# Utilitarian Bicycling

## A Multilevel Analysis of Climate and Personal Influences

Meghan Winters, MSc, Melissa C. Friesen, MSc, Mieke Koehoorn, PhD, Kay Teschke, PhD

**Background:** Increasing utilitarian bicycling in urban areas is a means to reduce air and noise pollution, increase physical activity, and reduce the risk of chronic diseases. We investigated the impact of individual- and city-level characteristics on bicycling in Canadian cities to inform transportation and public health policies.

**Methods:** The study population included 59,899 respondents to the 2003 Canadian Community Health Survey (CCHS) living in cities with populations greater than 50,000. In 2005, data on individual characteristics were drawn from the CCHS, and city-level climate data from Environment Canada records. Separate multilevel logistic regression models were developed for the general (nonstudent) and student populations.

**Results:** The proportion of the urban population reporting bicycling in a typical week was 7.9%, with students cycling more than nonstudents (17.2% vs 6.0%). In the general population, older age, female gender, lower education, and higher income were associated with lower likelihood of cycling. More days of precipitation per year and more days of freezing temperatures per year were both associated with lower levels of utilitarian cycling (odds ratios [ORs] for every 30-day increase in precipitation=0.84, 95% confidence interval [CI]=0.74–0.94, and for every 30-day increase in freezing temperatures OR=0.91, 95% CI=0.86–0.97). There was less variation in the proportion of students who cycled by age and income, and only the number of days with freezing temperatures influenced bicycling.

**Conclusions:** Bicycling patterns are associated with individual demographic characteristics and the climate where one lives. This evidence might be useful to guide policy initiatives for targeted health promotion and transportation infrastructure.

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## Background

Urban transportation is a public and environmental health issue. In North America, where urban environments have been shown to influence physical activity,[1] more than two thirds of adults are inactive.[2,3] The associated healthcare costs exceed $24 billion in the United States[4] and $2 billion in Canada.[3] In addition, motor vehicles are the major sources of air and noise pollution in most cities.[5,6] Thus, there is growing interest in promoting walking and bicycling for utilitarian purposes such as work and errands, as a way to integrate physical activity into routine activities and reduce chronic disease, traffic-related pollution, and congestion. Cycling appears to offer a great opportunity for change, because cycling rates in North American cities are only 10% to 20% as high as those in European centers.[7] Although travel by bicycle introduces health risks through injuries[8] and exposures to air pollution,[9] the benefits of cycling have been shown to outweigh the risks.[10]

Developing policies that increase cycling rates requires knowledge of factors that influence ridership. Individual-level factors such as age, gender, income, education, ethnicity, cycling experience, and commute distance, as well as community-level factors such as safety, weather, traffic, topography, cycling infrastructure, proportion of students, and population density have been suggested as determinants of ridership.[11–22] However, much of the evidence to date is based on convenience samples[13,19,22] or surveys with low response rates.[17,18,21] An exception is the National Household Travel Survey, which provides transportation demographics for the United States, including data on age, gender, income, race, and trends over the last 4 decades.[15,23]

The current study uses a nationwide household interview survey, the 2003 Canadian Community Health Survey (CCHS), to examine both individual- and city-level factors potentially influencing utilitarian cycling

From the Department of Health Care and Epidemiology, Faculty of Medicine, University of British Columbia (Winters, Koehoorn, Teschke); School of Occupational and Environmental Hygiene, University of British Columbia (Friesen, Koehoorn, Teschke), Vancouver, BC, Canada

Address correspondence and reprint requests to: Meghan Winters, BSc, Department of Health Care and Epidemiology, University of British Columbia, Mather Building, 5804 Fairview Ave., Vancouver, BC, Canada, V6T 1Z3. E-mail: mwinters@interchange.ubc.ca.



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rates in urban settings. To the authors' knowledge, this is the first study to assess the relative and independent effects of climate and demographic characteristics on utilitarian cycling, employing a multilevel statistical approach to evaluate the factors influencing cycling in individuals nested within cities.

# Methods

## Sample

The CCHS 2.1 was conducted by Statistics Canada and sampled people 12 years and older who live in private dwellings (~98% of the population) in all 133 health authorities.[24,25] It used multistage cluster sampling with computer-assisted personal and telephone interviewing, and was administered throughout all regions at randomly selected times from January to December 2003 to avoid seasonal bias. The study population was restricted to respondents residing in health authorities serving the 53 Canadian cities with populations >50,000, as climate data were sparse for cities smaller than this. Cities meeting the minimum size criterion were identified using data from the 2001 Census[26] and located within a 2003 health authority boundary using Statistics Canada reference maps.[27] Cycling and demographic variables for the study population were extracted from the CCHS public release dataset.[24]

## Measures

The outcome variable, utilitarian cycling, was constructed from the CCHS survey question "In a typical week, how much time did you usually spend bicycling to work or to school or while doing errands?" As such, this study considers only utilitarian cycling, not cycling for recreational purposes. Because of the low proportion of respondents who cycled, the six survey response categories, based on the numbers of hours cycled per week, were collapsed into a dichotomous variable for utilitarian cyclists (all responses greater than none) and noncyclists (response=none). Respondents with missing, refused or "don't know" answers were excluded.

Both individual- and city-level variables were considered as potential predictors of utilitarian cycling. Individual characteristics included age; gender; student status (i.e., attending school, college, or university); education level achieved; household income; and language spoken (combined CCHS categories English, French, or both, and compared to "other"). Respondents with missing demographic data were excluded.

City-level variables included the total population for each health region and the proportion that were students, calculated using the CCHS data. Population densities (in population per square kilometer) for the corresponding Census Metropolitan Areas and Census Agglomerations were abstracted from the 2001 Census. Data on average climate conditions ("climate normals") based on at least 15 years of data between 1971 and 2000 were obtained from Environment Canada for the main weather station located in each city.[28] Climate variables included the average summer (June/July/August) maximum temperature; average winter (December/January/February) minimum temperature; average windspeed; and average annual number of days with each of the following: precipitation, rain, snow on the ground, and freezing temperatures. To replace climate data missing from some weather stations, the mean observed value for all noncycling respondents was imputed.[29]

## Data Analysis

Analyses were completed in 2006 using SAS 9.1 (SAS Institute, Cary NC, 2002) for descriptive and preliminary analyses and MLwiN 1.1 (Multilevel Models Project Institute of Education, Bristol, UK, 2001) for multilevel modeling. Using sampling details for the CCHS provided by Statistics Canada,[25] probability weightings were applied to account for nonproportional sampling and produce population estimates.

Simple logistic regression was used to determine the crude associations between utilitarian cycling and each explanatory variable, and select variables for multilevel models ($p$ to enter: $<0.20$). Co-linearity was explored between independent variables using Pearson correlation; where $r > 0.7$, only the variable most strongly associated with cycling was retained. The individual-level variables of household income and education level were not correlated in the data set. Student status modified the associations between cycling and age, income, and education; all analyses were stratified by student status.

Multilevel multiple logistic regression modeling was used to estimate the odds of utilitarian cycling as a function of both city and individual characteristics. The model used restricted integrated generalized least squares parameter estimations[30] and sample weighting, and obtained sandwich estimators for variance. MLwiN does not generate deviance statistics for logistic models, so inferences on model fit cannot be made.[30] Models were developed incrementally to evaluate the between-city variance at each level. The null model included a random effect term for city but no fixed effects. The next model included significant individual-level variables. Hierarchical models were run for each of the city-level variables separately, while adjusting for the significant individual-level variables. Finally, all significant city-level variables were entered into the model. The final parsimonious model included only those variables significantly ($p<0.05$) related to utilitarian cycling.

# Results

## Study Population

Of the 134,072 Canadians interviewed in the CCHS, 74,388 were from the 53 selected cities, and 72,374 provided valid responses for utilitarian cycling in a typical week. Of those, 59,899 individuals had complete information for demographic characteristics and were included in this analysis. The sample sizes in each city ranged from 551 to 2825.

## Descriptive Results

Figure 1 indicates the proportions of utilitarian cyclists in the 53 study cities. The percentage (weighted estimate) of the total urban Canadian population (students and nonstudents) who cycle in a typical week was 7.9%, ranging from a high of 13.3% in Victoria, British Columbia, to a low of 3.6% in Fredericton, New Bruns-

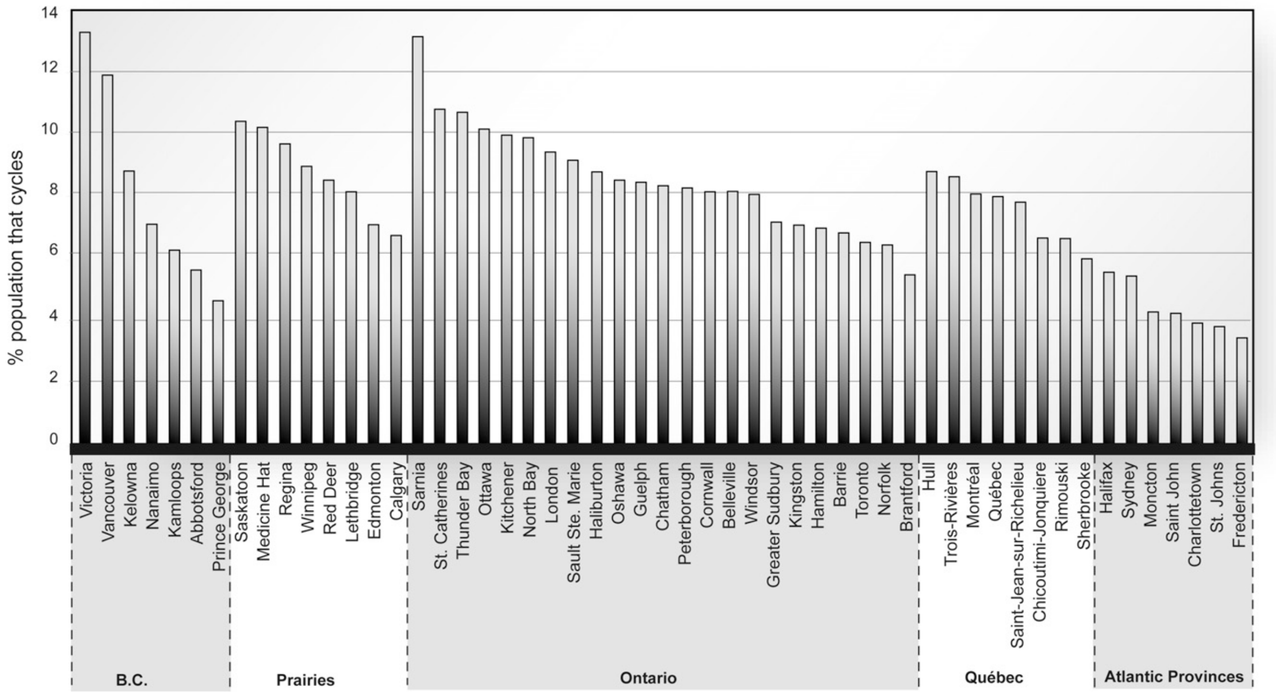


**Figure 1.** Percentage of the total population of 53 Canadian cities* reporting utilitarian cycling in a typical week. *Weighted estimates for Canadian cities with populations ≥50,000 in 2001 Census; study population defined as those living within the geographic boundaries of the health authority serving those cities.

wick. Nonstudents were less likely to cycle (6.0%) than students (17.2%).

Table 1 shows the distributions of individual-level variables in the general (nonstudent; $n$=50,977) and student populations ($n$=8922). As might be expected, students were significantly younger, from households with higher incomes, and had lower levels of education. Table 2 presents descriptive statistics for the city-level variables. There is considerable variability in all the climate variables.

There was co-linearity between average annual days with freezing temperatures and both average minimum winter temperature ($r = -0.91$) and days with snow on the ground ($r = 0.83$), and between average annual days with precipitation and rain ($r = 0.77$). The following variables were excluded from further analyses: the average minimum winter temperature, days with snow, and days with rain, because they were more weakly related to utilitarian cycling in simple logistic regressions. Each individual-level characteristic was significantly associated with utilitarian cycling, with the exception of household income for the student population, and language spoken in both populations (data not shown).

## Multilevel Analyses

Table 3 presents the results of the final parsimonious models of factors associated with utilitarian cycling. In the general population, women were only half as likely as men to cycle. Individuals aged 12–19 years were nearly three times more likely to cycle than those aged 20–29, and cycling decreased steadily with age. Education and household income were entered independently into the model. After adjusting for income and other demographics, people with higher education were more likely to cycle. More days of precipitation per year and more days of freezing temperatures per year were both associated with lower levels of utilitarian cycling (a 16% decrease in cycling for every 30-day increase in precipitation; and a 9% decrease in cycling for every 30-day increase in freezing temperatures). For the general population, the between-city variance in cycling in the null model was 0.092 (standard error [SE]=0.024), indicating significant heterogeneity in utilitarian cycling patterns. Adjusting for individual characteristics had only a negligible impact on the between-city variance (0.102, SE=0.026), but adding the climate variables reduced the variance to 0.070 (SE=0.020). Additional between-city variance remains to be explained.

Among students, more days of freezing temperatures per year were associated with lower levels of utilitarian cycling (a 6% decrease in cycling for every 30-day increase in freezing temperatures). Males, aged 12–19 years, and those who had not finished high school were most likely to cycle. The decline in cycling with age was weaker among students, and household income was not associated with cycling. In the student

**Table 1.** Distribution of individual-level variables[a] in the general (nonstudent) and student populations in 2003 in 53 Canadian cities with populations >50,000

| Individual-level variable | General (nonstudent) population ($n$=50,977) % | Student population ($n$=8922) % |
|---|---|---|
| **Gender** | | |
| Male | 50.1 | 47.7 |
| Female | 49.9 | 52.3 |
| **Age (years)** | | |
| 12–19 | 1.3 | 50.6 |
| 20–29 | 14.1 | 31.8 |
| 30–39 | 21.0 | 9.5 |
| 40–49 | 23.6 | 5.8 |
| 50–59 | 18.6 | 1.6 |
| 60–69 | 11.1 | 0.5 |
| 70–79 | 7.6 | 0.1 |
| ≥80 | 2.8 | <0.1 |
| **Household income** | | |
| <$15,000 | 6.5 | 8.2 |
| $15,000–$29,999 | 14.0 | 12.7 |
| $30,000–$49,999 | 21.9 | 18.3 |
| $50,000–$79,999 | 27.8 | 25.8 |
| ≥$80,000 | 29.9 | 35.0 |
| **Education** | | |
| Less than secondary | 18.5 | 42.2 |
| Secondary | 19.2 | 9.7 |
| Some post-secondary | 62.4 | 48.1 |
| **Language** | | |
| English and/or French | 98.3 | 99.0 |
| Other | 1.7 | 1.0 |

[a]Proportions weighted to account for multi-level cluster sampling.

population, the between-city variability in cycling in the null model was lower than in the general population, but still significant (0.065, SE=0.021) and similar to the variance after adjusting for individual characteristics (0.060, SE=0.023). After adding the single climate variable, the variance of the final model was 0.056 (SE=0.022), indicating that freezing temperatures account for a small amount of the between-city variance in cycling among students.

It would have been of interest to look at trends separately in the 12–15 age group (nondrivers) and in the 16–19 age group (potential drivers). Unfortunately, analysis was limited as the CCHS public release data set used aggregated age categories to protect the privacy of individuals, and thus the disaggregation of this age group was not possible.

## Discussion

Utilitarian cycling varied more than threefold across the 53 cities examined in this analysis, reinforcing the potential to change cycling rates.

In the Canadian urban population, older adults and women were much less likely to cycle for utilitarian purposes than young adults and men. These findings are similar to results from the U.S. National Household Travel Survey,[15] and market research in Toronto[18] and Vancouver.[21] The results contrast with data from European centers, where men and women are equally likely to cycle, and cycling rates vary little across age strata.[7] These differences highlight an opportunity in North America for recruitment of women and older adults to cycling as a mode of transportation.

Higher household incomes were independently associated with a lower likelihood of utilitarian cycling in the general population, whereas recent Toronto and Vancouver surveys instead reported a higher likelihood of cycling with increasing household income.[18,21] These city surveys presented only descriptive analyses, but no multivariable modeling to adjust for other key variables. Market surveys may be subject to participation bias; the response rate was only 20.9% in the Toronto study and was not reported in the Vancouver study. In another North American survey, the average commuter cyclist was characterized as a male professional with an income of more than $45,000.[22] The authors acknowledged the potential for participation bias because the questionnaire was distributed via e-mail listserves, newsletters, and magazines. The U.S.

**Table 2.** Summary statistics for city-level climate[a] and population variables, for Canadian cities with populations >50,000 ($n$=53 cities)

| City-level variables | Mean | Minimum | Maximum | IQR |
|---|---|---|---|---|
| # days per year with snow on the ground[b] | 95 | 8 | 150 | 61 |
| # days per year with >0.2 mm of precipitation | 154 | 99 | 216 | 25 |
| # days per year with >0.2 mm of rain | 113 | 26 | 171 | 20 |
| # days per year with freezing temperatures | 157 | 46 | 211 | 32 |
| Average wind speed (km/hr)[c] | 14 | 5 | 23 | 3 |
| Average winter minimum temperature (°C) | −11 | −22 | 2 | 6 |
| Average summer maximum temperature (°C) | 24 | 19 | 27 | 3 |
| Population of health authority | 344,000 | 59,000 | 2,228,000 | 234,000 |
| Population density (population per km$^2$) | 225 | 5 | 1208 | 214 |
| Percentage of population that are students (%) | 18.1 | 13.0 | 23.0 | 2.0 |

[a]Climate data based on ≥15 years of historical data from 1971–2001.
[b]Data missing for 5 health authorities in Ontario (5.7%), imputed value substituted: 97 days, mean value for all noncyclists.
[c]Data missing for 10 health authorities in Quebec and Ontario (16.9%), imputed value substituted: 14 km/hr, mean value for all noncyclists.
IQR, interquartile range.

**Table 3.** Final hierarchical models for the general (nonstudent) and student populations, showing odds ratios (OR) and 95% confidence intervals (CI) for urban utilitarian cycling

| | General (nonstudent) population $n$=51,073 | | Student population $n$=8931 | |
|---|---|---|---|---|
| **Variable** | **OR** | **95% CI** | **OR** | **95% CI** |
| **Individual-level variables** | | | | |
| **Gender** | | | | |
| Female | 0.46 | 0.42–0.50 | 0.51 | 0.45–0.56 |
| **Age (years)** | | | | |
| 12–19 | 2.98 | 2.37–3.66 | 1.78 | 1.47–2.16 |
| 20–29 | 1.00 | ref | 1.00 | ref |
| 30–39 | 0.85 | 0.76–0.96 | 1.01 | 0.80–1.28 |
| 40–49 | 0.81 | 0.73–0.92 | 0.81 | 0.60–1.11 |
| 50–59 | 0.54 | 0.48–0.62 | 1.00 | 0.58–1.72 |
| 60–69 | 0.40 | 0.34–0.48 | 0.62 | 0.21–1.86 |
| 70–79 | 0.31 | 0.26–0.39 | 1.68 | 0.40–7.00 |
| ≥80 | 0.15 | 0.09–0.24 | 0.86 | 0.02–32.14 |
| **Education** | | | | |
| Less than secondary | 1.04 | 0.88–1.15 | 1.51 | 1.21–1.87 |
| Secondary | 1.00 | ref | 1.00 | ref |
| Post-secondary | 1.25 | 1.12–1.37 | 0.85 | 0.69–1.05 |
| **Income** | | | | |
| <$15,000 | 1.73 | 1.44–1.98 | * | |
| $15,000–$29,999 | 1.31 | 1.17–1.52 | | |
| $30,000–$49,999 | 1.15 | 1.05–1.30 | | |
| $50,000–$79,999 | 1.00 | ref | | |
| ≥$80,000 | 0.92 | 0.84–1.03 | | |
| **City-level variables** | | | | |
| # days/year with precipitation[a] | 0.84 | 0.74–0.94 | * | |
| # days/year with freezing temperatures[b] | 0.91 | 0.86–0.97 | 0.94 | 0.89–1.00 |

[a]For ease of interpretation, the reported OR is based on a change of 30 days with precipitation, an increment close to interquartile range (26 days), and within the range of values (99–216 days).
[b]For ease of interpretation, the reported OR is based on a change of 30 days with freezing temperatures, an increment close to interquartile range (33 days), and within the range of values (46–211 days).
*Not significant in the student population.
ref, reference group.

National Household Travel Survey reported no association between income and cycling modal share[15]; its design was representative of the population, and the response rate was 41%.[23] The national, population-based CCHS used as the basis for this analysis was the least prone to selection bias, with an overall response rate of 80.7% and a sampling design intended to be provide valid estimates of health measures at the health region level.[24]

Certain climatic characteristics of cities were associated with utilitarian cycling in the general population, even after adjusting for individual characteristics. Fewer people cycled in cities with more days of precipitation or freezing temperatures. Other climatic conditions did not influence cycling: average summer maximum temperature and average wind speed. Rietveld and collegues[16] found no association between wind speed or rainfall and cycling in The Netherlands. The difference in results for rainfall may reflect true differences in the study populations. The Dutch are a unique population with the highest rates of cycling in the developed world (30% of all trips). Alternatively, it may be that climate conditions in The Netherlands are not as variable or extreme as in Canada, or that the difference is an artifact of using different measures (i.e., millimeters of rain vs. days with precipitation).

Utilitarian cycling patterns among students are more similar, regardless of the city and climate in which they live. This may be because students have fewer transportation options (i.e., cycling is economical) or that students make shorter trips more amenable to cycling (i.e., may live in close proximity to school), and concurs with a previous study examining commuter cycling in students that also found that weather is not a strong barrier.[19] Student status is an important modifier of cycling behavior, yet it is not often reported in cycling research; such data should be collected in the future.

The city-level population variables (population, percentage of students, and population density) were not significant determinants of utilitarian cycling in hierarchical models. Higher urban density is thought to encourage cycling, as trip distances are likely shorter and more bikeable.[31] Unfortunately, the measure of population density available in this study was based on census geographic boundaries, not health authority boundaries, so error in this variable may have affected the ability to detect an association. In addition, a city-level variable for population density may be at too aggregate a level to observe an effect, because density often varies widely between neighborhoods. Ecologic analyses in the United States have shown that cities with a higher proportion of students have higher cycling rates,[11,12,14] with suggestions that this is a result of unique cultures of college towns. The different rates of cycling among students and nonstudents in this study suggest that the observed association in the United States may be a result of higher cycling rates among students.

In this study, the individual and climatic variables in the final models explained 24% and 14% of the between-city differences in utilitarian cycling in the general and student populations, respectively. Other unmeasured factors, such as city-specific cycling initiatives or topography, may account for the remaining between-city differences.

The CCHS survey allowed for calculation of the proportion of the population who cycle for utilitarian purposes. This outcome measure differs from measures of modal share (proportion of trips made by bicycle) frequently used in the transportation literature. In a review of cycling trends in 27 Canadian cities, Pucher and colleagues[32] report the highest modal share in Victoria (4.8%) and the lowest in St. John's (0.1%). The highest proportion of utilitarian cyclists was in Victoria, and the second lowest in St. John's. The city with the lowest proportion in this study, Fredericton, was not included in Pucher's analysis. These parallel results illustrate that although the measures and methods differ, the conclusions about geographic differences in cycling are similar.

This study was facilitated by high-quality publicly available data from Statistics Canada and Environment Canada. Still, these data have limitations. Sampling in the CCHS was based on health authorities, so these cities were of necessity defined by these regions, and the extent to which rural residents might be included within the bounds of mainly urban health authorities is unknown. Due to the nature of the CCHS question (utilitarian cycling in a typical week), only regular cyclists are likely to be captured in the data. Although this study examined the effect of climate on utilitarian cycling, one could not evaluate the effect of daily weather changes on decisions about cycling on any particular day. A large number of respondents ($n$=11,558) were excluded from the analyses because income data were missing. Removing the income term from the final models and then including the individuals who had missing income data changed the odds ratio estimates by $<$10%, and did not change their direction or significance.

This study used available city-level administrative data to provide a broad geographic scope, and included 53 cities across Canada. Other potentially important features of cities (i.e., cycling infrastructure, land-use mix, topography) were not included because such data are not routinely collected in a standardized fashion.[31] These factors would be a welcome focus of future research, and will require labor-intensive primary data collection.

Even with these limitations, using the CCHS data has a significant advantage over other cycling studies, which have employed convenience sampling and had small sample sizes or low response rates. In addition, whereas other studies have included multilevel variables without considering the nested nature of the data[33] or have evaluated determinants of cycling in ecologic analyses,[11,12,14,16] hierarchical modeling was employed to evaluate influences on individual cycling behavior.

The results of this research indicate that there are strong differences in the proportions of the populations of Canadian cities who cycle, and in the proportions who cycle by gender, age, student status, income, education, and the climates of the cities they live in. These results can direct evidence-based policies to increase cycling. The demographic differences can be used to target segments of the population for promotion of cycling and for further studies to understand the factors that deter them from cycling (e.g., women with young children). Reductions in cycling due to precipitation and freezing temperatures might be countered by infrastructure supports (snow clearing and sanding or salting of ice along cycling routes, dedicated bike lanes, bike-friendly transit); bicycle gear (bicycle tires and brakes for rainy or icy conditions); and education about how to ride safely in inclement weather. In addition, cycling can be specifically promoted when warmer, drier seasons begin. Finally, overall differences in cycling between cities can be used as a basis for a comparative examination of policies, infrastructure, education, and culture related to cycling.

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