	
Bachelor/higher degree	112	27.2	117	34.1	

*Vocational qualification includes apprenticeship, trade certificate.
Bold: $P < 0.05$.

Table 3: Mode share of students' transport to and from school (% of trips), parent-reported data.

Travel mode	Baseline (n = 410)	Followup (n = 358)	P value
Car	46.3	44.2	0.076
Walk	27.8	28.7	0.352
Cycle	13.9	15.9	**0.015**
Scooter/skate	6.2	5.0	**0.026**
Other (public transport)	5.8	6.2	0.621
Total active trips (walk, cycle, and scooter/skate)	47.9	49.6	0.125

Bold: $P < 0.05$.

baseline and followup ($P = 0.042$), although approximately 3% of respondents did not answer this question at both time points.

Baseline and follow-up parent surveys included questions about children's modes of travel to and from school. Post program, there was a small nonsignificant decrease in the proportion of trips to and from school by car for five consecutive weekdays (from 46.3% to 44.2%, $P = 0.076$) and a corresponding small increase in active trips that was not significant (from 47.9% to 49.6%, $P = 0.125$), due to a significant increase in cycling (from 13.9% to 15.9%, $P = 0.015$) (Table 3).

Logistic regression analysis was used to assess whether levels of students' active transport to school, as reported by parents, were significantly different at followup relative to baseline. In order to detect possibly small changes in active/inactive trips to and from school among students, a binary outcome variable was created (no active trips in the last five school days = 0, 1–10 active trips in the last five school days = 1).

The analysis was conducted in three stages. First, the crude association between active transport and the intervention (baseline = 0, followup = 1) was examined. At followup, the proportion of students using 1–10 trips to and from school by active transport was 5.9% higher than at baseline (62.9% at baseline, 68.8% at followup). A chi-square test for difference in proportions and a simple logistic regression showed that this difference was not statistically significant ($P = 0.087$).

Second, regression analysis was conducted accounting for clustering by school. Schools with parent and student participant numbers less than 20 at either baseline or followup were combined for clustering, based on school location, environmental context, and how the program was implemented and supported by schools. This resulted in eight school clusters. After accounting for clustering by school, no association was found between the intervention and students using active transport to or from school at least once per week (adjusted OR = 1.30, 95% CI = 0.95–1.79, $P = 0.107$).

Third, to account for potential confounding factors, a number of predictor variables were added to the model (Table 4). Significant results (using chi-square test of difference in proportions) for associations with children's use of active transport to or from school were simultaneously entered into the model in one block, to adjust for covariates that may affect the relationship between the outcome (active trips) and the data collection period (intervention) (Table 5). After accounting for clustering by school and adjusting for predictor variables (school location (regional or metropolitan), distance to school, number of cars per adult in household, child grade, how often spouse/partner cycles, and possibility of regular walking/cycling to school), a statistically significant increase in active transport post intervention was detected (adjusted OR = 1.67, 95% CI = 1.04–2.68, $P = 0.035$).

Student Survey. Surveys were completed by 479 students at baseline (33.6% response rate) and 403 students at followup (28.3% response rate). Student respondent characteristics are shown in Table 6. There were broadly similar proportions of students in grades 4, 5, and 6. The average age of students was significantly higher at followup than baseline (11 years and 10 years, respectively, $P < 0.0001$), consistent with the timing of the baseline and followup surveys (predominantly in March 2007 and November 2007).

Student-reported data were broadly similar to parents' reports on students' travel modes to and from school, including those using active and inactive modes (Table 7). However, post program, there was a small nonsignificant increase in the proportion of trips to and from school by car for five consecutive weekdays (from 42.9% to 43.1%, $P = 0.920$), and a significant decrease in active trips (from 51.1% to 48.7%, $P = 0.029$), mostly from trips by scooter/skate (from 7.2% to 4.9%, $P \leq 0.0002$). This differs from parent-reported data,

Table 4: Predictor variables for active transport to school, parent-reported baseline data.

Variable	Student use of active transport		P
	No active transport (no trips) n^* (%)	Active transport (1–10 trips) n^* (%)	
School location			
Regional	112 (40.3)	166 (59.7)	**0.050**
Metropolitan	40 (30.3)	92 (69.7)	
Child gender			
Male	70 (37.0)	119 (63.0)	0.952
Female	81 (37.3)	136 (62.7)	
Child grade			
Grade 4	59 (48.8)	62 (51.2)	
Grade 5	44 (32.6)	91 (67.4)	**0.007**
Grade 6	48 (32.0)	102 (68.0)	
Distance to school			
Less than 0.5 km	3 (4.7)	61 (95.3)	
0.5–1 km	7 (8.5)	75 (91.5)	
1.1–2 km	30 (29.1)	73 (70.9)	**0.000**
2.1–4 km	33 (47.1)	37 (52.9)	
4.1–10 km	47 (82.5)	10 (17.5)	
More than 10 km	27 (100.0)	0 (0.0)	
Number of children in household			
One	20 (32.3)	42 (67.7)	
Two	68 (34.7)	128 (65.3)	0.405
Three	47 (43.1)	62 (56.9)	
Four or more	17 (39.5)	26 (60.5)	
Number of cars per adult in household**			
None	0 (0.0)	11 (100.0)	
One	130 (36.0)	231 (64.0)	**0.001**
Two	22 (59.5)	15 (40.5)	
Parent's country of birth			
Australia	130 (37.6)	216 (62.4)	0.521
Overseas	21 (33.3)	42 (66.7)	
Parent education			
No qualification since secondary school	58 (40.0)	87 (60.0)	0.364
Vocational qualification or higher	90 (35.4)	164 (64.6)	
Parent employment			
Both parents work full-time	43 (39.8)	65 (60.2)	0.492
At least one parent works part-time or is not employed	109 (36.1)	258 (62.9)	
How often parent cycles			
Once per month or less	126 (39.4)	194 (60.6)	0.069
At least once per week	26 (28.9)	64 (71.1)	
How often spouse/partner cycles			
No spouse or partner/once per month or less	133 (40.3)	197 (59.7)	**0.011**
At least once per week	19 (24.7)	58 (75.3)	
Walking to or from school on a regular basis is a possibility for child			
No	100 (83.3)	20 (16.7)	**0.000**
Yes/maybe	51 (17.7)	237 (82.3)	
Cycling to or from school on a regular basis is a possibility for child			
No	89 (64.0)	50 (36.0)	**0.000**
Yes/maybe	61 (23.1)	203 (76.9)	

*Number of students.
**0.5 cars were rounded up to one.
Bold: $P < 0.05$.

Table 5: Impact of the Ride2School program on students' use of active transport at least once per week, unadjusted and adjusted for predictor variables, parent-reported data.

Variable	OR	95% CI	P	AOR	95% CI	P
Data collection period (reference = baseline)	1.30	0.95–1.79	0.107	1.67	1.04–2.70	**0.035**
School location (reference = metropolitan)	0.64	0.41–1.00	**0.050**	1.12	0.77–1.63	0.559
Child grade				1.64	1.33–2.03	**0.000**
Grade 4		Reference				
Grade 5	1.97	1.19–3.27	**0.008**			
Grade 6	2.02	1.23–3.32	**0.005**			
Distance to school				0.42	0.35–0.51	**0.000**
Less than 0.5 km	8.36	2.43–28.72	**<0.000**			
0.5–1 km	4.4	1.82–10.65	**0.001**			
1.1–2 km		Reference				
2.1–4 km	0.46	0.24–0.87	**0.016**			
4.1–10 km	0.09	0.04–0.20	**<0.000**			
More than 10 km		Not applicable (zero in one cell)				
Number of cars per adult				0.48	0.14–1.65	0.245
None		Not applicable (zero in one cell)				
One		Reference				
Two	0.38	0.19–0.77	**0.005**			
How often spouse/partner cycles	0.49	0.28–0.85	**0.011**	1.79	0.68–4.71	0.239
Walking to school is a possibility	0.43	0.02–0.08	**0.000**	5.63	3.48–9.11	**0.000**
Cycling to school is a possibility	0.17	0.11–0.26	**0.000**	2.81	1.52–5.18	**0.001**

Bold: $P < 0.05$.

Table 6: Student characteristics at baseline and followup.

Demographic variable	Baseline		Followup		P value
	n	%	n	%	
Grade					
4	140	29.2	133	33.8	
5	166	34.7	138	35.0	0.228
6	173	36.1	123	31.2	
Gender					
Female	253	52.8	207	51.4	0.718
Male	226	47.2	196	48.6	
Age (years)					
Mean	10		11		**<0.0001**
Range	8–13		8–13		

Bold: $P < 0.05$.

Table 7: Mode share of students' transport to and from school (% of trips), student reported data.

Travel mode	Baseline $n = 479$	Followup $n = 403$	P value
Car	42.9	43.1	0.920
Walking	28.4	27.7	0.464
Cycling	15.5	16.1	0.450
Scooter/skate	7.2	4.9	**<0.0002**
Other (public transport)	6.0	8.2	**<0.0002**
Total active trips (walk, cycle, and scooter/skate)	51.1	48.7	**0.029**

Bold: $P < 0.05$.

which showed a small, though not significant, increase in active transport.

As with the parent data, analysis of the student data was undertaken in three stages using logistic regression to assess whether levels of students' active transport to school, as reported by students, were different at followup relative to baseline. At followup, the proportion of students using active transport to and from school at least once per week (1–10 trips) was 5.0% lower than at baseline (70.8% at baseline, 65.8% at followup). A chi-square test for difference in proportions and a simple logistic regression showed that this difference was not statistically significant ($P = 0.109$). After taking into account clustering by school, no statistically significant difference was detected between baseline and followup for students using active transport to or from school at least once per week ($P = 0.409$). Potential predictor variables were then added into the model to account for possible confounders. After accounting for clustering by schools and adjusting for the only significant predictor variable (school location) (Table 8), no statistically significant difference in active transport after the intervention was detected (adjusted OR = 0.80, 95% CI = 0.46–1.38, $P = 0.421$).

In summary, for the 13 schools that participated in Phase 2 of the Ride2School program, there was inconsistent evidence of a postprogram change in grades 4, 5, and 6 students' rates of active transport to school. Parent-reported data showed a significant increase in the proportion of students using

Table 8: Predictor variables for active transport to school, student baseline data.

Variable	Student use of active transport		P
	No active transport (no trips) n^* (%)	Active transport (1–10 trips) n^* (%)	
School location			
Regional	110 (31.8)	236 (68.2)	**0.043**
Metropolitan	29 (22.3)	101 (77.7)	
Child gender			
Male	62 (27.6)	163 (72.4)	0.455
Female	77 (30.7)	174 (69.3)	
Child grade			
Grade 4	48 (34.8)	90 (65.2)	
Grade 5	48 (29.1)	117 (70.9)	0.160
Grade 6	43 (24.9)	130 (75.1)	
Whether student cycles after school hours			
Never/sometimes	71 (33.2)	143 (66.8)	0.077
Quite often/most days	67 (25.8)	193 (74.2)	
Whether adults in the household cycle			
No	58 (33.5)	115 (66.5)	0.114
Yes	80 (26.7)	220 (73.3)	
Whether student had participated in Bike Ed.			
No	59 (26.1)	167 (73.9)	0.158
Yes	80 (32.0)	170 (68.0)	

*Number of students.
Bold: $P < 0.05$.

active transport to school at least once a week after adjusting for potential confounding factors, but student-reported data indicated no statistically significant change.

Similar to Phase 1 of the Ride2School program, impacts varied across the 13 schools that participated in Phase 2 of the program. Qualitative data collected as part of the process evaluation can assist in providing some insights into variable program impacts. School communities are complex socioenvironmental entities that interact with externally initiated programs such as the Ride2School program in complex ways. As noted in the "Realistic Evaluation" approach to program evaluation, in addition to assessing the net impact of interventions in multisite programs, it is also important to explore "What works for whom under what circumstances?" [39].

3.2.2. Qualitative Data. The qualitative data were initially organised in the form of brief case studies of individual program schools. Quantitative data from parent and student surveys were added to the qualitative data to form an overall picture of the Ride2School program in each school, covering school context, program impacts, and program implementation.

The motivations, supports, and barriers to implementing and promoting the Ride2School program differed for each of the 13 program schools. A summary of these factors, across the 13 program schools, is as follows.

Variation in Program Implementation. Schools had different levels of interest, commitment, support, and resources to implement the program and to implement it well. Therefore, the program was implemented to varying degrees at each school. However, the number of activities schools participated in did not appear to predict changes in active transport rates. Most were one-off activities such as the Ride2School Day (a yearly event) that were relatively easy to organize and implement, but appeared not to result in sustained, schoolwide change.

Schools had different expectations of the Ride2School program in terms of how the program would be implemented in their school and the assistance that would be provided by the Ride2School Coordinators. In some cases, these expectations were at odds with both the expectations of the Coordinators and the services and resources provided through the program. This resulted in schools' expectations often not being met. The Ride2School Coordinators often had different perceptions (from those of teachers and principals) about what motivated schools to participate in the program; what some of the supports and barriers were to promoting the program; and generally how well the program was implemented. The three schools that appeared to experience increased rates of active transport to school post program were schools that the Coordinators found difficult to work with. According to Ride2School Coordinators, program impacts did not appear to reflect program implementation. In contrast, increased levels of active transport to school appeared to be associated more with highly motivated school communities, including parents, situated in supportive physical and sociocultural environments, who drew on the resources provided through the Ride2School program to further support what they were already doing.

School Setting and Surrounding Environment. In terms of the physical and social environments associated with the schools, there was a clear distinction between schools located in regional areas and those in metropolitan areas. Many of the regional schools were constrained by being located near busy roads and long distances to travel to school, resulting in travel by car or school bus. On the other hand, metropolitan schools were mainly in inner suburban areas, with infrastructure that is more supportive of active transport (e.g., walking/cycling paths, high density, and street connectivity).

Many schools referred to the "car culture" in the school community as a barrier to promoting travel ehavior change. This appeared to have been less of an issue in metropolitan schools, who identified a local culture of environmental concern and/or sustainable practices (including active transport) as supports for the program.

All of the regional schools were in disadvantaged areas and appeared to experience more barriers to implement

the Ride2School program than metropolitan schools. For example, regional schools appeared to have other important issues to deal with, which meant that "add-on" programs like the Ride2School program received less attention than other key priority issues. Several of these schools appeared to require greater levels of support and resources to implement the program than the metropolitan schools.

Program Impacts on Individual Program Schools. There was some evidence of a program impact in three program schools (sample sizes precluded testing for statistical significance), one in a metropolitan area and two in regional areas. Qualitative data suggest that the combination of secure bicycle storage facilities, the promotion of all active transport modes (walking, cycling, and skating) equally by committed and energetic school staff, and a school and/or local community culture of active transport (including parents accompanying children to school by active transport) may have contributed to increased rates of active transport to school in these schools.

4. Discussion

Evaluation of the pilot phase of the Ride2School program, which involved an inner suburban primary school and an outer suburban primary school, indicated an increase in active transport to school in the inner suburban school, but not in the outer suburban school. Data from qualitative interviews and an examination of the socioenvironmental characteristics of the two school communities suggest that program, school community, and socioenvironmental factors contributed to the differing outcomes.

The inner suburban school was a relatively small (approximately 360 students from preparatory to grade 6), established school with a high level of interest in, and commitment to, increasing active transport to school. The school made good use of the resources available through the Ride2School program, including infrastructure improvements in and around the school. The school was also located in an area with higher rates of walking and cycling among the general population than in the greater Melbourne metropolitan area [40]. Children are more likely to use active transport to school in areas where active transport is more prevalent in the wider community [41].

The outer suburban school, on the other hand, was located in a rapidly developing area with relatively poor access by foot or bicycle to the school from surrounding residential areas. Trip distances also appeared to be greater than for the inner suburban school. The area has poor public transport, low levels of active transport, and high levels of car use [40]. As a new school undergoing rapid expansion (the number of enrolled students increased from 507 in 2006 to 846 in 2007), the school faced a number of challenges which meant that, while there was interest in promoting active transport to school, other issues had higher priority.

Findings from this pilot phase of the Ride2School program provide some support for the "Realistic Evaluation" approach to program evaluation which emphasizes the importance of not only measuring the aggregate effect of a multisite intervention, but also gaining a more nuanced understanding of "What (program factors) works for whom (population factors) under what circumstances (socioenvironmental factors)?" [39, 42]. The Community-Based Social Marketing model (on which the Ride2School program was loosely based) also highlights the importance of understanding how the supports and barriers to active transport vary across settings and population segments [43]. In terms of increasing active transport to school in a school setting with substantial barriers to active transport, it is likely that more intensive, targeted, and sustained behaviour change measures are required, in addition to environmental measures designed to make active transport to school a realistic, safe, appealing, and convenient alternative to car travel. This is consistent with recommendations from the evaluation of the TravelSmart Schools program in New South Wales, which advised that future programs to promote active transport to school should be implemented with greater intensity at fewer schools, over a longer period of time and for at least two years [44].

Evaluation of Phase 2 of the Ride2School program found inconsistent evidence of program impacts in the 13 participating schools. Parent-reported travel data indicated an increase in the proportion of grades 4, 5, and 6 students using active transport to school at least once a week, but student-reported data found no significant change. Differences between parent-reported and student-reported travel to school behaviour were also found in the evaluation of a program promoting walking to school in Sydney, where parent-reported data indicated a program impact, but student-reported data showed no significant program impact [22]. Given that research literature on the reliability of parent-proxy and student-reported data on travel to school shows both sources to be reliable [45–47], there is no consistent evidence that one source is preferable to the other for children in this age group. This study therefore concludes that there was inconsistent evidence of an overall program impact in the 13 schools that participated in the second phase of the Ride2School program, with differences between parent and student data likely due to a range of methodological issues discussed in more detail below.

Sample size limitations precluded a quantitative assessment of program impacts in individual schools, but there were some indications of a small-to-modest program impact in one metropolitan and two regional schools. These apparently successful schools did not appear to differ markedly or consistently from less successful schools in terms of extent or quality of program implementation or the key socioenvironmental correlates of active transport to school [41]. However, it is of interest to note that the Ride2School Coordinators described them as operating fairly independently of the Ride2School program, suggesting a high degree of commitment to active transport to school and the ability to draw on multiple resources (including, but not limited to, the Ride2School program) to foster active transport to school. They also appeared to have more widespread school and community support for active transport to school, rather than being dependent on one or two teachers (often keen cyclists) to promote the program. Previous research has found that programs using a community participation and/or

development approach have been successful in producing an increase in active transport to school internationally [48, 49] and in Australia [50, 51].

Other factors that may have limited the success of the Ride2School program include the stronger focus on cycling to school than on walking to school. Other active school travel programs in Australia have found it easier to increase rates of walking to school than cycling to school [23], possibly due to generally poor cycling infrastructure and adverse traffic conditions in Australia.

In the early years of the program (the subject of this study) the focus of the program tended to be on high profile one-off events and activities designed to create a profile for the program and, in the words of one interviewee, "get some runs on the board." More recently, the program has incorporated capacity building within schools (e.g., professional development opportunities for teachers) and assisted schools to conduct more regular active transport activities (e.g., Walking Wheeling Wednesdays) [52].

The program focused on working directly with students and teachers, and there was limited active participation from parents. Parental involvement in travel behaviour change is crucial because parents are the principal decision-makers for how children of primary school age travel to school [53]. While parental participation in school programs is not always easy, it is important that parents be involved in identifying the benefits and barriers to active transport and car travel and suggesting strategies to address these benefits and barriers [54].

Apart from providing the inner suburban primary school in the pilot phase of the program with a school crossing and secure bicycle storage, the Ride2School program was predominantly a behaviour change program. In the program schools, it did not involve any substantial infrastructure changes in most schools (two schools received funding for bike storage improvements through Ride2School). Travel behaviour change programs such as those promoting active transport to school are often seen as a low-cost approach to achieving a mode shift from car travel to active transport [55–57]. However, there is some debate in the literature regarding whether substantial, sustained levels of active transport to school can be achieved in the absence of an integrated package of measures including improved walking and cycling infrastructure and traffic calming measures [41, 58–62]. Given the impact of the physical environment on active transport [33, 34, 58, 63], it meant that schools participating in this program with existing infrastructure that supported active transport, such as bicycle paths and secure bicycle storage, might have been better placed to successfully implement behaviour change measures.

Finally, the relatively short time period for program implementation (approximately six months) may have been too short to change school travel behaviour. Change in mode share from inactive to active trips to and from school can be difficult to achieve in the short term [18, 24].

In common with many studies of the impacts of active school travel interventions [18], this study has several methodological limitations. As an external evaluation working within the time constraints of the program, recruiting adequate and sufficient comparison groups into the evaluation prior to baseline data collection was difficult, therefore placing limitations on the study design. These issues reflect the difficulties of working within a "real world" program, rather than a controlled community intervention trial [64].

The pilot and program schools self-selected to participate in the Ride2School program, and many of the 13 program schools had relatively high rates of active transport to school at baseline (particularly for cycling) compared with Victorian state-level data [65], suggesting that schools with an existing interest in active transport to school may have self-selected into the program. Recruiting schools with a preexisting interest in active school travel might be advantageous in terms of working with motivated schools; however, it might also make further increases in active transport difficult as active transport is not a feasible or appealing option for all parents and students (e.g., those who live too far from school, have no safe route to school, or simply prefer to drive).

In Phase 2 of the study, time constraints prevented testing of the validity and reliability of the data collection measures. Further, parent and student survey response rates were low (approximately 30%). While this is not unusual when active parental consent is required for research conducted in schools (as in this study) [66, 67], the low response rates may have led to nonresponse bias. This might have resulted in an overestimate of rates of active transport to school, though this bias is likely to be similar at baseline and followup. This study relied on classroom teachers to distribute surveys and consent forms to students in a timely manner, and their commitment to this varied. This highlights the difficulties of conducting research in schools that require active participation from school staff and parents.

The study may also have been underpowered (i.e., too few schools and parent and student respondents) to detect the small changes in travel mode share reported in evaluations of similar programs in Australia and internationally [18]. As noted by Sullivan and Percy (2008) large sample sizes are required to rigorously measure these small changes. Although some evaluations of active school travel programs have reported substantial increases in active transport, those that have used more rigorous evaluation designs have generally reported smaller impacts (most commonly in the range of 0–4%) [18, 22, 24]. The observational methods (counts of students using active transport modes and bicycles on school grounds) used in the evaluation of the pilot program could have been used to add strength to the data from the surveys (overcoming biases associated with nonresponse, social desirability, and inaccurate responses). However, these observational counts are very resource-intensive and were not practical, given the resource constraints of the study, to be conducted at all schools, particularly schools in regional areas.

5. Conclusion

Based on the substantial health, environmental, transport, and community benefits of active transport to school, the promotion of active transport to school is potentially a

worthwhile investment [68]. However, evidence for the effectiveness of programs aimed at increasing children's rates of active transport to school is inconsistent, with variable program impacts occurring both between programs and for individual schools within multisite programs [18, 22, 44].

This study also reported mixed evidence for the effectiveness of the Ride2School program. However, use of a mixed methods impact-process evaluation design enabled exploration of the impact of contextual factors on the effectiveness of the active transport intervention in schools. In this study, relatively intensive support for active transport to school, in an inner suburban primary school that was located in a supportive environment for active transport and had a strong commitment to promoting active transport, appeared to be effective in increasing active transport to school. Less intensive support and resourcing of a larger number of primary schools (13) in inner suburban areas of Melbourne and regional areas were less effective in increasing active transport to school, though a small number of schools achieved small-to-modest increases in active transport to school.

Important questions for future evaluation research into programs promoting active transport to school include gaining a better understanding of the program, school, population, and contextual factors that shape the effectiveness of interventions; the optimal mix of "soft" (behaviour change) measures and "hard" (infrastructure) measures; the reach of active transport initiatives; and the sustainability of change.

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Research Article

Health-Related Factors Associated with Mode of Travel to Work

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Active commuting (AC) to the workplace is a potential strategy for incorporating physical activity into daily life and is associated with health benefits. This study examined the association between health-related factors and mode of travel to the workplace. *Methods*. A volunteer convenience sample of employed adults completed an online survey regarding demographics, health-related factors, and the number of times/week walking, biking, driving, and using public transit to work (dichotomized as no walk/bike/drive/PT and walk/bike/drive/PT 1 + x/week). Logistic regression was used to predict the likelihood of each mode of transport and meeting PA recommendations from AC according to demographics and health-related factors. *Results*. The sample (n = 1175) was aged 43.5 ± 11.4 years and was primarily White (92.7%) and female (67.9%). Respondents reported walking (7.3%), biking (14.4%), taking public transit (20.3%), and driving (78.3%) to work at least one time/week. Among those reporting AC, 9.6% met PA recommendations from AC alone. Mode of travel to work was associated with several demographic and health-related factors, including age, number of chronic diseases, weight status, and AC beliefs. *Discussion*. Mode of transportation to the workplace and health-related factors such as disease or weight status should be considered in future interventions targeting AC.

1. Introduction

The economic cost of preventable chronic disease in the United States is substantial, with the direct and indirect costs associated with cancer, cardiovascular disease, diabetes, mental health disorders, and pulmonary conditions estimated at more than $1 trillion for the general population in 2003. Among employed adults, much of this economic burden is shouldered by employers in terms of private health insurance expenditures and lost productivity, with the costs associated with chronic disease nearing $465 billion [1]. The visionary initiative targeting population level health is found in the US Department of Health and Human Services' Healthy People 2020 and includes goals of attaining high-quality, longer lives free of preventable disease and premature death [2]. This document includes goals and objectives focused on changing health behaviors that contribute to chronic disease morbidity and mortality, including specifically improving rates of physical activity participation along with environmental and policy approaches aimed at supporting this behavior across the lifespan.

Evidence outlining the benefits of regular physical activity participation for the prevention of chronic disease and premature mortality is substantial [3, 4]. Epidemiological and clinical trials have documented the benefits of physical activity in preventing diabetes and metabolic disorders [5–8], cardiovascular disease [9–11], certain cancers [12–16], and mental health disorders [17–19]. The majority of these studies include data on all forms of physical activity (leisuretime, occupational, and transportation related). When specifically examining the health effects of transportation-related physical activity to work, known as active commuting (AC), data from epidemiological surveys have found relationships between active travel and a lesser presence of self-reported obesity [20–22] and a reduced risk of cardiovascular disease and all-cause mortality [23–26]. Despite these known benefits of active transport, in the United States, rates of AC remain low (3% reporting walking to work, <1% report biking to work), especially in comparison to other countries (e.g., The Netherlands: 25% of trips are made by bicycle) [27–29].

Recent research has addressed individual, social, and environmental factors associated with AC to work. Some

documented correlates of AC include demographics (age, gender, income, and race/ethnicity) [30, 31], psychosocial (self-efficacy, behavioral beliefs, attitudes, and intention) [32–35], and environmental influences (traffic, walkable and bikeable features, safety, and convenient public transport close to the workplace) [36–41]. However, few, if any, studies have focused in much depth on how diverse health-related factors are associated with AC [42], despite the acknowledgment that health is a prime determinant, motivator, and outcome of AC [25]. Moreover, the impact of health-related influences on specific modes of travel (e.g., walking, biking, transit, and driving) has received even less attention. Additionally, few studies have explored the extent to which AC provides sufficient opportunity to achieve recommended levels of physical activity that are adequate to achieve health benefits [43–45]. Moreover, to the extent that this is possible, what are the characteristics of individuals who engage in enough AC to meet physical activity recommendations?

Given these considerations, the purpose of this study was twofold. Our primary aim was to examine the relationship between numerous demographic and health-related factors and mode of travel to work (walking, biking, driving, and public transit). The secondary aim of the study was to examine the health-related factors associated with achieving current public health recommended levels of physical activity [46] via AC.

2. Methods

2.1. Survey Design. This cross-sectional survey was delivered online from June to December 2011 using Qualtrics (Provo, UT) and was approved by the Pennsylvania State University Institutional Review Board.

2.2. Participants and Recruitment. To be eligible, participants had to be over the age of 18 years, employed full- or part-time outside of the home, and physically able to walk or bike. Recruitment was focused in the mid-Atlantic region of the USA (PA, OH, WV, MD, NJ, and DE). The primary recruitment strategy involved visiting the websites of large employers (e.g., K-12 school districts, local/county government, private businesses, and universities/colleges) in medium to large cities for employee email addresses and subsequently contacting the employees directly with an email invitation. In cases where employee email addresses were not available, we contacted employers directly and asked them to distribute an electronic invitation to participate in the survey via listserv, e-newsletter, or mass email to their employees. Among employers contacted directly ($n = 142$), two employers refused to send out an email invitation, 84 did not respond in any way, and 56 sent out a recruitment invitation. Recruitment of participants is displayed in Figure 1.

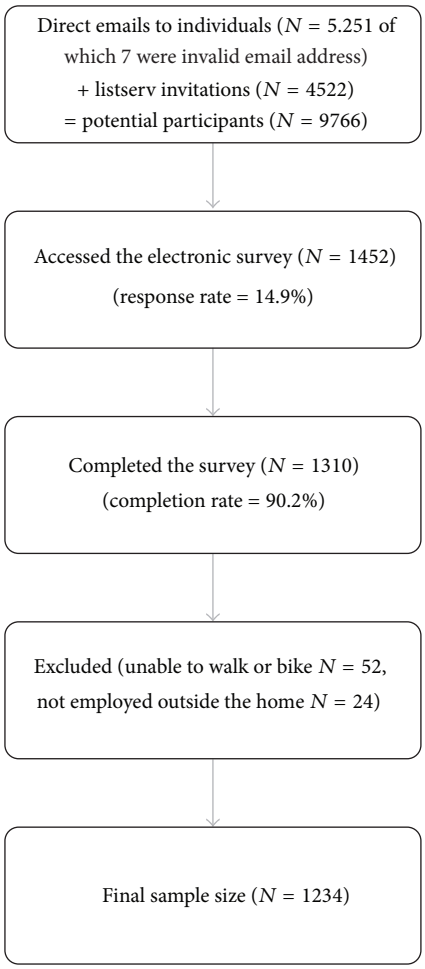

Figure 1: Participant recruitment.

2.3. Measures

2.3.1. Commuting Patterns. Participants were asked to reflect on the previous month and report the average number of times per week in the last month that they walked, biked, drove, and took public transportation (where available) to and from work. For each mode of travel, a dichotomized variable was created to indicate no travel by the mode of travel or travel via the mode one or more times per week. Public transportation ridership was only considered among those who had public transit available to them as determined by self-report of public transit availability in their community ($n = 748$). Respondents also indicated the perceived number of minutes it would take them to walk and bike to work using one item for each mode.

2.3.2. Demographics and Health Outcomes. Participants reported their age, sex, race/ethnicity (collapsed into non-Hispanic White, non-Hispanic Black, and other racial/ethnic groups), and income level. Participants responded (yes/no) if they had any cardiovascular/pulmonary disease (heart disease, high blood pressure, elevated cholesterol, and chronic obstructive pulmonary disease), metabolic disease (diabetes, liver, or thyroid disease), musculoskeletal disease (arthritis, osteoporosis), or depression, and a total number of chronic diseases was calculated. Diseases were then collapsed into the four categories and dichotomized (e.g., yes/no for reporting a metabolic disease). Individuals were also asked to report their height and weight for body mass

index (BMI) calculations (weight in kg/(height in meters)^2). Respondents also rated their current health status from 1 (poor) to 5 (excellent). To determine if individuals were meeting current physical activity recommendations (at least 150 minutes/week of moderate intensity physical activity) [46] from their AC participation, the number of trips per week walking and biking were multiplied by the amount of time they reported for a walk or bike trip to work. The total number of minutes of AC time was calculated and was then dichotomized as meeting recommendations via active commuting (+150 minutes/week of active travel to work) or not meeting recommendations.

2.3.3. Perceived Health Benefits of AC. Respondents indicated their agreement with eight statements related to physical or mental health benefits of AC (e.g., AC helps me control my weight; AC can help me to relieve stress) using a 7-point Likert scale (1 = completely disagree to 7 = completely agree). A summed score was computed for all 8 items. This scale was based on a previously-tested measure [47] and showed excellent reliability in the present sample ($\alpha = 0.89$).

2.4. Statistical Analyses. Basic descriptives and frequencies were used to describe the sample. To examine the primary aim, for each mode of travel, separate univariate logistic regression models were used to predict the likelihood of walking, biking, driving, and public transit use at least once per week according to demographics and health-related factors (age, sex, income, race/ethnicity, chronic disease presence, perceived health status, and perceived health benefits of AC). Factors significantly associated with walking, biking, driving, and use of public transit were examined simultaneously in four multivariate logistic regression models and the Nagelkerke R^2 was calculated for each of the full models to examine the factors associated with each mode of travel. To address the secondary aim, the likelihood of meeting physical activity recommendations via AC was examined via univariate logistic regression with the same demographics and health-related factors and then a full model with significant factors was performed. All analyses were performed using SPSS 20.0 (Armonk, NY) and significance levels were set at $P < 0.05$.

3. Results

The demographics of the sample are shown in Table 1. Participants were primarily non-Hispanic White (92.1%), female (68.3%), and had a high (over $60,000) income level (63.2%). The mean age of respondents was 43.8 years (s.d. = 11.4) and slightly more than half of respondents were overweight (31.5%) or obese (19.5%). Most individuals (78.3%) reported driving to work one or more times/week and 20.3% reported using public transit, though relatively few reported walking (7.3%) or biking (14.4%) one or more times/week. Among those traveling using active methods, 9.6% met physical activity recommendations via AC.

3.1. Walking to Work One or More Times/Week. Univariate influences on walking to work at least once per week are found in the first columns of Table 2. Age was negatively related to being a walker (OR = 0.97, 95% CI = 0.95–0.99). Those from "other" racial/ethnic groups were more likely to walk (OR = 2.99, 95% CI = 1.44–6.25) compared to non-Hispanic Whites. Better perceived health status was associated with being a walker (OR = 1.64, 95% CI = 1.24–2.17) and being in the obese weight category was associated with being a non-walker (OR = 0.46, 95% CI = 0.23–0.93). The full model of significant correlates resulted in a Nagelkerke R^2 of 0.07, with race ("other" racial/ethnic group OR = 2.91, 95% CI = 1.34–6.31), age (OR = 0.97, 95% CI = 0.95–0.99),

Table 1: Characteristics of the sample (n = 1234).

Variable	n (%)	Mean (SD)
Demographic		
Age		43.76 (11.44)
Sex		
Male	327 (31.7)	
Female	706 (68.3)	
Income level		
<$30 K/year	55 (5.5)	
$30–60 K/year	309 (31.2)	
>$60 K/year	626 (63.2)	
Race/ethnicity		
Non-Hispanic White	941 (92.1)	
Non-Hispanic Black	33 (3.2)	
All other racial/ethnic groups	48 (4.8)	
Health related		
Number of chronic disease		0.64 (1.01)
Reporting chronic disease		
CV pulmonary disease	286 (21.8)	
Metabolic disease	133 (10.2)	
Musculoskeletal disease	120 (9.2)	
Depression	170 (13.0)	
Body mass index		
Normal weight	460 (49.0)	
Overweight	296 (31.5)	
Obese	183 (19.5)	
Psychological		
Perceived health status (range 1–5)		3.68 (0.81)
Perceived health benefits (range 8–56)		44.04 (7.91)
Mode of travel to work		
Walking one or more time/week	95 (7.3)	
Biking one or more time/week	188 (14.4)	
Driving one or more time/week	1026 (78.3)	
Public transit use one or more time/week	152 (20.3)	

AC: active commuting.

Table 2: Univariate influences on walking, biking, driving, and taking public transit to work, meeting physical activity recommendations via active transport modes.

Variable	Walking to work at least 1 time/week		Biking to work at least 1 time/week		Driving to work at least 1 time/week		Public transit to work at least 1 time/week		Meeting physical activity recommendations via active transport modes	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Demographic variables										
Age	0.97**	0.95–0.99	0.93***	0.92–0.95	1.04***	1.03–1.06	0.97**	0.95–0.99	0.93***	0.91–0.95
Income										
<$30,000/year (referent)	1		1		1		1		1	
$30,000–60,000/year	0.71	0.29–1.71	0.38**	0.20–0.71	1.1	0.52–2.32	0.67	0.32–1.41	0.32***	0.17–0.63
>$60,000/year	0.64	0.26–1.41	0.33***	0.18–0.60	1.94	0.94–4.05	0.46*	0.23–0.93	0.24***	0.13–0.45
Sex: female (male referent)	0.85	0.54–1.35	0.31***	0.22–0.43	2.88***	1.98–4.19	0.60**	0.41–0.87	0.28***	0.19–0.41
Race										
Non-Hispanic White (referent)	1		1		1		1		1	
Non-Hispanic Black	0.73	0.17–3.13	0.33	0.08–1.38	0.91	0.31–2.64	1.65	0.63–4.36	0.19	0.04–1.92
All other racial/ethnic groups	2.99**	1.44–6.25	3.04***	1.65–5.59	0.21***	0.11–0.39	2.32*	1.17–4.60	3.41***	1.77–6.57
Health-related variables										
Number of chronic disease	0.96	0.77–1.18	0.78*	0.65–0.94	2.13**	1.72–2.64	1.03	0.88–1.22	0.76*	0.61–0.96
Reporting chronic disease (no disease as referent)										
CV pulmonary disease	0.98	0.59–1.63	1.37	0.92–2.04	3.37***	2.20–5.16	0.88	0.58–1.33	0.58*	0.34–0.97
Metabolic disease	0.58	0.25–1.35	0.26***	0.11–0.60	4.20***	2.11–8.37	1.23	0.67–2.25	0.58*	0.35–0.97
Musculoskeletal disease	1.1	0.52-2.33	1.73	0.91–3.28	3.29***	1.70–6.37	1.21	0.66–2.21	0.34*	0.14–0.85
Depression	1.28	0.72–2.28	1.21	0.78–1.87	2.75***	1.64–4.63	0.68	0.44–1.09	1.14	0.67–1.93
Body mass index										
Normal weight	1		1		1		1		1	
Overweight	0.77	0.47–1.27	0.58**	0.39–0.85	1.34	0.88–2.04	0.98	0.64–1.51	0.62*	0.39–0.97
Obese	0.46*	0.23–0.93	0.26***	0.14–0.47	2.59**	1.40–4.79	0.77	0.44–1.34	0.35**	0.18–0.67
Psychological variables										
Perceived health status[a]	1.64**	1.24–2.17	1.98***	1.59–2.45	0.63***	0.49–0.80	0.87	0.69–1.11	1.64***	1.28–2.11
Perceived health benefits of AC	1.03	0.99–1.06	1.05***	1.03–1.08	0.98	0.95–1.01	0.99	0.97–1.02	1.04**	1.01–1.07

Note: $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$, [a]scale ranges 1 (poor) to 5 (excellent), and AC: active commuting.

and perceived health status (OR = 1.60, 95% CI = 1.17–2.20) as significant predictors of walking to work.

3.2. Biking to Work One or More Times/Week. The univariate influences for biking to work are found in Table 2. Similar to those walking to work, age was negatively associated with being a biker (OR = 0.93, 95% CI = 0.92–0.95) and females were less likely to bike to work than males (OR = 0.31, 95% CI = 0.22–0.43). Higher income status was associated with being a non-biker, with both the $30,000–$60,000 groups (OR = 0.38, 95% CI = 0.20–0.71) and the $60,000 and up group (OR = 0.31, 95% CI = 0.18–0.60) less likely to bike to work than the lowest income group (<$30,000/year). Those from "other" racial/ethnic groups were more likely to bike (OR = 3.04, 95% CI = 1.65–5.59) compared to non-Hispanic Whites. A greater number of chronic diseases was associated with being a non-biker (OR = 0.78, 95% CI = 0.65–0.94) while better perceived health status was associated with biking (OR = 1.98, 95% CI = 1.59–2.45). Those reporting metabolic disease (OR = 0.26, 95% CI = 0.11–0.60), overweight (OR = 0.58, 95% CI = 0.39–0.85), and obese status (OR = 0.26, 95% CI = 0.14–0.47) were less likely to report biking. Those with greater perceived health benefits of AC were more likely to be bikers (OR = 1.05, 95% CI = 1.03–1.08). A full multivariate model revealed a Nagelkerke R^2 of 0.27, with race ("other" racial/ethnic group OR = 2.40, 95% CI = 1.09–5.30), age (OR = 0.93, 95% CI = 0.92–0.95), income ($30,000–60,000/year OR = 0.31, 95% CI = 0.14–0.69; <$60,000/year

OR = 0.36, 95% CI = 0.16–0.78), perceived health status (OR = 1.95, 95% CI = 1.47–2.61), and AC health beliefs (OR = 1.05, 95% CI = 1.02–1.08) as significant predictors.

3.3. Driving to Work One or More Times/Week. Univariate analyses for driving to work are displayed in Table 2. Older age was associated with driving one or more times per week (OR = 1.04, 95% CI = 1.03–1.06), and those from "other" racial/ethnic groups were less likely to be drivers compared with non-Hispanic Whites (OR = 0.21, 95% CI = 0.11–0.39). Females were more likely to report driving compared to males (OR = 2.88, 95% CI = 1.98–4.19). A greater number of chronic diseases (OR = 2.13, 95% CI = 1.72–2.64) and poorer perceived health status (OR = 0.63, 95% CI = 0.49–0.80) were also associated with being a driver. Reporting cardiopulmonary disease (OR = 3.37, 95% CI = 2.20–5.16), metabolic disease (OR = 4.20, 95% CI = 2.11–8.37), musculoskeletal disease (OR = 3.29, 95% CI = 1.70–6.37), depression (OR = 2.75, 95% CI = 1.64–4.63), or being overweight (OR = 2.59, 95% CI = 1.40–4.79) was associated with being a driver. The full model resulted in a Nagelkerke R^2 value of 0.12, with race ("other" racial/ethnic group OR = 0.26, 95% CI = 0.13–0.55), age (OR = 1.03, 95% CI = 1.01–1.05), and perceived health status (OR = 0.62, 95% CI = 0.46–0.84) as significant predictors.

3.4. Public Transportation One or More Times/Week. Table 2 outlines the univariate influences on public transportation use. Similar to walking and biking, younger age was associated with being a public transit rider to work (OR = 0.97, 95% CI = 0.95–0.99). Those reporting a higher income were less likely to report public transit ridership compared with those at the lowest income level (OR = 0.46, 95% CI = 0.23–0.93). Females were less likely to be transit riders compared to males (OR = 0.60, 95% CI = 0.41–0.87), and those from "other" racial/ethnic groups were more likely to use transit compared with non-Hispanic Whites (OR = 2.32, 95% CI = 1.17–4.60). There were no health-related variables significantly associated with public transit use. The full model had a Nagelkerke R^2 of 0.06, with age (OR = 0.97, 95% CI = 0.95–0.99) as a significant predictor.

3.5. Meeting Physical Activity Recommendations via Active Commuting. The univariate analyses examining influences on meeting physical activity recommendations via AC are found in Table 2. Younger age was associated with meeting recommendations from AC (OR = 0.93, 95% CI = 0.91–0.95). Those earning \$30,000–60,000/year (OR = 0.32, 95% CI = 0.17–0.63) and greater than \$60,000/year (OR = 0.24, 95% CI = 0.13–0.45) were less likely to meet recommendations via AC compared with those in lower income groups. Females were less likely to meet recommendations relative to males (OR = 0.28, 95% CI = 0.19–0.41) and those in the "other" racial/ethnic group were more likely to meet recommendations compared with non-Hispanic Whites (OR = 3.41, 95% CI = 1.77–6.57). Participants reporting more chronic diseases (OR = 0.76, 95% CI = 0.61–0.96) and specifically cardiopulmonary (OR = 0.58, 95% CI = 0.34–0.97), metabolic (OR = 0.58, 95% CI = 0.35–0.97), or musculoskeletal disease (OR = 0.34, 95% CI = 0.14–0.85) were less likely to meet recommendations. Overweight (OR = 0.62, 95% CI = 0.39–0.97) and obese (OR = 0.35, 95% CI = 0.18–0.67) individuals were also less likely to meet recommendations from AC. Finally, those who perceived greater health benefits of AC (OR = 1.04, 95% CI = 1.01–1.07) and more positive personal health status (OR = 1.64, 95% CI = 1.28–2.11) were more likely to meet recommendations. The full model resulted in a Nagelkerke R^2 of 0.26, with perceived health status (OR = 1.53, 95% CI = 1.11–2.12), age (OR = 0.94, 95% CI = 0.92–0.96), higher income (\$30,000–60,000/year OR = 0.29, 95% CI = 0.13–0.68 and <\$60,000/year OR = 0.26, 95% CI = 0.11–0.59), and female gender (OR = 0.24, 95% CI = 0.15–0.39) as significant predictors.

4. Discussion

This study revealed a number of relationships between health-related outcomes and mode of travel to work. For the active transportation modes, there were a number of significant health-related influences while poorer health outcomes were associated with the more passive forms of travel. Understanding this relationship between choice of travel mode to work and health outcomes allows for the development of interventions to promote AC, with considerations for some of the health-related concerns addressed with this study. Among those who were active enough using active transportation modes, the noted health-related influences have considerable implications for public health.

There is clear evidence that physical activity participation [3], and specifically AC, can result in positive health outcomes [20, 21, 23, 25]. Other studies have also highlighted how continued physical activity participation and lifestyle choices can help to manage diabetes [48, 49] or cardiovascular disease [50–52] and help with cancer survivorship [53, 54]. In the current study, those with cardiopulmonary, metabolic and musculoskeletal disease, and depression were more likely to choose the more passive mode of travel, driving. Although these individuals are already impacted with these chronic conditions, the evidence suggests that increased physical activity can help with management of these diseases, and active travel could possibly contribute to achieving current public health recommendations for physical activity [46].

A small portion of participants in the current study reported meeting physical activity recommendations based on active transportation alone. Recent models attempting to understand the influences on physical activity participation have indicated that active transportation is an often overlooked method of accumulating recommended amounts of physical activity [55, 56]. Data from Kaczynski and colleagues indicated that adults reporting walking or biking for transportation at least once per week was associated with meeting physical activity recommendations [45], similar to a study by Berrigan and colleagues [57]. Other studies by Yang et al. [42] and Sahlqvist et al. [44] found a positive relationship between AC and daily physical activity participation and other studies have confirmed that more time spent in cars is associated with less time for physical activity participation [58]. Using public transportation can often serve as a catalyst for encouraging physical activity; for example, studies have

shown that using public transportation is associated with significant walking to and from transit [43, 59], and many individuals meet current physical activity recommendations through active transport to and from transit locations [43, 60]. Therefore, where feasible, public health campaigns may wish to encourage transit use over vehicular commuting, and this strategy and behavior may be more palatable to a large segment of the population who eschew the idea of biking and walking to work.

The majority of literature has focused on travel to work as a collapsed variable (e.g., walking and biking combined) and limited research as examined how specific modes of travel are related to health outcomes. A study examining the relationship between commuting and health outcomes in Sweden also found poorer health outcomes (sleep quality, everyday stress, and frequent illness) and perceived health associated with commuting via car [61]. Hemmingsson and colleagues [62] found that commuting via bicycle (but not walking) was associated with improved diabetes biomarkers among obese women. Frank and colleagues [63] also noted an elevated risk of obesity as time spent in cars increased, and time walking was associated with less obesity. Another study noted that switching to commuting by public transportation instead of a car increased energy expenditure and decreased body fat [64]. Zheng [65] also noted that those commuting by public transportation were 44.6% less likely to be overweight due to an increase in walking or biking associated with transit use. The present study adds to our understanding of how a variety of health-related factors and other demographic indicators are associated specifically with each of walking, biking, driving, and use of public transportation to work.

In the current study, race/ethnicity was a significant influence in several analyses. Limited research has addressed racial/ethnic differences in AC among adults, though a number of studies have noted different trends among youth traveling to school [66–68]. There is some evidence to suggest that there are differences in active transportation rates among adults [42, 57, 69] though there is little mode-specific information available. Other studies have indicated that rates of leisure time physical activity are lower in ethnic minority groups, and household or occupational activity is higher [70–74]. This would suggest that some social or cultural differences associated with AC may exist that have not been well-explored. The results of this study add to the limited research in this area regarding mode choice to work and race/ethnicity.

Employee health is often a significant concern for employers, with absenteeism, productivity, and health insurance benefits representing substantial costs. Interventions and strategies targeting physical activity participation in worksite settings have noted positive cost effectiveness outcomes associated with behavior change among employees [75–79]. Therein, there is notable interest in understanding all types of physical activity participation and influences among employed adults. As noted above, transportation related activity has many documented benefits and may be a time-effective approach to including physical activity into one's day for busy, working adults. Lachapelle and Frank [60] noted that employer-sponsored transit passes were associated with increased physical activity participation and other research has shown that workplace supports for AC can be a significant influence on participation [37, 80]. Employers may benefit from developing supporting policies or programs to encourage active forms of travel with the long term goal of reduced chronic disease morbidity and mortality among employees, for example, enacting policies regarding a flexible dress code to allow for active travel or develop incentive programs to reward employees who walk or bike to work.

This study also revealed that older adults and those in poorer health are less likely to actively travel to work. These findings present some challenges for practitioners looking to target this behavior within this population. Additional research may be needed to determine what the specific barriers to AC are for these populations in order to effectively improve behavior. For example, some research has shown that sidewalks, a key piece of the active transportation infrastructure in many communities, are more lacking in quality in lower income areas [81]. This may be especially problematic for older adults and persons with mobility impairments. Additionally, intervention strategies targeting AC could draw on the abundance of evidence found in physical activity interventions tailored for older adults or clinical populations. Some of the strategies that could be translated into an intervention targeting older employees or employees with chronic conditions could include use of social support from coworkers or family, improving self-efficacy for AC, providing education on the benefits of AC, enlisting healthcare providers' advice for increasing physical activity, use of self-monitoring and self-regulatory skills, and creating activity-friendly environments and policies [82–86]. Behavior-change theory should also be applied to target known mediators of AC (e.g., self-efficacy, outcome expectations) and improve the effectiveness of interventions [87].

Although this study yielded a number of important insights into the relationship between mode of transportation and health outcomes, there are some noteworthy limitations. The convenience sampling strategy used in this study may not have recruited respondents who are representative of the larger population, though rates of AC were similar to many of the other studies cited. Though the response rate was also low, it was calculated conservatively, as we were unable to determine how many of our email invitations were channeled into "junk/spam" mailboxes, thereby remaining unread by potential respondents. The cross-sectional study also limits our ability to draw causal inferences between AC and health outcomes. Although significant evidence has indicated the importance of environmental-level variables, these were not examined in the current study; however additional analyses with these variables are found elsewhere [80]. It should also be noted that dichotomizing the mode of travel as none versus one or more trips per week may have resulted in frequent walkers and bikers being categorized with those who walk or bike infrequently. Although those who actively commute even a limited amount of time are likely to be more similar to employees who walk or bike to work a lot than those who do not actively commute at all, these categorization decisions could present some challenges with interpreting our findings. Finally, we used self-reported, unvalidated measures of AC

behavior and health outcomes, which have limited objectivity. Future studies should use multiple measures of behavior and health outcomes to enhance the validity and reliability of the data.

Despite these limitations, this study contributes to the literature on how mode of travel to work is associated with health outcomes. Given the documented benefits associated with participation in physical activity and specifically AC, there is merit in examining the possible role these behaviors can contribute to reducing morbidity and mortality from the leading chronic diseases and associated healthcare expenditures. Community design and environmental supports, along with worksite programs and policies, can influence travel choices and should be considered as targets for interventions for improving population-level health.

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Research Article

Environmental Determinants of Bicycling Injuries in Alberta, Canada

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This study examined environmental risk factors for bicycling injuries, by combining data on bicyclist injuries collected by interviews in the emergency department (ED) with street-level environmental audits of injury locations, capturing path, roadway, safety, land use, and aesthetic characteristics. Cases were bicyclists struck by a motor vehicle (MV) or with severe injuries (hospitalized). Controls were bicyclists who were not hit by a car or those seen and discharged from the ED, matched on time and day of injury. Logistic regression odds ratios (ORs) adjusted for age, sex, peak time, and bicyclist speed with 95% confidence intervals (CIs) were estimated to relate injury risk to environmental characteristics. Factors contributing to MV events included greater traffic volume (OR 5.13; 95% CI [1.44, 18.27]), intersections (OR 6.89; 95% CI [1.48, 32.14]), retail establishments (OR 5.56; 95% CI [1.72, 17.98]), and path obstructions (OR 3.83; 95% CI [1.03, 14.25]). Locations where the road was in good condition (OR 0.25; 95% CI [0.07, 0.96]) and where there was high surveillance from surrounding buildings (OR 0.32; 95% CI [0.13, 0.82]) were associated with less severe injuries. These findings could be used by bicyclists and transportation planners to improve safety.

1. Introduction

Physical activity, such as bicycling, provides health benefits for all ages [1, 2]. Bicycling can reduce the risk of all-cause mortality independent of participation in other types of leisure activity [1, 2]. Despite its potential to improve health, rates of bicycling vary widely by country and between cities [3–6]. Individual-level characteristics (e.g., gender, age, and income), nonmodifiable factors (e.g., climate and geography), and environmental characteristics, including urban design and safety, contribute to these variations and influence whether people choose to bicycle [7, 8].

The inherent injury risks associated with bicycling in part explain why more people do not cycle. Only 1.3% of Canadians cycled to work in 2006 [9]. Bicycling injuries are common and result in an important number of emergency department (ED) visits and hospitalizations [10–12]. Bicycling injuries involving motor vehicles (MVs) tend to result in severe injuries and may result in death [10]. Personal characteristics including age (<6 years or >39 years), sex (males), alcohol use, and high speed are known to be associated with severe bicycling injuries [10, 13, 14].

To date, the majority of injury risk studies have focused on individual-level risk factors with few taking into consideration upstream determinants of risk such as urban and transportation planning and policy [15]. Creating built environments that are safe and convenient for bicycling as well as other forms of physical activity is an example of an upstream intervention that has the potential to both

lower the incidence of injuries and increase levels of physical activity at the population level. While there is a plethora of evidence associating built environmental characteristics with physical activity behaviour [15, 16], limited evidence on the relationship between built environment and injury exists, especially for injuries involving bicyclists. Nevertheless, the available evidence suggests an increased risk of injury associated with bicycling on the sidewalk compared with bicycling off-road paths or trails [17, 18]—a finding which may be due to poor sidewalk maintenance or conflicts with pedestrians. Roundabouts have also been found to be particularly dangerous for bicyclists [19, 20], perhaps due to a high number of potential conflict points or driver distraction and other challenges while navigating the roundabout. Apart from these factors, there is a lack of data on built environmental determinants of bicycling injuries. This area of research has been identified as a priority in order to develop effective place-related interventions for activity promotion and injury prevention [8].

The purpose of this study was to examine the built environmental characteristics (e.g., road/path characteristics, natural features, and obstacles) of locations where bicycling injuries occurred in two urban Alberta cities, by combining data on injury circumstances with street-level environmental audits of crash locations. The objectives were to (1) compare the characteristics of locations where bicyclists were struck by a MV with those of locations where bicyclists were injured in non-MV-related incidents and (2) compare the characteristics of severe injury crash locations with those of nonsevere injury locations.

2. Materials and Methods

2.1. Study Design and Sample Recruitment. In this case-control study, participants were injured bicyclists of all ages who presented to any one of 7 EDs in Calgary (Alberta Children's Hospital, Foothills Medical Centre, Rockyview Hospital, Peter Lougheed Centre) or Edmonton (Stollery Children's Hospital, University of Alberta Hospital, North East Community Health Centre), Alberta, from May to October 2010. These EDs were chosen as they represent all the hospitals in Calgary and a sufficient number of sites in Edmonton to cover a representative catchment area in that city. In addition, the Foothills Medical Centre, Alberta Children's Hospital, University of Alberta Hospital, and Stollery Children's Hospital are designated adult and paediatric regional trauma centres for their respective areas.

Any injured bicyclist who presented to one of the study EDs was eligible. Eligible patients were identified using the Regional Emergency Department Information System and by reviewing ED records daily. Patients were excluded if they did not speak English, were cycling indoors, using a stationary exercise bicycle, were not riding the bicycle (e.g., cleaning or walking with the bike) at the time of the injury, or if they could not provide sufficient details about the crash location for auditors to visit the site. Bicyclists who were injured outside the established city limits of Calgary or Edmonton were also excluded due to feasibility issues in conducting the audits (i.e., distance). Following informed consent, eligible bicyclists were interviewed in the ED using a questionnaire developed for the study. The questionnaire was based on previous work on bicycle and motorcycle injuries [10, 21], and was pilot tested with a convenience sample of respondents. If bicyclists were missed in the ED, they were mailed a study information package and contacted by telephone. If they consented, a telephone interview was conducted. Participants were asked questions about the circumstances surrounding their crash, including the location, date, and time. Injury information was extracted from the patients' medical chart.

Two case definitions were used. The first case group included bicyclists injured in a collision with an MV. The second case group included bicyclists whose injuries required admission to a hospital unit after their ED presentation. If a bicyclist had a collision with an MV and was hospitalized, they were included in both case groups. Controls were recruited from the same EDs. A separate control group was selected for each case series. The first control group (for MV cases) was composed of bicyclists injured while riding on the road or the sidewalk but not struck by an MV. Bicyclists riding on the sidewalk were included as potential controls for MV cases because they were exposed to MVs even though they were not riding directly on the road (e.g., when crossing a street). The second control group (for severe cases) included bicyclists with minor injuries, regardless of riding location (e.g., bike paths) or mechanism of injury (MV or other). Cases and controls were individually matched based on time and day of the week, within two weeks prior to or following the case event. Each case was matched to as many as 3 controls; however, MV cases with severe injuries were matched with up to 6 controls (3 MV controls and 3 minor injury controls). We combined data on bicyclists' crash circumstances and injuries with information on the environmental characteristics of the crash locations.

2.2. Environmental Audits of Crash Locations. Street-level data were collected by auditing crash locations using the Systematic Pedestrian and Cyclist Environment Scan (SPACES), which has been demonstrated to have acceptable levels of interrater reliability [22]. Auditors recorded information for both sides of a street segment. Side 1 was defined as the bicyclist's direction of travel. If the direction of travel was unknown, auditors agreed on which side to record as side 1. In general, the area under observation was approximately equal to one street block; however, this varied depending on the location. An additional audit form (see Supplementary Material, available online at doi:10.1155/2012/487681) was created to record features thought to be related to bicycling that were not captured by the SPACES. Trained research assistants (RAs) visited the locations for each matched set at the same time of day as the case injury event, as soon as possible after the event. When resources permitted, two RAs visited the sites and conducted the audits separately in order to assess interrater reliability. One RA was blinded to the case-control status of the location, and their data were used for the analysis. The environmental features examined

Table 1: Definitions of environmental characteristics assessed in audits of bicycling injury locations.

Variable	Definition
Traffic speed	≤30 km/hr versus >30 km/hr estimated average vehicle speed.
Traffic volume	Number of vehicles per hour; 3 categories: (1) low (≤250 vehicles/hr); (2) medium (250–749 vehicles/hr); (3) high (≥750 vehicles/hr).
Bicyclist volume	No bicyclists observed at location versus at least one bicyclist.
Path type	Sidewalk, multiuse path (shared by bicyclists and pedestrians) with markings (e.g., center line, stencils), or without markings.
Path location	For each side 3 categories: (1) within 1 metre of roadway; (2) between 1 and 3 metres; (3) >3 metres.
Path material	For each side, continuous or slab concrete and bitumen (asphalt) versus gravel and grass.
Path/road slope	Flat versus moderate or steep slope (for each side of path).
Path/road condition	Good versus moderate, poor, or under repair (for each side of path).
Path obstructions	For each side, presence of permanent obstructions (poles, signs, trees, benches, tables, fences) versus none.
Bike lane	Marked designated bicycle lane on roadway versus no marked lane.
Roadway lanes	1–3 lanes versus 4 or more lanes.
Curb	For each side 3 categories: (1) mountable curb; (2) nonmountable; (3) no curb. Reference category was mountable curb.
Traffic control devices	Presence of traffic control devices (roundabout, speed bump, chicanes/chokers, lane narrowing, and signals) versus no traffic controls.
Crossing	Presence of crossings (zebra, signals, bridge) versus no crossings.
Crossing aids	Presence of crossing aids (median, kerb extension) versus no crossing aids.
Other routes	Presence of alternate routes (lanes, path through park, no through road) versus no alternate route.
Intersections	Path-path and path-road intersection versus no intersection.
Streetlights	For each side, presence of street lighting versus no street lights.
Lighting on path	For each side, whether lighting covered the path or not.
Destinations	The location provided access to services or other destinations (e.g., park, convenience store, businesses) versus no destinations.
Surveillance	Location could be observed from ≥75% versus less than 75%.
Maintenance	Location gardens and verges were >75% well maintained versus less than 75%.
Verge trees	Presence of tress along the verge versus no trees.
Tree height	Tall or medium sized trees versus small trees.
Cleanliness	Location is clean (free of debris, garbage, graffiti, etc.) versus some uncleanliness.
Natural features	Presence of parks, green space, river, lakes, and so forth.
Path width	Path is 150 centimetres or less versus wider than 150 centimetres.
Age	≤14 years old versus ≥15 years old.
Bicyclist speed ("speed")	<15 km/hr versus ≥15 km/hr.
Bicycling faster than usual ("riding fast")	Bicyclist reported "cycling faster than usual" at the time of the incident.
Peak time	Peak time (Monday–Friday 06:31–08:30 and 16:01–18:00) versus off-peak time and weekends (Saturday and Sunday)

were divided into six groups including traffic factors (e.g., traffic volume), land use (e.g., types of buildings), path characteristics (e.g., path material), roadway characteristics (e.g., number of lanes), safety features (e.g., surveillance), and aesthetics (e.g., cleanliness). Table 1 presents a summary of the definitions of environmental characteristics assessed in the audits.

2.3. Statistical Analysis. The characteristics of locations were described by case and control status. Using a complete case analysis, conditional logistic regression was used to examine the effect of each exposure (i.e., 37 environmental characteristics) on the outcomes of interest while controlling for confounders. The number of matched sets in the study limited the number of potential independent variables that could be examined in the conditional logistic regression. It has been suggested that for modeling, the number of independent variables should not exceed 10% of the number of participants in the least frequent outcome category (in this analysis, cases) [23]. Given our matched design, this

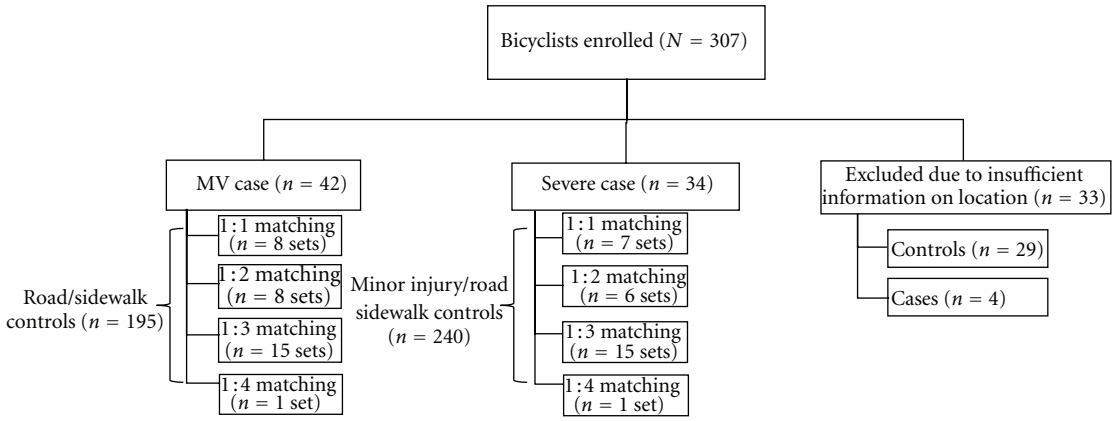

Figure 1: Study sample selection process for matched cases and controls.

guideline was applied to the number of discordant sets [24]. It has also been suggested that the "rule" can be relaxed, allowing the researcher to explore more independent variables to assess confounding [25]. We adopted this approach given the importance of considering known individual risk factors for bicycle injuries. Potential confounders were added to the model individually, and if any of the confounders changed the crude estimate by >15% [25], it was retained. If more than one variable changed the estimate by 15%, the one which produced the greatest change was retained. Potential confounders included age, sex, bicycling faster than usual, and self-reported bicyclist speed [10, 26, 27]. Although alcohol use has been shown to be associated with severe bicycling injuries, it was not included as a potential confounder because of its low prevalence in the study sample. "Not applicable" or "unknown" data were treated as missing values and thus were not included in the logistic regression estimates. Adjusted odds ratios (ORs) and corresponding 95% confidence intervals (CIs) were calculated.

To adjust for multiple confounders simultaneously, we conducted a sensitivity analysis where the matching was unlinked. Unconditional logistic regression was used, and the original matching criteria were added as a variable in the model, in addition to potential confounders. The results of the unmatched analysis were compared with the matched results. Again, we relaxed the 10% "rule" [23], and potential confounders were added to the model following a 5–9 event per variable guideline [24, 25, 28].

Ethical approval was granted from the University of Calgary Conjoint Health Research Ethics Board and the University of Alberta Health Research Ethics Board. All patients gave informed consent.

3. Results

In total, 274 injury sites were audited (Figure 1). There were 151 audits conducted in Edmonton, and 123 in Calgary. Six MV cases were also included in the severe case group. Twenty-nine controls and 4 cases were excluded from the study because they did not provide enough details about the crash location for auditors to visit the sites. We chose to report differences of at least 20% in the proportions of either case group and associated controls with a particular feature (Table 2) and estimates that suggested at least a 50% change in the odds of MV collision or severe injury (Tables 3 and 4). None of the estimates suggesting a change less than 50% were statistically significant.

3.1. Characteristics of Case and Control Locations. Table 2 indicates that, compared with controls, a greater proportion of MV case sites had estimated vehicle speeds above 30 km/hr. While the predominant land use was housing, MV case locations occurred more often close to retail establishments. A higher proportion of MV case locations had path obstructions, ≥4 lanes of traffic, or were intersections. Natural features were more prevalent at MV control compared with case sites. A higher proportion of severe injury control sites had sidewalks, roads in good condition, lighting over the path, or high surveillance. A higher proportion of severe case sites had ≥4 lanes of traffic.

3.2. Risk Factors for MV Collisions. From Table 3, in the matched analysis, compared with low traffic volume locations, medium and high volume sites were associated with higher odds of MV collisions. When the volume estimates were adjusted for sex (not shown), the estimated OR for high volume was 2.92 (95% CI [1.07, 7.96]), compared with low volume. The presence of retail or service establishments, path obstructions, parking restrictions, nonmountable curbs, traffic control devices, intersections, or destinations, each significantly increased the odds of being involved in a collision with an MV. The odds of a collision with an MV were lower in locations where natural features were present compared with locations where natural features were absent.

The results of the unmatched analysis were similar to the conditional logistic regression estimates (Table 3). The estimates for traffic volume, retail, path obstructions, destinations, and natural features were comparable, with some increase in precision demonstrated by narrower confidence intervals. After adjusting for multiple confounders the

Table 2: Bicycle crash location characteristics by case and control groups.

	MV controls $n = 195$	(%)	MV cases $n = 42$	(%)	Severe controls $n = 240$	(%)	Severe cases $n = 34$	(%)
Traffic and land use characteristics								
Estimated avg. speed > 30 km/hr	121	(62.1)	35	(83.3)	134	(55.8)	22	(64.7)
n/a	8	(4.1)	0	(0.0)	38	(15.8)	7	(20.6)
Unknown	25	(12.8)	1	(2.4)	25	(10.4)	1	(2.9)
Predominant feature								
Housing	114	(58.5)	17	(40.5)	122	(50.8)	15	(44.1)
Retail	7	(3.6)	10	(23.8)	12	(5.0)	5	(14.7)
Nature	34	(17.4)	4	(9.5)	58	(24.2)	6	(17.6)
Path characteristics (side 1)								
Path type								
No path	19	(9.7)	5	(11.9)	21	(8.8)	3	(8.8)
Sidewalk	137	(70.3)	30	(71.4)	154	(64.2)	20	(58.8)
Shared with markings	11	(5.6)	1	(2.4)	26	(10.8)	6	(17.6)
Shared no markings	28	(14.4)	6	(14.3)	39	(16.3)	5	(14.7)
Path location								
Within 1 m of road	114	(58.5)	30	(71.4)	128	(53.3)	16	(47.1)
Btw 1 and 3 m of road	33	(16.9)	6	(14.3)	33	(13.8)	7	(20.6)
>3 m from road	28	(14.4)	1	(2.4)	54	(22.5)	8	(23.5)
n/a	19	(9.7)	5	(11.9)	21	(8.8)	3	(8.8)
Unknown	1	(0.5)	0	(0.0)	4	(1.7)	0	(0.0)
Good condition	111	(56.9)	20	(47.6)	135	(56.3)	15	(44.1)
n/a	19	(9.7)	5	(11.9)	21	(8.8)	3	(8.8)
Any obstructions	79	(40.5)	22	(52.4)	103	(42.9)	13	(38.2)
n/a	19	(9.7)	5	(11.9)	21	(8.8)	3	(8.8)
Path characteristics (side 2)								
Path type								
No path	62	(31.8)	8	(19.0)	68	(28.3)	7	(20.6)
Sidewalk	110	(56.4)	26	(61.9)	128	(53.3)	14	(41.2)
Shared with markings	4	(2.1)	1	(2.4)	13	(5.4)	4	(11.8)
Shared no markings	16	(8.2)	6	(14.3)	24	(10.0)	4	(11.8)
n/a	3	(1.5)	0	(0.0)	6	(2.5)	5	(14.7)
Unknown	0	(0.0)	1	(2.4)	1	(0.4)	0	(0.0)
Path location								
Within 1 m of road	80	(41.0)	25	(59.5)	93	(38.8)	12	(35.3)
Btw 1 and 3 m of road	32	(16.4)	8	(19.0)	36	(15.0)	4	(11.8)
>3 m from road	17	(8.7)	0	(0.0)	32	(13.3)	6	(17.6)
n/a	65	(33.3)	8	(19.0)	74	(30.8)	12	(35.3)
Unknown	1	(0.5)	1	(2.4)	5	(2.1)	0	(0.0)
Good condition	85	(43.6)	21	(50.0)	103	(42.9)	13	(38.2)
n/a	65	(33.3)	8	(19.0)	74	(30.8)	12	(35.3)
Any obstructions	48	(24.6)	19	(45.2)	64	(26.7)	9	(26.5)
n/a	65	(33.3)	8	(19.0)	74	(30.8)	12	(35.3)
Roadway characteristics								
Marked bike lane	8	(4.1)	4	(9.5)	11	(4.6)	1	(2.9)
n/a	0	(0.0)	0	(0.0)	30	(12.5)	7	(20.6)
Unknown	3	(1.5)	1	(2.4)	3	(1.3)	1	(2.9)
Good road condition	132	(67.7)	25	(59.5)	144	(60.0)	13	(38.2)
n/a	0	(0.0)	0	(0.0)	30	(12.5)	7	(20.6)

Table 2: Continued.

	MV controls $n = 195$	(%)	MV cases $n = 42$	(%)	Severe controls $n = 240$	(%)	Severe cases $n = 34$	(%)
>4 lanes of traffic	62	(31.8)	23	(54.8)	70	(29.2)	15	(44.1)
n/a	0	(0.0)	0	(0.0)	30	(12.5)	7	(20.6)
Unknown	4	(2.1)	0	(0.0)	4	(1.7)	0	(0.0)
Mountable curb (side 1)	115	(59.0)	22	(52.4)	123	(51.3)	14	(41.2)
n/a	19	(9.7)	2	(4.8)	50	(20.8)	8	(23.5)
Unknown	2	(1.0)	0	(0.0)	2	(0.8)	0	(0.0)
Traffic control devices	130	(66.7)	18	(42.9)	133	(55.4)	15	(44.1)
n/a	0	(0.0)	0	(0.0)	30	(12.5)	7	(20.6)
Missing	4	(2.1)	0	(0.0)	2	(0.8)	2	(5.9)
Intersections	118	(60.5)	36	(85.7)	152	(63.3)	22	(64.7)
Unknown	6	(3.1)	0	(0.0)	88	(36.7)	12	(35.3)
Safety characteristics								
Lights over path (side 1)	114	(58.5)	27	(64.3)	129	(53.8)	15	(44.1)
n/a	47	(24.1)	10	(23.8)	75	(31.3)	12	(35.3)
Unknown	1	(0.5)	0	(0.0)	3	(1.3)	0	(0.0)
Lights over path (side 2)	106	(54.4)	30	(71.4)	126	(52.5)	13	(38.2)
n/a	46	(23.6)	5	(11.9)	68	(28.3)	12	(35.3)
Unknown	1	(0.5)	0	(0.0)	4	(1.7)	0	(0.0)
Destinations	92	(47.2)	30	(71.4)	116	(48.3)	17	(50.0)
Unknown	0	(0.0)	0	(0.0)	1	(0.4)	0	(0.0)
High surveillance	101	(51.8)	19	(45.2)	116	(48.3)	10	(29.4)
n/a	5	(2.6)	0	(0.0)	19	(7.9)	5	(14.7)
Aesthetic characteristics								
Natural features	105	(53.8)	14	(33.3)	133	(55.4)	22	(64.7)
Attractive for cycling	169	(86.7)	32	(76.2)	208	(86.7)	27	(79.4)
Difficult for cycling	48	(24.6)	14	(33.3)	66	(27.5)	12	(35.3)
Continuity	172	(88.2)	39	(92.9)	210	(87.5)	33	(97.1)
n/a	1	(0.5)	0	(0.0)	1	(0.4)	0	(0.0)
Unknown	7	(3.6)	0	(0.0)	7	(2.9)	0	(0.0)

estimates for services, parking restrictions, curb design, and traffic control devices were no longer statistically significant.

3.3. Risk Factors for Severe Injury (Hospitalization). The matched analysis results in Table 4 suggest that traffic volume may be related to severe injuries; however, the result was not statistically significant. The presence of a retail establishment increased the odds of severe injury. Locations with a multiuse path had lower odds of severe injury compared with locations with a sidewalk. Good road conditions, compared with poor road condition, lowered the odds of severe injury. Nonmountable curbs increased the odds of severe injury.

The unmatched analysis results were similar to the matched results. The presence of retail land use remained an important predictor of severe injuries, while good road condition still reduced the odds of severe injury. The presence of street lighting and high surveillance from surrounding buildings both had a point estimate that indicated a reduction in the odds of a severe injury.

3.4. Audit Data Interrater Reliability. Ninety-seven locations were audited by two observers. Interrater agreement was generally high (≥95%); most items had a 1%-2% difference in responses. Items with ≥5% differences between raters included path condition, slope, and obstructions. For land use, path, and roadway characteristics, Kappa (κ) ranged from 0.3 for presence of offices and cleanliness to 0.9 for schools and number of lanes; overall, 78% of items had at least substantial agreement ($\kappa \geq 0.61$). For MV cases the proportion of items with substantial agreement was 60%, compared with 73% for controls. For severe cases and minor injury controls, 76% of items had substantial agreement.

4. Discussion

This study provides a comprehensive description of the locations where bicycling injuries occurred, bringing attention to built environmental features that increase the likelihood of a bicyclist-MV collision or severe injury. Our results show

Table 3: Matched and un-matched logistic regression estimates of the association between environment risk factors and MV/bicyclist collisions.

	Matched OR	95% CI	Adjustment factors	Un-matched OR	95% CI	Adjustment factors
Traffic volume						
Low[a]	1	Reference	[b]	1	Reference	[b]
Med[a]	5.13*	1.44, 18.27	Riding fast	3.49*	1.37, 8.88	Age
High[a]	2.34	0.75, 7.24	Riding fast	2.83*	1.24, 6.42	Age
High speed limit (>30 km/hr)	3.18	0.62, 16.41	[b]	2.59	0.87, 7.71	[b]
Land use						
Offices	8.8	0.99, 78.16	[b]	3.01	0.73, 12.36	Age, day/time and riding fast
Retail	5.56*	1.72, 17.98	Age	7.54*	3.15, 18.03	Age and speed
Industry	2.07	0.28, 15.43	[b]	3.70	0.48, 28.82	Age and speed
Services	3.80*	1.29, 11.69	[b]	2.02	0.96, 4.23	Age
Nature	0.38	0.14, 1.00	Speed	0.44*	0.21, 0.91	[b]
Path characteristics (side 1)						
Type of path						
Sidewalk	1	Reference		1	Reference	
No path	1.66	0.14, 19.75	Age	1.30	0.43, 3.89	Speed
Multi-use path[#]	0.63	0.16, 2.51	Age	1.05	0.41, 2.68	Speed
Path location (distance from road)						
Within 1 m	1	Reference		1	Reference	
Btw 1 and 3 m	1.02	0.26, 3.95	Sex	0.40	0.14, 1.12	Age and day/time
>3 m	0.17	0.02, 1.53	Age	0.16	0.02, 1.29	Age and day/time
Sloped path	1.60	0.35, 7.36	[b]	1.14	0.35, 3.71	Riding fast
Path obstructions	1.05	0.38, 2.93	Age	1.80	0.88, 3.70	[b]
Path characteristics (side 2)						
Type of path						
Sidewalk	1	Reference		1	Reference	
No path	0.38	0.12, 1.26	Riding fast	0.68	0.28, 1.68	Age and speed
Multi-use path[#]	0.61	0.10, 3.78	Riding fast	1.69	0.59, 4.85	Age and speed
Sloped path	0.15	0, 1.99	[b]	0.72	0.18, 2.98	Day/time, riding fast and speed
Path obstructions	3.83*	1.03, 14.25	[b]	2.59*	1.13, 5.90	Speed
Roadway characteristics						
Designated bike lane	0.64	0.10, 4.19	[b]	1.83	0.42, 8.02	Day/time, riding fast and age
Parking restrictions	3.88*	1.31, 11.55	[b]	1.74	0.85, 3.55	Age
Curb						
Mountable	1	Reference		1	Reference	
Not mountable	3.03*	1.04, 8.82	Sex	1.35	0.65, 2.82	Riding fast
No curb	0.84	0.13, 5.59	Sex	0.55	0.12, 2.56	Riding fast
Curb cuts	2.71	0.84, 8.72	[b]	0.82	0.38, 1.78	Riding fast and age
Traffic control devices	2.74*	1.02, 7.35	Riding fast	1.59	0.74, 3.45	Age and day/time
Intersection	6.89*	1.48, 32.14	[b]	2.83*	1.11, 7.20	Age
Crossings	1.68	0.62, 4.54	[b]	1.54	0.73, 3.26	Age and day/time
Crossing aids	0.4	0.10, 1.52	[b]	0.43	0.16, 1.18	Age and speed
Safety characteristics						
Street lights (side 2)	2.38	0.51, 10.99	[b]	1.54	0.43, 5.58	Age
Lighting over path (side 2)	1.03	0.30, 3.53	[b]	1.70	0.69, 4.16	[b]
Destinations	2.4	1.01, 6.00*	Sex	2.35*	1.11, 4.97	Riding fast

Table 3: Continued.

	Matched OR	95% CI	Adjustment factors	Un-matched OR	95% CI	Adjustment factors
Aesthetic characteristics						
>1 tree/block (side 1)	3.25	0.37, 28.46	[b]	1.71	0.63, 4.63	Riding fast
Tall trees (side 1)	2.27	0.26, 20.06	[b]	1.08	0.21, 5.45	Riding fast
Natural views	0.2*	0.07, 0.69	Age	0.43*	0.21, 0.86	[b]
Difficult for bicycling	2.00	0.68, 5.92	[b]	1.92	0.55, 6.66	Speed and day/time

MV: motor vehicle; OR: odds ratio; CI: confidence interval.
*Represents significance based on CI not including the null value.
[a]Low volume: ≤250 vehicles/hr, medium volume: 250–749 vehicles/hr, high volume: ≥750 vehicles/hr.
[b]If model could not accommodate the addition of one or more covariates or there was no evidence of confounding, the crude estimate was retained.

that traffic volume is a significant risk factor for bicycle-MV collisions. Medium and high volume presented at least a twofold increase in the odds of collision compared with low volume roads. At intersections the odds of collision were much higher than at nonintersection locations. Good road conditions were associated with a reduction in the odds of severe injury. When we examined the odds ratio estimates associated with various types of land use, bicyclists were more at risk near retail establishments. Some aesthetic and safety items, such as streetlights and high surveillance showed a 30%–40% reduction in the odds of severe injury. We examined the effect of several potential confounders previously shown to be related to bicycling injuries: age, sex, self-reported bicyclist speed, bicycling faster than usual, and time of day [10, 12, 29]. In both the matched and unmatched analyses, adjustment for age had the greatest impact on the magnitude of the odds ratio estimates between the environmental characteristics and injury. This is consistent with other research where age has been identified as one of the major risk factors for injury in bicyclists [10, 11].

The estimates for high traffic volume were lower than those for medium volume, which may be related to road configuration. High volume roads might be thoroughfares where traffic flow is uninterrupted (e.g., highways), creating fewer opportunities for bicyclists and vehicles to cross paths. Alternatively, medium volume locations might be areas with many intersections, presenting more opportunities for encounters. While few studies have directly examined the link between traffic volume and bicyclist injury, it has been shown that roads designed to accommodate more traffic, such as arterial and divided roads, increase the overall risk of bicycle-vehicle collisions [30, 31].

Significantly lower odds of severe injury were observed for locations with multiuse paths compared with sidewalks in the matched analysis. Bicycle paths are reported to be favoured by many and have been linked to increased bicycling [32]. Other studies have found an increased risk of injury on sidewalks compared with off-road paths [17, 18, 33], a reduced risk of injury on paths compared with the road [34] and reduced odds of fatality or hospitalization when bicycling on a facility other than the road such as sidewalks, driveways, or multiuse paths [11, 29]. This growing evidence suggests that separating bicyclists from pedestrians and MVs with facilities like dedicated bicycling lanes can reduce the risk of injury.

For land use, the presence of retail establishments increased the odds of MV collisions and severe injuries. It is likely that these commercial sites have more traffic volume, population density, intersections, and distractions, creating opportunities for bicyclist-MV encounters. The relationship between commercial establishments and bicyclist-MV crashes has been found elsewhere with the presence of strip malls and big box stores (e.g., Wal-Mart), which were associated with an increased number of bicyclist-MV encounters compared with noncommercial locations [31]. This suggests that safety gains could be made by diverting bicyclists away from heavy traffic in commercial areas (e.g., parking lots), perhaps by locating parking lots at the rear of shops or by providing designated bicycle path access to shops.

Streetlights and surveillance were associated with significant reductions in the odds of severe injury. It may be that driving behaviour is influenced by having "eyes on the street" (e.g., people drive slower when they are aware of people watching them), resulting in fewer or less severe bicycling injuries. Alternatively, traffic volume may be higher in areas with less surveillance (e.g., arterial roads). While few studies have examined safety or aesthetic features and injuries together, some studies have examined the effect of street lighting. These studies have shown that severe injuries are more likely in unlit areas, and that lighting reduces injuries in rural areas [26, 35, 36]. It is important to keep this evidence in mind, especially in locations like Alberta where it is dark early in the morning and late in the afternoon for much of the year, which correspond to commuting times. This is an important finding from a planning perspective and suggests that more street lighting or better light coverage for roadways and pathways could help prevent injuries.

When comparing the factors related to MV and severe injury outcomes we found that factors related to one outcome were not necessarily related to the other. Recognizing that features of the environment associated with MV collisions and severe injuries may differ from one another is important for planners, as it signals that multiple design elements need to be considered in order to reduce the occurrence of each type of event. Focusing on the factors that are identified as predictors of both outcomes is crucial.

Table 4: Matched and un-matched logistic regression estimates of the association between environment risk factors and severe bicyclist injury.

	Matched OR	95% CI	Adjustment factors	Un-matched OR	95% CI	Adjustment factors
Traffic volume						
Low[a]	1	Reference		1	Reference	
Med[a]	3.20	0.63, 16.25	Riding fast	1.22	0.37, 4.01	Age
High[a]	2.01	0.51, 7.94	Riding fast	1.53	0.61, 3.85	Age
Avg. traffic speed (>30 km/hr)	1.7	0, 3.91	[b]	4.13	0.89, 19.11	Speed and riding fast
High speed limit (>30 km/hr)	1.85	0.46, 7.47	[b]	1.14	0.41, 3.21	[b]
Land use						
Retail	8.12*	1.66, 39.7	[b]	2.53*	1.10, 5.83	Age
School	0.24	0.03, 1.05	[b]	0.35	0.04, 2.84	Age and speed
Nature	0.41	0.14, 1.24	Age	1.25	0.60, 2.57	[b]
Path characteristics (side 1)						
Type of path						
Sidewalk	1	Reference		1	Reference	
No path	1.29	0.24, 6.81	Riding fast	1.10	0.30, 4.02	[b]
Multi-use path[#]	0.24*	0.08, 0.77	Riding fast	1.30	0.59, 2.87	[b]
Path location (distance from road)						
Within 1 m of road	1	Reference		1	Reference	
Btw 1 and 3 m of road	0.54	0.14, 2.09	Age	1.68	0.59, 4.81	Speed
>3 m from road	0.48	0.16, 1.45	Age	1.42	0.52, 3.85	Speed
Sloped path	0.42	0, 1.63	[b]	1.83	0.71, 4.76	Speed
Path obstructions	0.36	0.13, 1.01	Age	0.81	0.38, 1.74	[b]
Path characteristics (side 2)						
Type of path						
Sidewalk	1	Reference		1	Reference	
No path	1.14	0.36, 3.62	Age	0.86	0.28, 2.65	Age and speed
Multi-use path[#]	0.40	0.10, 1.68	Age	2.12	0.73, 6.21	Age and speed
Path location (distance from road)						
Within 1 m	1	Reference		1	Reference	
Btw 1 and 3 m	0.11	0.01, 1.64	Age	0.96	0.28, 3.31	Speed
>3 m	0.36	0.06, 2.06	Age	1.95	0.59, 6.49	Speed
Sloped path	1.11	0.23, 5.32	[b]	1.93	0.65, 5.75	[b]
Path obstructions	3.32	0.65, 16.9	[b]	1.10	0.45, 2.73	[b]
Roadway characteristics						
Good road condition	0.25*	0.07, 0.96	[b]	0.43*	0.19, 0.96	[b]
>4 lanes of traffic	2.59	0.80, 8.4	[b]	2.31	0.87, 6.16	Age, speed, and riding fast
Curb						
Mountable	1	Reference		1	Reference	
Non-mountable	4.51*	1.08, 18.8	Sex	1.62	0.71, 3.71	[b]
No curb	0.34	0.04, 3.17	Sex	0.44	0.05, 3.53	[b]
Crossings	1.1	0.39, 3.15	[b]	1.85	0.75, 4.58	Speed
Other routes	0.44	0.16, 1.16	Riding fast	0.75	0.34, 1.68	Speed
Safety characteristics						
Street lights (side 1)	1.90	0.70, 5.12	Age	0.78	0.34, 1.79	Speed
Street lights (side 2)	0.89	0.29, 2.77	[b]	0.38*	0.15, 0.97	Age and speed
Lighting over path (side 1)	0.36	0.07, 1.86	[b]	0.43	0.15, 1.22	Sex
Lighting over path (side 2)	0.58	0.16, 2.15	[b]	0.39	0.15, 1.04	Sex
High surveillance	0.53	0.17, 1.71	[b]	0.32*	0.13, 0.82	Speed

Table 4: Continued.

	Matched OR	95% CI	Adjustment factors	Un-matched OR	95% CI	Adjustment factors
Aesthetic characteristics						
>1 tree/block (side 1)	2.19	0.41, 11.78	[b]	2.07	0.57, 7.53	Speed
>1 tree/block (side 2)	1.98	0.22, 17.88	[b]	1.75	0.48, 6.42	Speed
Clean	1.79	0.59, 5.43	Age	1.52	0.60, 3.85	[b]
Attractive for bicycling	0.4	0.13, 1.23	[b]	0.49	0.18, 1.32	Age and speed
Continuity of path	3.0	0.35, 25.96	[b]	2.34	0.29, 19.04	Age, speed, and riding fast

MV: motor vehicle; OR: odds ratio; CI: confidence interval.
*Represents significance based on CI not including the null value.
[a]Low volume: ≤250 vehicles/hr, medium volume: 250–749 vehicles/hr, high volume: ≥750 vehicles/hr.
[b]If model could not accommodate the addition of one or more covariates, the crude estimate was retained.

4.1. Limitations. This study has some limitations that require discussion. We collected information on potential confounders; however, it is possible that factors we did not anticipate or collect information on could be independently related to the outcomes and the characteristics we examined. One such possible confounder is bicyclist volume. While we did count bicyclists, the majority of the sites we visited had low/no bicyclist volume. Given the lack of information on this factor, it was not included in the adjusted analysis. It has been suggested that greater bicyclist volume is associated with a reduction in the number of injuries (i.e., the "safety in numbers" effect); however, a causal relationship has not been established [4, 37, 38]. We did examine bicyclist volume as an independent predictor of MV events and severe injuries and did not find evidence of an association.

To determine the audit sites, we relied on the participant's description of the crash location. Some patients had trouble remembering the exact crash site or their direction of travel at the time. The information they provided is subject to limitation of recall, especially if the patient was interviewed sometime after the event. However, the average time between the injury and the audit date was 48 days, and nearly 80% of audits were conducted within 2 months of the injury date. Many interviews were conducted by telephone, and resources did not permit us to provide maps for patients to pinpoint their crash site.

Bicyclists who could not provide sufficient details about the crash location for it to be accurately identified were excluded from the analysis. If these bicyclists differed systematically from those included in the sample, it could introduce selection bias. To examine this potential bias, the excluded bicyclists were compared with the overall study sample. Few differences were detected between the two groups; compared with the study sample, a slightly higher proportion of excluded bicyclists were 13–17 years old, and they had a lower proportion of helmet use. Because of these minor differences, it may be that there were fewer adolescents in our sample than would have been included otherwise. Adjustment for age in the analysis would have eliminated this concern. In addition, because excluded bicyclists made up a very small proportion of the overall sample, their exclusion is unlikely to have had any major effect on the findings.

While there is potential for misclassification of the built environment characteristics of audited locations, when we examined the reliability of the audit data from locations where two observers completed observations, there was no indication that items were inconsistently recorded. Kappa values indicated "substantial" to "almost perfect" agreement for the majority of items, and differences in agreement between case and control locations were minor. In addition, we used the data from the blinded auditor for all analyses, reducing the likelihood of observer bias.

5. Conclusion

The built environment cannot be overlooked in injury prevention strategies. Creating safe, activity friendly environments is vital to encouraging higher levels of physical activity participation [8], especially considering the obesity epidemic and the shift towards encouraging eco-friendly transportation. Our findings point to specific built environmental characteristics including traffic volume, land use, path designs, and roadway features as risk factors for MV collisions or severe injuries. This information should provide urban and transportation planners with robust evidence upon which to base decisions regarding environments that are safe and conducive to bicycling. Furthermore, by disseminating this information to end users, bicyclists will be aware of the dangers posed by certain features, enabling them to make safe route choices.

Abbreviations

ED: Emergency department
MV: Motor vehicle
OR: Odds ratio
CI: Confidence interval.

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