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The relationship between utilitarian walking, utilitarian cycling, and body mass index in a population based cohort study of adults: Comparing random intercepts and fixed effects models ☆

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ABSTRACT

Objective. To examine associations between utilitarian walking, utilitarian cycling, leisure time physical activity and body mass index (BMI).

Methods. Participants from the National Population Health Survey (NPHS) of Statistics Canada were interviewed by telephone every two years from 1994 to 2010. Analysis includes data from 6894 living participants aged 18–64 years. Fixed effects and random intercepts models examined the association between BMI, utilitarian walking, and utilitarian cycling, controlling for behavioral and sociodemographic factors.

Results. The final adjusted fixed effects models showed no significant relationship between utilitarian walking and BMI. In the unbalanced sample utilitarian cycling for 1 to 5 h per week ($b = -0.15$, 95% CI: −0.28 to −0.02), and more than 5 h per week ($b = -0.22$, 95% CI: −0.44 to 0.00) was significantly associated with BMI over time. In the fully balanced sample utilitarian cycling for 1 to 5 h per week ($b = -0.12$, 95% CI: −0.27 to 0.03), more than 5 h per week ($b = -0.16$, 95% CI: −0.45 to 0.13) was not significantly associated with BMI over time.

Conclusion. The results suggest that utilitarian walking is not related to BMI. The relationship between utilitarian cycling and BMI is less clear.

Introduction

In Canada between 2007 and 2009, 15% of adults (17% of men and 14% of women) accumulated the recommended 150 min per week of MVPA in 10-minute bouts (Colley et al., 2011). Physical inactivity contributes, in part, to increasing rates of overweight and obesity as measured by body mass index (BMI) (Shields et al., 2010). BMI is related to a number of health conditions (Pabayo et al., 2011; Katzmarzyk et al., 2001; Bryan and Katzmarzyk, 2009; Caballero, 2007). Low prevalence of physical activity and increasing rates of obesity among adults contribute to a growing call for population based public health strategies to prevent obesity (Fress, 2004; Bray, 2004).

The association between leisure time physical activity (LTPA) and BMI has been extensively studied (Fogelholm and Kukkonen-Harjula, 2000; Saris et al., 2003). However, increasing total physical activity by increasing LTPA is suggested to be limited because individuals may not be willing to increase the proportion of their leisure time spent doing physical activity. Researchers have suggested utilitarian transportation, as a form of physical activity that can be incorporated into daily routines, does not take away from leisure time and increases overall physical activity (Morrison, 2003; Sahlqvist et al., 2013).

Utilitarian transportation is defined by the Public Health Agency of Canada as any form of human-powered transportation resulting in energy expenditure, such as walking or cycling (Butler et al., 2006). Utilitarian transportation has the potential to contribute to the population meeting recommended levels of physical activity for health benefits. For adults, a number of cross-sectional studies have demonstrated that utilitarian transportation is associated with lower BMI, waist circumference, and improved blood lipid profiles (i.e., total cholesterol, low density lipoprotein cholesterol, and triglycerides), while controlling for LTPA (Barengo et al., 2006; Bassett et al., 2008; Hu et al., 2002; von Huth Smith et al., 2007). A recent review and meta-analysis identified a number of prospective cohort studies examining the relationship between active transportation and BMI in children (Bere et al., 2011; Heelan et al., 2005; Pabayo et al., 2010) did not identify any prospective cohort studies examining the relationship between active transportation and BMI in adults (Saunders et al., 2013). Therefore, there is a need for longitudinal studies examining the relationship between active transportation and BMI in order to gain a better understanding of the relationship between active transportation and weight among adults. The

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purpose of the present study is to examine the relationship between utilitarian walking, utilitarian cycling, and BMI in a population based prospective cohort of adults.

Methods

Design

Data for the analysis were available in the National Population Health Survey (NPHS) of Statistics Canada, a longitudinal nationally representative survey. Ethics approval is not required for data use. Statistics Canada ensures participant confidentiality by housing the data at secure Research Data Center (RDC) locations. A detailed description of the study methods has been published elsewhere (Tambay and Catlin, 1995). Briefly, a total of 17,276 persons from all ages were recruited in 1994/1995. Data were collected in telephone-administered self-report questionnaires. Participants were interviewed every two years. Question wording and procedures were the same across surveys. The present analysis includes data from 9 survey cycles spanning 1994/1995 to 2010/2011. Response rates of for cycles 1 through 9 ranged from 92.8% to 69.7%. The study population for the current analyses was limited to living adults aged 18–64 years during the study period.

Measures

Dependent variable

Participants reported their height and weight for each survey cycle. BMI was computed using the standardized formula (weight [kg] / height [m] (Shields et al., 2010)). BMI values, rather than standardized values or BMI cut points, were used to facilitate interpretation of the results. BMI values <10 (n = 7) and >65 (n = 6) were recategorized as having a BMI of 10 and 65, respectively.

Independent variables

Utilitarian walking and utilitarian cycling were measured by self-report to the question, "in a typical week in the past 3 months, how many hours did you usually spend walking/cycling to work or to school or while doing errands?" Utilitarian walking and cycling were categorized as 1) none, 2) <1 h, 3) 1–5 h and 4) >5 h.

Covariates

Data on LTPA were collected using a modified version of the Physical Activity Monitor (PAM) (Craig et al., 2002). The PAM has good test–retest reliability and criterion validity (Craig et al., 2002). In order for the LTPA measure to be on a weekly scale (comparable to utilitarian walking and cycling) the total minutes of LTPA in the past 3 months was divided by 12 to represent the number of 15-minute bouts of LTPA per week. The number of weekly 15-minute bouts of leisure time physical activity was included as a continuous variable in the models.

Additional covariates were selected based on previous research (Bryan and Katzmarzyk, n.d.) indicating association with utilitarian walking, cycling and BMI. These included age, marital status, children (yes/no), restrictions to activity (yes/no), education, student status (yes/no), income, smoking, residing in an urban or rural area, year, and the season when the participant responded to the survey.

Statistical analysis

All data was screened and cleaned according to standardized procedures using Stata version 12 in 2013 and 2014 (Tabachnik and Fidell, 2006). Unless specified all analyses are weighted using sampling and bootstrap weights provided by Statistics Canada (Tambay and Catlin, 1995). These weights represent the inverse probability of selection adjusted to compensate for non-response.

Analyses used random intercepts (Raudenbush and Bryck, 2002) and fixed effects models (Woolridge, 2002). The fixed effects approach to longitudinal data analysis differs from traditional methods used to examine relationships between utilitarian walking and utilitarian cycling and BMI. Longitudinal studies examining utilitarian transportation and BMI have used logistic or linear regression with cycle variables or random intercepts models (a form of multilevel model) (Pabayo et al., 2011; Bryan and Katzmarzyk, 2009). Use of linear or logistic regression for longitudinal data analysis is inappropriate because assumptions of independence are violated (Raudenbush and Bryck, 2002). Eq. (1) shows the model equation for fixed and random effects regression.

$$y_{it} = |\alpha_i + \chi'_{it}\beta + \varepsilon_{it} + \mu_i \quad (1)$$

where i and t represent individual and time dimensions, respectively. While α_i is a random variable, χ_{it} is a vector of covariates or explanatory variables, β is a vector of fixed population parameters, ε_{it} is the error term and μ_i is a term for individual-specific, time-constant effects. Fixed effects models remove all time constant effects μ_i (omitted or not) from the equation. These time constant factors are characteristics of the individual that do not change over time, sex of the participants for example. Random intercepts models assume that time constant factors μ_i are not correlated with α_i or ε_{it}. That is, individual specific effects are uncorrelated with the explanatory variables and error term of all time periods for the same individual. If the assumptions are met random intercepts models are more efficient than fixed effects models and are preferred (Fress, 2004). However, if the assumptions are not met, in random intercepts models, this suggests that there are omitted time constant variables and that a fixed effects model is preferred. A Hausman test was used to examine the random intercepts models and the fixed effects models (Hausman and Taylor, 1981; Hausman, 1978).

Both the random intercepts and fixed effects analyses were conducted using an unbalanced sample (i.e., data with missing repeated measures for at least one covariate), and a balanced sample (i.e., complete cases with no missing data for all variables across all survey cycles). A step up approach was used for model building with utilitarian walking, utilitarian cycling, and leisure time activity being entered one at a time into the models (i.e. the crude relationships between each of these three physical activity exposures with the outcome). Then all models were adjusted for year, season, age, sex, education, marital status, rural/urban, children in the home, mobility restrictions, student status, and smoking status.

Finally, sensitivity analyses were conducted including daily number of fruit and vegetable consumed in the models. The fruit and vegetable variable was only available for cycles 5 through 9 of the NPHS.

Results

After keeping participants with at least one year of data for utilitarian walking or cycling in the analysis the unbalanced sample included 6894 respondents. On average the respondents in the unbalanced sample had complete measures for all variables in 6 of the possible 9 survey cycles. Limiting the sample to those with complete data for all variables yielded the final sample size of n = 2066 participants in the fully balanced sample.

Table 1 shows the weighted sociodemographic characteristics for the unbalanced and fully balanced samples. The weighted mean age of participants for the unbalanced sample was 37.4 years; 49.3% of the weighted sample was male. The weighted mean BMI at baseline was 24.9 (*SD* = 4.39) and the weighted frequency 15-minute bouts of LTPA per week was 5.2.

The weighted trajectory of utilitarian walking indicated there was an increase of the estimated proportion participating in utilitarian walking from 1994 to 2006 (Fig. 1 shows the weighted trajectories of each category of utilitarian walking and utilitarian cycling). The weighted percent of the sample that did not walk for utilitarian purposes decreased from 41.6% to 35.7% during follow-up, while the percent of those walking 1–5 h per week increased from 24.3% to 33.1%. The weighted trajectories of cycling were low and decreased from 1994 to 2010 for each category of cycling. Taken together the weighted percent of any utilitarian cycling went from 7.9% in 1994 to 5.3% in 2010, a decrease of 33%.

Weighted unbalanced sample

Table 2 shows the results of the random intercepts and fixed effects regression in the unbalanced and fully balanced samples. The weighted fully adjusted random intercepts regression on the unbalanced data shows that respondents who engaged in utilitarian walking do not

Table 1
Sample characteristics from cycle 1 (1994/1995) of the Canadian National Population Health Survey.

	Unweighted sample size (n) unbalanced sample (n = 6894)	Weighted percent unbalanced sample (n = 6894)	Unweighted sample size (n) fully balanced sample (n = 2066)	Weighted percent fully balanced sample (n = 2066)
Body mass index (mean)	6894	Mean = 24.88	6894	Mean = 25.20
Utilitarian walking				
None	2722	39.49	823	40.26
<1 h per week	1121	16.26	313	15.32
1–5 h per week	1795	26.03	532	26.02
>5 h per week	1255	18.21	376	18.41
Utilitarian cycling				
None	6353	92.15	1887	92.32
<1 h per week	261	3.78	68	3.33
1–5 h per week	205	2.98	66	3.25
>5 h per week	75	1.09	22	1.10
Leisure time physical activity	6894	Mean = 5.19	6894	Mean = 5.12
Education				
Some higher education	2954	42.85	755	36.94
Diploma	2104	30.52	589	28.83
Bachelor's degree	1380	20.02	512	25.04
Post-graduate degree	396	5.74	170	8.34
Other	60	0.87	17	0.85
Income				
Less than $15,000	618	8.97	98	4.78
$15,000–$49,999	1952	28.32	477	23.32
$50,000–$79,999	3060	44.38	1002	49.00
Greater than $80,000	1264	18.33	468	22.91
Marital status				
Married	3918	56.83	1302	63.68
Living with partner	574	8.32	175	8.55
Single	1737	25.19	383	18.74
Widowed	78	1.13	23	1.13
Divorced/separated	588	8.53	161	7.90
Children in home				
Yes	4367	63.35	1410	68.97
No	2527	36.65	634	31.03
Age	6894	Mean = 37.38	6894	Mean = 39.12
Restrictions to mobility				
Yes	647	9.38	183	8.97
No	6247	90.62	1861	91.03
Student				
Yes	1062	15.41	280	13.69
No	5832	84.59	1764	86.31
Smoke				
Daily	1619	23.48	381	18.66
Sometimes	376	5.46	104	5.09
Not at all	4899	71.06	1559	76.25
Sex				
Male	3395	49.25	1065	52.11
Female	3499	50.75	979	47.89
Season of interview				
Winter	1861	27.00	522	25.56
Spring	0	0.00	0	0.00
Summer	3306	47.95	994	48.63
Fall	1727	25.05	528	25.81

have significantly different BMI than those who did not engage in utilitarian walking. This relationship held for all categories of utilitarian walking, less than 1 h per week ($b = 0.00$, 95% CI: −0.06 to 0.07), 1 to 5 h per week ($b = 0.00$, 95% CI: −0.05 to 0.05), and more than 5 h per week ($b = -0.04$, 95% CI: −0.10 to 0.03). Results indicate that utilitarian cycling for 1 to 5 h per week ($b = -0.18$, 95% CI: −0.29 to −0.06), and more than 5 h per week ($b = -0.24$, 95% CI: −0.45 to −0.04) was significantly associated with lower BMI over time.

In the weighted fully adjusted unbalanced fixed effect analysis, those who engaged in utilitarian walking do not have significantly different BMI than those who did not engage in utilitarian walking. This relationship held for all categories of utilitarian walking, less than 1 h per week ($b = 0.01$, 95% CI: −0.06 to 0.07), 1 to 5 h per week ($b = 0.00$, 95% CI: −0.06 to 0.05), and more than 5 h per week ($b = -0.05$, 95% CI: −0.11 to 0.01). Utilitarian cycling for 1 to 5 h per week ($b = -0.15$, 95% CI: −0.28 to −0.02), and more than 5 h per week ($b = -0.22$, 95% CI: −0.44 to 0.00) was significantly associated with BMI over time.

Weighted fully balanced sample

The weighted fully adjusted random intercepts regression on the fully balanced data showed that utilitarian walking less than 1 h per week ($b = 0.02$, 95% CI: −0.07 to 0.11), 1 to 5 h per week ($b = -0.01$, 95% CI: −0.09 to 0.07), and more than 5 h per week ($b = -0.06$, 95% CI: −0.15 to 0.03) was not associated with BMI. Utilitarian cycling for 1 to 5 h per week ($b = -0.14$, 95% CI: −0.29 to 0.02), and more than 5 h per week ($b = -0.19$, 95% CI: −0.47 to 0.09) was not significantly associated with a lower BMI trajectory.

In the weighted fully adjusted fully balanced fixed effect analysis, utilitarian walking less than 1 h per week ($b = 0.02$, 95% CI: −0.06 to 0.10), 1 to 5 h per week ($b = -0.01$, 95% CI: −0.09 to 0.06), and

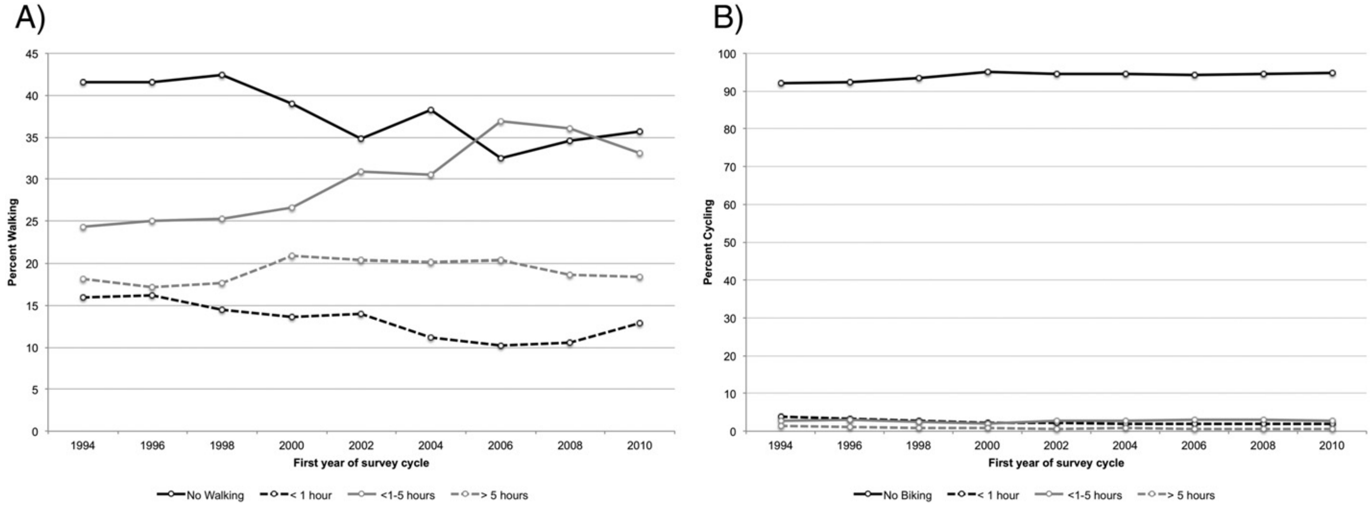

Fig. 1. Weighted trajectory of utilitarian walking categories, cycles 1 through 9 of the Canadian National Population Health Survey.

more than 5 h per week ($b = -0.07$, 95% CI: −0.15 to 0.01) was not associated with BMI over time. Utilitarian cycling for 1 to 5 h per week ($b = -0.12$, 95% CI: −0.27 to 0.03), and more than 5 h per week ($b = -0.16$, 95% CI: −0.45 to 0.13) was not significantly associated with BMI over time. Fig. 2 shows the predicted BMI over time for each category of utilitarian walking and cycling based on the final weighted fully balanced regression models.

Hausman test

To test the random intercepts versus fixed effects models a Hausman test compared the random intercepts and fixed effects models for both the unbalanced and fully balanced samples. The Hausman test hypothesizes that both random intercept and fixed effect estimators are consistent (i.e., there is no omitted variable bias), but that the random intercepts model is more efficient. The Hausman test was significant for both the unbalanced ($\chi^2 = 1074.57$, $p < 0.05$) and fully balanced samples ($\chi^2 = 336.97$, $p < 0.05$). As a result, using a random intercepts model is not preferred because the results are inconsistent, suggesting the existence of omitted variable bias in the model.

Sensitivity analysis

Table 3 shows the results of sensitivity analyses including cycles 5 through 9 from the analysis to in order to include the number of fruits and vegetables consumed per day. The results show that the number of fruits and vegetables consumed was significantly associated with BMI over time in both the random intercepts ($b = -0.06$, 95% CI: −0.07 to −0.04), and fixed effects ($b = -0.05$, 95% CI: −0.07 to −0.03) models. When fruit and vegetable consumption was included in the models the associations for utilitarian cycling 1 to 5 h per week remained significant in both models, while utilitarian cycling 6 or more hours per week was no longer statistically significant.

Discussion

The purpose of the present study was to examine the association between utilitarian walking and utilitarian cycling, and BMI in a prospective cohort study of adults. Findings indicate that for each dose of utilitarian walking there is no significant relationship with BMI. For utilitarian cycling the picture is less clear. In the random intercepts models, utilitarian cycling more than 1 h per week was associated with a lower BMI over time, however, in the fixed effects models this relationship was not significant. The results of the fully balanced fixed effects models are preferred as they control time constant omitted variables. As well, the Hausman tests support the choice of the fixed effects models.

The primary argument for the promotion of utilitarian transportation is that it is a form of physical activity that can be incorporated into daily routines (Feng et al., 2009; Sallis et al., 2012). Thus it is argued that utilitarian transportation has the potential to increase population levels of physical activity. The argument also assumes a negative relationship between physical activity and BMI. While this may be the case (Bassett et al., 2008), the results of the present study and others (Berentzen et al., 2008; Rosenberg et al., 2006) suggest that there is a

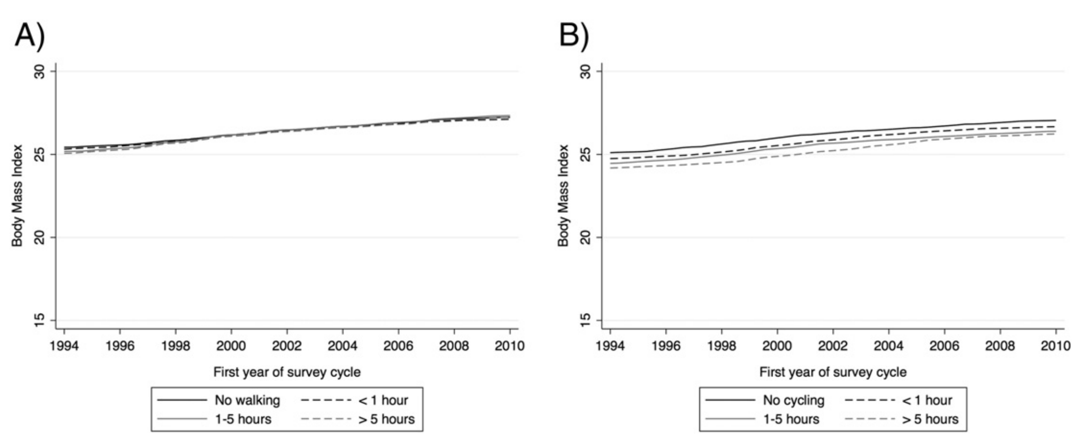

Fig. 2. Weighted trajectory of utilitarian cycling categories, cycles 1 through 9 of the Canadian National Population Health Survey.

Table 2
Unstandardized beta coefficients (*b*) and bootstrapped 95% confidence intervals (CI) obtained from random intercepts and fixed effects models including cycles 1 through 9 of the Canadian National Population Health Survey.

	Random effects (coefficient (95% CI))		Fixed effects (coefficient (95% CI))	
	Unbalanced sample (n = 6894)	Fully balanced sample (n = 2066)	Unbalanced sample (n = 6894)	Fully balanced sample (n = 2066)
Utilitarian walking				
None	1	1	1	1
<1 h per week	0.00 (−0.06 to 0.07)	0.02 (−0.07 to 0.11)	0.01 (−0.06 to 0.07)	0.02 (−0.06 to 0.10)
1–5 h per week	0.00 (−0.05 to 0.05)	−0.01 (−0.09 to 0.07)	0.00 (−0.06 to 0.05)	−0.01 (−0.09 to 0.06)
>5 h per week	−0.04 (−0.10 to 0.03)	−0.06 (−0.15 to 0.03)	−0.05 (−0.11 to 0.01)	−0.07 (−0.15 to 0.01)
Utilitarian cycling				
None	1	1	1	1
<1 h per week	−0.06 (−0.17 to 0.06)	−0.01 (−0.19 to 0.17)	−0.03 (−0.16 to 0.11)	0.01 (−0.20 to 0.22)
1–5 h per week	−0.18 (−0.29 to −0.06)	−0.14 (−0.29 to 0.02)	−0.15 (−0.28 to −0.02)	−0.12 (−0.27 to 0.03)
>5 h per week	−0.24 (−0.45 to −0.04)	−0.19 (−0.47 to 0.09)	−0.22 (−0.44 to 0.00)	−0.16 (−0.45 to 0.13)
Leisure time physical activity	1	1	1	1
Standard deviations of residuals within groups	4.26	4.36	4.61	4.67
Standard Deviations of residuals	1.84	1.76	1.84	1.76
Intraclass correlation	0.84	0.86	0.86	0.88
Hausman test	χ^2 = 1074.57 (33df), $p < 0.05$		χ^2 = 336.97 (33df), $p < 0.05$	

Note: Models adjusted for year, season, age, sex, education, marital status, rural/urban, children in the home, mobility restrictions, student status, and smoking status.

more nuanced relationship between utilitarian walking, utilitarian cycling, and BMI.

There are plausible explanations for our findings. Assuming that utilitarian walking is not, and utilitarian cycling is associated with BMI over time, intensity of active transportation may play an important role in BMI trajectories (Tremblay et al., 1990; de Geus et al., 2006). Tremblay et al. showed that participants in a vigorous physical activity intervention lost more subcutaneous fat than participants in an intervention with a higher total volume but lower intensity of activity (Tremblay et al.,1990). Numerous studies show that utilitarian cycling is more intense than utilitarian walking (Troped et al., 2008; Duncan et al., 2007).

The lack of a significant association between utilitarian walking and utilitarian cycling and BMI over time may be due to unmeasured confounders associated with both utilitarian cycling and BMI that have not been properly accounted for in the literature. The most plausible unmeasured confounders that could influence the results were nutritional status and the built environment. Sensitivity analyses showed that when including fruit and vegetable consumption into the model the strength of the association between cycling for 1 to 5 h per week increased and 6 or more hours per week increased but the estimate for 6 or more hours per week was not statistically significant. Another plausible unmeasured confounder is built environment factors such as walkability and population density of the place residence as these factors have been shown to be associated with both utilitarian walking and cycling and BMI (Sallis et al., 2012).

Despite the statistically insignificant findings, the clinical meaning of the associations between minutes of utilitarian cycling per week and BMI should be discussed. Utilitarian cycling more than 5 h per week had an effect size of ranging from −0.16 to −0.35 BMI points. For a 5′ 10″ individual weighing 174 lb (BMI = 25) a BMI reduction of 0.30 converts to an approximate weight reduction of 2.1 lb (−1.2% change in body weight) from utilitarian cycling. Studies have shown that a body weight loss of less than 5% was not consistently associated with cardiovascular risk factor improvements (Douketis et al., 2005; Blackburn, 1995). A meta-analysis conducted on US studies showed that five years after a structured weight-loss program, the average individual maintained a weight loss of greater than 7 lb (Flegal et al., 2010). Past research suggests that the estimated weight loss of 2.1 lb associated with utilitarian cycling likely has minimal clinical significance for improvements in cardiovascular risk factors. Despite limited evidence of statistically or clinically meaningful findings for weight loss, physical activity has health benefits over and above those associated with weight loss that was not assessed in this study (Warburton and Bredin, 2006; Williams, 2001).

Table 3
Unstandardized beta coefficients (*b*) and bootstrapped 95% confidence intervals (CI) obtained from random intercepts and fixed effects models including cycles 5 through 9 of the Canadian National Population Health Survey.

	Random effects (coefficient (95% CI))	Fixed effects (coefficient (95% CI))
	Sample (n = 5744)	Sample (n = 5744)
Utilitarian walking		
None	1	1
<1 h per week	−0.03 (−0.12 to 0.06)	−0.02 (−0.11 to 0.07)
1–5 h per week	−0.02 (−0.09 to 0.05)	−0.03 (−0.10 to 0.05)
>5 h per week	−0.04 (−0.12 to 0.04)	−0.06 (−0.14 to 0.03)
Utilitarian cycling		
None	1	1
<1 h per week	−0.12 (−0.32 to 0.07)	−0.09 (−0.29 to 0.11)
1–5 h per week	−0.29 (−0.48 to −0.11)	−0.25 (−0.44 to −0.06)
>5 h per week	−0.35 (−0.71 to 0.01)	−0.30 (−0.66 to 0.06)
Leisure time physical activity	1	1
Number of fruits and vegetables per day	−0.06 (−0.07 to −0.04)	−0.05 (−0.07 to −0.03)
Standard deviations of residuals within groups	4.64	4.95
Standard deviations of residuals	1.68	1.68
Intraclass correlation	0.88	0.90
Hausman test	χ^2 = 240.54 (30df), $p < 0.05$	

Note: Models adjusted for year, season, age, sex, education, marital status, rural/urban, children in the home, mobility restrictions, student status, and smoking status.

Limitations

The study has two primary limitations. First, loss to follow-up is a concern for this survey. Of the initial 17,276 our analysis included 6894 who had at least one complete measure for each of the variables of interest (unbalanced sample), or 2066 who had complete measure for each variable in all cycles (fully balanced sample).

Second, the physical activity questions are self-report and may lead to misclassification of the types of physical activity. For example, the lead in to the LTPA question is "now I'd like to ask you about some of your physical activities. To begin with, I'll be dealing with physical activities not related to work, that is, leisure time activities." The lead in for LTPA does not necessarily exclude utilitarian transportation and respondents may report some of their utilitarian transportation as LTPA. This non-differential misclassification will bias the results toward the null and underestimate the true effect.

Conclusion

Discussions related to the potential contribution of utilitarian transportation and BMI have been simplified to a direct negative relationship; increase utilitarian transportation and decrease BMI. However, the results of the present study suggest a more nuanced relationship between utilitarian transportation and BMI.

Conflict of interest

The authors declare there is no conflict of interest.

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