Catalogue no. 82-003-X
ISSN 1209-1367

Health Reports

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Release date: July 14, 2015

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..	not available for a specific reference period
...	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published
*	significantly different from reference category ($p < 0.05$)

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Abstract

Background: Evidence from large, population-based studies about the association between neighbourhood walkability and the prevalence of obesity is limited.

Data and methods: The study population consisted of 106,337 people aged 20 or older living in urban and suburban Ontario, who participated in the National Population Health Survey and the Canadian Community Health Survey from 1996/1997 to 2008. Based on their postal code, individuals were grouped into one of five walkability categories, ranging from very car-dependent to "Walker's Paradise," according to the Street Smart Walk Score®, a composite measure of neighbourhood walkability. Logistic regression models, adjusted for demographic, socioeconomic and lifestyle characteristics, were used to estimate odds ratios relating neighbourhood walkability to overweight/obesity and physical activity.

Results: Compared with residents of "Walker's Paradise" areas, those in very car-dependent areas had significantly higher odds of being overweight or obese. Despite similar levels of leisure physical activity among residents of all walkability areas, those in "Walker's Paradise" areas reported more utilitarian walking and weighed, on average, 3.0 kg less than did those in very car-dependent areas.

Interpretation: Living in a low-walkability area is associated with a higher prevalence of overweight/obesity. Neighbourhood walkability is related to the frequency of utilitarian walking.

Keywords: Obesity, overweight, physical activity, walkability

The rising prevalence of obesity in Canada[1] has led researchers to examine not only individual behaviours, but also, environmental factors that may be contributing to the increase. Interest is growing in potential effects of the built environment, notably, neighbourhood walkability, on the risk of obesity and related diseases.

People living in walkable neighbourhoods are more likely to engage in utilitarian physical activity, that is, walking or bicycling to accomplish everyday tasks, such as travelling to school and work, and doing errands.[2-6] Research suggests that proximity to destinations such as grocery stores and restaurants is associated with more walking and lower rates of obesity.[7-9] However, some of these studies had small sample sizes, and some used ecological-level data.[10] Moreover, most previous studies were unable to adjust for variables such as leisure physical activity, smoking, stress and alcohol consumption, which may confound the association between neighbourhood utilitarian walkability and the risk of obesity. Evidence from large, population-based studies is limited.

Walkability indices have been created for individual study settings,[11-14] but the Street Smart Walk Score® is the only one that can be readily accessed via the internet (www.walkscore.com) for all postal codes in Canada. The Score has been shown to be a valid measure of neighbourhood walkability in multiple geographic locations and at multiple spatial scales,[15-18] and is positively associated with utilitarian walking among populations in the United States.[19,20]

The objective of this study was to determine if the prevalence of overweight and obesity is associated with neighbourhood walkability. The analysis tested whether a dose-response relationship between the Street Smart Walk Score® and various measures of physical activity, overweight, and obesity existed in a large, population-based sample of adults in urban and suburban Ontario (Appendix).

Data and methods

Study population

The study population was derived from the cross-sectional components of Statistics Canada's 1996/1997 National Population Health Survey (NPHS) and cycles 1.1 (2001), 2.1 (2003), 3.1 (2005), 2007 and 2008 of the cross-sectional Canadian Community Health Survey (CCHS). These surveys used a multistage stratified cluster sampling strategy to collect demographic, socioeconomic, geographic and health-related information from a representative sample of people living in private dwellings. Response rates ranged from 75.1% to 94.4%. For this analysis, Ontario data from the surveys were combined.[21] If respondents were interviewed more than once (fewer than 1%), only data from the earliest survey were used. Details about the NPHS and CCHS methodology are described elsewhere.[22]

Street Smart Walk Score®

The Street Smart Walk Score® is a proprietary measure of walking distances from a given address to a diverse set of amenities—grocery stores, restaurants, shopping, coffee, banks, parks, schools, books, and entertainment. Points are assigned for each type of amenity, added, and then normalized to yield a score from 0 to 100. Certain categories, such as grocery stores and restaurants, are weighted more heavily than other categories

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to reflect destinations associated with more walking trips. Areas with fewer road intersections and larger average block lengths received a penalty of up to 5% of the score.

A polynomial distance decay function was applied in which a full score or near full score was assigned for amenities within 0.25 miles (about 400 metres) of the origin. Scores decreased with distance, such that amenities 1 mile away (about 1,600 metres) received about 12% of the score they would have received had they been right next to the origin; amenities more than 1.5 miles away did not contribute to the score.

Based on an average walking speed of 3 miles (4.8 kilometres) per hour, a quarter of a mile translates into a 5-minute walk; one mile, a 20-minute walk; and a mile and a half, a 30-minute walk. Unlike its predecessor, the Walk Score, which used a circular ("as the crow flies") buffer, the Street Smart Walk Score® uses street network buffers that account for actual walking paths. More details about the Score and its validation can be found elsewhere.[15,18]

This analysis pertains to 106,337 people who were aged 20 or older when they were interviewed and who were living in urban and suburban postal codes in Ontario. To maintain confidentiality, the exact address of respondents was not available. Therefore, the smallest geographical unit available in the data—the postal code—was used to determine the Walk Score. A walkability score was assigned to each respondent according to the latitude and longitude of the centroid of their postal code of residence at the time of the survey. Based on their Walk Score, respondents were classified as living in one of five walkability categories[23]:

1. "very car-dependent" (almost all errands require a car; 0 to 24 points)
2. "car-dependent" (a few amenities within walking distance; 25 to 49 points)
3. "somewhat walkable" (50 to 69 points)
4. "very walkable" (70 to 89 points)
5. "Walker's Paradise" (daily errands do not require a car; 90 to 100 points)

Residents of rural and small-town Ontario (less than 10,000 population) were excluded from this study because their postal codes cover very large areas, and the distances people in these areas have to walk to reach amenities vary substantially.

Study variables

The adjusted models controlled for age, sex, area-based household income quintiles, household income adequacy, highest level of education, marital status, immigrant status, race/ethnicity, smoking, alcohol consumption, fruit/vegetable consumption, stress, physical activity, sitting most of the day, and survey year. Area-based income quintiles were household-size-adjusted, calculated from 2006 Census data at the Dissemination Area level (geographical units of 400 to 700 residents). Each respondent was assigned to an income quintile ranging from 1 (lowest) to 5 (highest). Household income adequacy, a four-level measure—lowest, lower-middle, upper-middle, and highest income—was derived using self-reported annual household income and household size reported in the CCHS and NPHS.[24,25] Race/Ethnicity was categorized as white, Chinese, South Asian, Black, or other.

Lifestyle and risk factors that may be related to excess weight were examined: current smoking; alcohol consumption (regular drinker, occasional drinker, former drinker, did not drink in past 12 months); inadequate fruit and vegetable consumption (fewer than three times a day); and psychosocial stress (feeling "extremely" or "quite a bit" versus "not at all," "not very" or "a bit" stressed most days).

The physical activity measures were: utilitarian walking (to work or school or to do errands—less than 1 hour, 1 to 5 hours, or more than 5 hours per week); leisure physical activity energy expenditure based on type, frequency, and duration of activity over the past three months—active (energy expenditure 3.0 or more kcal/kg/day), moderately active (1.5 to 2.9 kcal/kg/day) or inactive (less than 1.5 kcal/kg/day); and a dichotomous variable for participation in more than 15 minutes of leisure physical activity a day. Participants were asked whether they "usually sit during the day and don't walk around very much as part of their daily activities or work habits." Two body mass index (BMI) categories, derived from self-reported height and weight, were examined: overweight (including obese) (25 or more kg/m^2) and obese (30 or more kg/m^2).

Statistical analysis

Descriptive statistics were used to compare the age- and sex-standardized prevalence of demographic and socioeconomic characteristics, risk factors, and weight-related variables across the five walkability categories. The direct standardization method was used, with five-year age groups and the 2001 Census population of Ontario as the standard population.

Logistic regression was used to derive odds ratios relating neighbourhood walkability to individual physical activity and weight-related measures. Models were adjusted for age, sex, area-based household income, household income adequacy, education, race/ethnicity, immigrant status, marital status, leisure physical activity, sitting most of the day, smoking status, stress, alcohol consumption, fruit and vegetable consumption, and survey year. Leisure physical activity and sitting most of the day were included because they are associated with the risk of obesity and may be correlated with neighbourhood walkability. Multivariate linear regression models, adjusted for these covariates were used to examine weight differences between residents of lower walkability areas (Walk Score less than 10, very car-dependent, car-dependent, somewhat walkable) versus "Walker's Paradise" areas. A sensitivity analysis using only the more recent cycles of the CCHS (2005/2006 and 2007/2008) was conducted. SAS® 9.3 statistical software was used for all analyses. The analyses were weighted by Statistics Canada's sample weights to

Table 1
Age- and sex-standardized prevalence of sociodemographic, lifestyle, physical activity and weight-related characteristics, by Street Smart Walk Score® category, urban and suburban population aged 20 or older, Ontario, 1996/1997, 2001, 2003, 2005, 2007 and 2008 combined

	Street Smart Walk Score® category (score)				
Characteristics	Very car-dependent (less than 25)	Car-dependent (25 to 49)	Somewhat walkable (50 to 69)	Very walkable (70 to 89)	"Walker's Paradise"† (90 or more)
Sample size	32,197	31,384	23,586	14,800	4,370
Sociodemographic characteristics					
Age, mean (years)	46.2	46.2	46.2	46.2	46.2
Age group (%)					
20 to 44	51.6	51.6	51.6	51.6	51.6
45 to 64	31.4	31.4	31.4	31.4	31.4
65 or older	17.0	17.0	17.0	17.0	17.0
Male (%)	48.8	48.8	48.8	48.8	48.8
Area-based household income quintile (%)					
1 (lowest)	5.3**	13.6**	23.4**	36.4	34.8
2	11.2**	19.2	25.4**	24.2**	17.4
3	21.0**	22.4**	21.4**	14.8	15.9
4	27.1**	23.8**	17.1**	12.2	12.7
5 (highest)	35.4**	20.9	12.6**	12.4**	19.1
Household income adequacy (%)					
1 (lowest)	4.3**	5.1**	7.1**	9.5**	12.3
2	12.4**	14.0**	16.8	19.0	17.5
3	27.5 *	28.3 *	29.2**	28.9**	25.2
4 (highest)	38.3**	35.9**	29.1	26.5	28.3
Less than secondary graduation (%)	14.4	15.4	17.3 *	18.2 *	15.0
Immigrant (%)	21.7**	33.3**	39.9**	44.5	44.8
Race/Ethnicity (%)					
White	89.7**	79.2**	73.8	71.6	71.5
Chinese	1.6**	3.8**	4.8**	4.3**	7.1
South Asian	2.1**	5.7	7.0 *	6.8	5.2
Black	1.1**	2.8	3.6	3.9	3.6
Other	5.5**	8.5**	10.8 *	13.4	12.6
Not married or common-law (%)	28.0**	31.6**	35.2**	40.8**	48.7
Lifestyle and risk factors					
Current smoker (%)	21.8**	22.5**	24.2	25.6	25.4
Alcohol consumption (%)					
Regular drinker	65.5 *	62.3	57.9 *	55.7**	61.8
Occasional drinker	17.6**	18.8**	18.2 *	19.2**	14.9
Former drinker	11.4	10.9 *	12.9	13.4	13.0
Did not drink in past 12 months	5.4**	8.0 *	11.0	11.8	10.3
Inadequate fruit/vegetable consumption (less than 3 times/day) (%)	22.3	22.7	23.9	23.6	23.3
Weak sense of community belonging (%)	34.6**	37.8**	39.3 *	40.7	41.9
Psychosocial stress (%)	23.4	24.3	24.4	24.2	24.4
Physical activity and weight-related outcomes					
Walk to work, school, errands (hours/week) (%)					
Less than 1	44.9**	44.9**	42.2**	39.7**	31.1
1 to 5	30.9**	32.0**	34.1**	35.2**	41.9
More than 5	24.2 *	23.1**	23.7 *	25.0	27.0
More than 15 minutes leisure physical activity per day (%)	36.7	33.5	32.3 *	32.7 *	35.2
Leisure physical activity (%)					
Inactive	49.8**	54.2	57.1	56.6	54.7
Moderately active	25.7	24.2	23.0	23.2	24.3
Active	24.5 *	21.5	20.0	20.2	21.0
Sit most of day (%)	24.3**	26.9**	27.7**	29.4 *	32.5
BMI, mean (kg/m^2)	25.9**	25.7**	25.5**	25.4**	24.8
Overweight (including obese) (BMI ≥ 25 kg/m^2) (%)	52.4**	50.0**	48.9**	46.5**	42.4
Obese (BMI ≥ 30 kg/m^2) (%)	16.5**	15.7**	14.5**	14.6**	10.4

† reference category
* signficantly different from reference category ($p < 0.05$)
** significantly different from reference category ($p < 0.01$)
Notes: All estimates were weighted by the survey sample weight. Because this table reports age- and sex-standardized estimates, age and sex distributions are identical across the five walkability categories.
Sources: 1996/1997 National Population Health Survey, 2001, 2003, 2005, 2007 and 2008 Canadian Community Health Survey (combined).

account for the complex survey sampling design and to improve generalizability of the estimates.[21] Bootstrap methods were used to calculate 95% confidence intervals (2.5th and 97.5th percentile of the 500 bootstrap rates or the natural logarithm of odds ratios) and p-values (using the standard z-test in which the rate or the logarithm of the odds ratio was divided by the standard deviation of this statistic across the 500 bootstrap samples).[26,27] All tests were two-sided; $p < 0.05$ was considered to be statistically significant.

Statistics Canada obtained informed consent from respondents to use the information collected in the surveys. Only data for those who consented were included in this study. Records were anonymized before analysis. The study was approved by the Research Ethics Board at Sunnybrook Health Sciences Centre.

Results

Demographic, socioeconomic and lifestyle characteristics

Compared with residents of "Walker's Paradise" areas (mainly inner-city postal codes), those in lower walkability areas reported higher income adequacy and educational attainment, and were more likely to be married or in common-law relationships (Table 1). People in lower walkability areas were more likely to be white, non-immigrant and regular or occasional drinkers, but less likely to be current cigarette smokers. The prevalence of inadequate fruit and vegetable consumption was similar across the five walkability categories.

Physical activity, overweight, and obesity

Residents of less walkable areas were more likely than people in more walkable areas to spend less than an hour a week walking to work or school or doing errands (Table 1). The mean BMI of people in lower walkability areas was relatively high: for example, 25.9 kg/m^2 for those in very car-dependent areas versus 24.8 kg/m2 for those in "Walker's Paradise" areas ($p < 0.001$). The prevalence of overweight and obesity decreased as area walkability increased (Figure 1).

Levels of leisure physical activity were similar regardless of area walkability, except for people in very car-dependent areas, who reported the highest levels of physically active leisure.

Multivariate adjusted odds ratios

Even when the demographic, socio-economic, lifestyle and physical activity characteristics of people in the five walkability categories were taken into account, those in very car-dependent areas weighed, on average, 3.0 kg more (2.8 kg more among men; 3.0 kg more among women) than people in "Walker's Paradise" areas (Table 2).

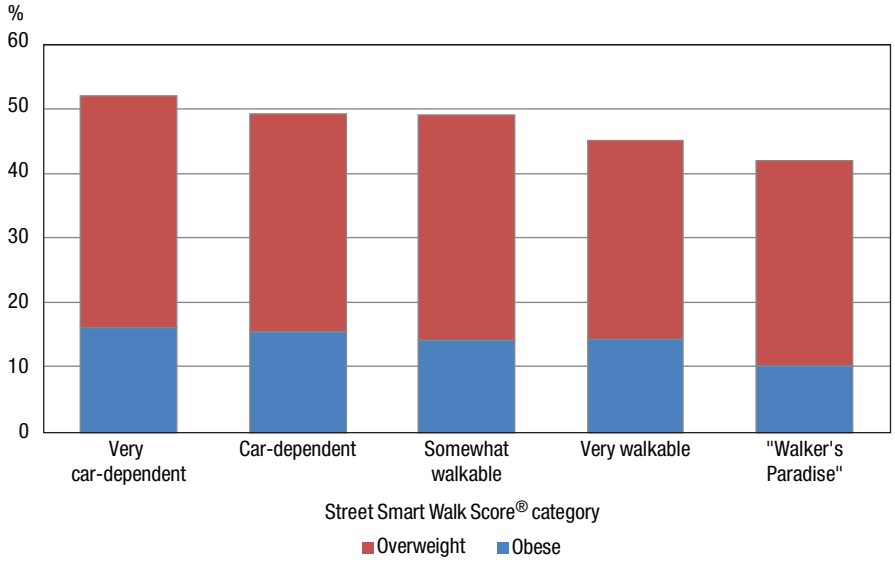
People in very car-dependent areas had significantly higher odds of overweight/obesity (OR = 1.44, $p < 0.001$) and obesity (OR = 1.74, $p < 0.001$), compared with those in "Walker's Paradise" areas. No significant gender differences emerged (data not shown). The results of a sensitivity analysis that limited the study population to more recent CCHS cycles were similar (OR = 1.50, $p < 0.0001$ for overweight/obesity; OR = 1.55, $p < 0.0001$ for obesity).

The odds of utilitarian walking at least an hour a week were lower among people in less walkable areas, compared with residents of "Walker's Paradise" areas (Figure 2). By contrast, differences in leisure physical activity between people in various walkability areas were not significant.

Discussion

This is the largest study to examine associations between a composite measure of neighbourhood walkability—the Street Smart Walk Score®—and the prevalence of excess weight among Canadians. The Score, which was designed to measure how conducive an area is to walking to accomplish everyday tasks, correlated well with utilitarian walking. Adults in urban and suburban Ontario reported similar levels of leisure activity regardless of where they lived, but those in highly walkable neighbourhoods were more likely to report utilitarian walking.

Figure 1
Age- and sex-standardized percentage overweight or obese, by Street Smart Walk Score® category, urban and suburban population aged 20 or older, Ontario, 1996/1997, 2001, 2003, 2005, 2007 and 2008 combined



Notes: All estimates were weighted by the survey sample weights. Overweight (including obese) was defined as BMI ≥ 25 kg/m^2; obese was defined as BMI ≥ 30 kg/m^2.
Sources: 1999/1997 National Population Health Survey; 2001, 2003, 2005, 2007 and 2008 Canadian Community Health Survey.

Table 2
Multivariate-adjusted weight differences among urban and suburban population aged 20 or older living in lower walkability versus "Walker's Paradise" areas, by sex, Ontario, 1996/1997, 2001, 2003, 2005, 2007 and 2008 combined

Street Smart Walk Score® category (score) and sex	Weight difference (kg)	95% confidence interval	
		from	to
Street Smart Walk Score® less than 10 versus "Walker's Paradise" (90 to 100)			
Total	**3.2**	**2.3**	**4.1**
Men	3.2	1.7	4.6
Women	3.0	1.8	4.2
Very car-dependent (0 to 24) versus "Walker's Paradise" (90 to 100)			
Total	**3.0**	**2.2**	**3.9**
Men	2.8	1.5	4.0
Women	3.0	1.8	4.2
Car-dependent (25 to 49) versus "Walker's Paradise" (90 to 100)			
Total	**2.4**	**1.7**	**3.2**
Men	2.4	1.2	3.5
Women	2.3	1.3	3.2
Somewhat walkable (50 to 69) versus "Walker's Paradise" (90 to 100)			
Total	**2.2**	**1.5**	**3.0**
Men	2.4	1.2	3.4
Women	1.9	0.9	2.9

Notes: Models were adjusted for age, sex, area-based household income, household income adequacy, education, race/ethnicity, immigrant status, marital status, leisure physical activity, sitting most of the day, smoking, stress, alcohol consumption, fruit/vegetable consumption, and survey year. All estimates were weighted by the survey sample weights.
Sources: 1996/1997 National Population Health Survey, 2001, 2003, 2005, 2007 and 2008 Canadian Community Health Survey (combined).

Further, residents of very car-dependent areas were significantly more likely to be overweight/obese than were those in "Walker's Paradise" areas.

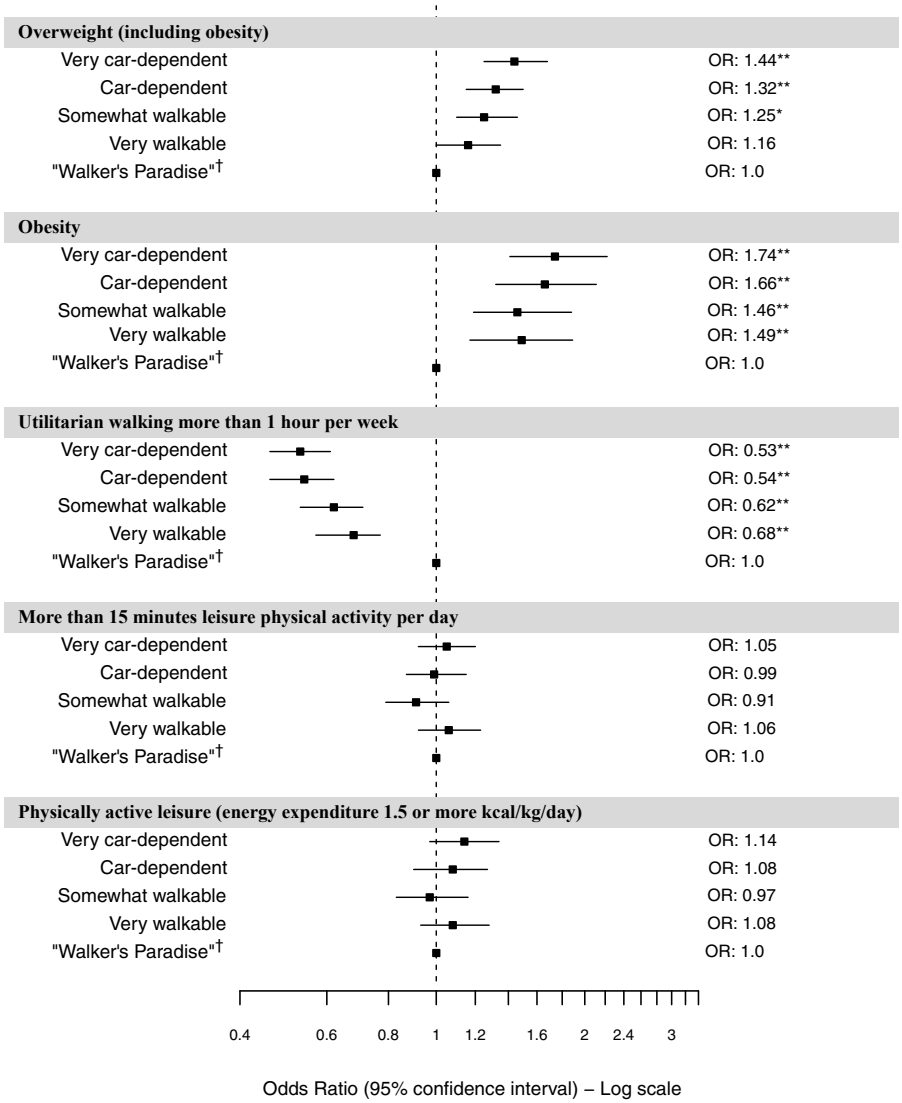
The results are consistent with an ecological analysis of adults from the 1998-2000 U.S. Behavioral Risk Factor Surveillance System (BRFSS) surveys, which found that people in the most sprawling (low-density, auto-dependent) environments were more likely to be obese.[8] Using county- and metropolitan-level data from the 2000 BRFSS survey, Lopez observed a clear association between urban sprawl and excess weight.[28] Similarly, based on individual-level data, Frank et al. noted that living in neighbourhoods within walking distance of shops and businesses was associated with a 7% lower risk of obesity; every additional 30 minutes a day spent in a car translated into a 3% greater chance of obesity.[9] On average, males in low-density, residential-only subdivisions weighed 4.5 kg more than their counterparts in compact neighbourhoods,[9] similar to the present findings that Ontario adults in very car-dependent urban and suburban areas weighed, on average, 3.0 kg more than those in "Walker's Paradise" areas.

A longitudinal study of 701 subjects from the U.S. Multi-Ethnic Study of Atherosclerosis reported that moving to a location with a 10-point higher Walk Score was associated with a 16.0-minute-per-week increase in utilitarian walking and a 0.06 kg/m^2 reduction in BMI.[29] Other studies found a positive association between the Walk Score and walking for transport,[20] and with meeting physical activity recommendations through purposive walking.[19]

The similarity of results from different walkability indices in a variety of settings among different populations provides evidence that the inverse association between neighbourhood walkability and weight may be related to utilitarian physical activity. However, an examination of both the benefits and risks (for example, more air pollution) associated with highly walkable and population-dense areas is warranted.

Currently, a minority (15%) of Canadian adults meet minimum daily recommended levels of physical activity,[30] and rates of overweight/obesity have been rising for the past decade.[31] Given that non-leisure activities dominate most people's daily schedules, maximizing energy expenditure while performing these activities may help achieve recommended levels of daily physical activity.[3,5,32-34]

Figure 2
Adjusted odds ratios (OR) relating Street Smart Walk Score® categories to overweight, obesity and physical activity, urban and suburban population aged 20 or older, Ontario, 1996/1997, 2001, 2003, 2005, 2007 and 2008 combined



† reference category
* significantly different from reference category ($p < 0.05$)
** significantly different from reference category ($p < 0.001$)
Notes: Models were adjusted for age, sex, area-based household income, household income adequacy, education, race/ethnicity, immigrant status, marital status, leisure physical activity, sitting most of the day, smoking, stress, alcohol consumption, fruit/vegetable consumption, and survey year. All estimates were weighted by the survey sample weights.
Sources: 1996/1997 National Population Health Survey; 2001, 2003, 2005, 2007 and 2008 Canadian Community Health Survey.

Strengths and limitations

A strength of this study is the ability to control for potential confounders such as household income, education, immigrant status, physical activity, smoking, stress, and alcohol consumption. However, the cross-sectional design limits the inferences that can be drawn. It is not clear if living in low-walkability areas resulted in a higher risk of overweight/obesity or if people who were overweight or

What is already known on this subject?

- People in highly walkable neighbourhoods are more likely than those in less walkable areas to engage in utilitarian physical activity such as walking or cycling to work or school.
- Studies of the relationship between neighborhood walkability and obesity have been relatively small and limited in their ability to adjust for important confounders.

What this study adds

- This is the largest population-based study to examine neighbourhood walkability and overweight/obesity in Canada.
- The odds of overweight/obesity were higher among people living in lower walkability areas, compared with those in higher walkability areas.
- Dose-response relationships emerged between Street Smart Walk Score® categories and utilitarian physical activity, as well as the prevalence of overweight/obesity.
- These associations persisted when confounders such as age, sex, income, education, race/ethnicity, alcohol consumption, diet, smoking and leisure physical activity were taken into account.

obese tended to choose areas that were less walkable. Nonetheless, a study that adjusted for this potential selection bias found that low neighbourhood walkability remained significantly associated with an increased risk of excess weight, thus suggesting that selection bias is likely weak.[35] Population-based studies that assess physical activity and weight before and after moving into low-walkability areas might produce more conclusive results. Longitudinal analysis of people moving between low- and high-walkability areas, and of health before and after major changes to the built environment, are needed to provide stronger evidence of a causal association between neighbourhood walkability and obesity.

Another limitation is the use of self-reported data, to calculate BMI. As well, residual confounding due to the lack of information available on diet (calories, nutrients) and sleep is possible. In addition, calorie consumption may have a spatial component; the proximity of fast-food outlets and the availability of healthy/unhealthy foods would be important to investigate.

Finally, no information is available about other route attributes, such as aesthetics, traffic and safety, which may influence physical activity. However, a large systematic review[6] found that these factors have limited direct effects on utilitarian walking among adults.

Conclusion

This population-based analysis found that area walkability was associated with the prevalence of overweight/obesity among urban and suburban adults in Ontario. Residents of highly walkable areas engaged in more utilitarian walking and had a lower prevalence of obesity than did adults in low-walkability areas. These findings may be generalizable to other areas in Canada. ■

Acknowledgements

The authors acknowledge the respondents to the National Population Health Survey (NPHS) and the Canadian Community Health Survey (CCHS) and the Statistics Canada staff involved in data collection and survey management. The authors also acknowledge Walk Score® (walkscore.com) for the derivation of the Street Smart Walk Scores. Dr. Chiu is supported by a Fellowship from the Canadian Institutes of Health Research (CIHR). Dr. Shah is supported by a New Investigator grant from CIHR. Dr. Austin is supported by a Career Investigator Award from the Heart and Stroke Foundation. Dr. Tu is supported by a Canada Research Chair in Health Services Research and a Career Investigator Award from the Heart and Stroke Foundation of Ontario. This project was supported in part by a Public Health Agency of Canada grant and an Institute for Circulatory Health-Canadian Institutes of Health Research Chronic Diseases Team grant (grant no. TCA 118349) to the Cardiovascular Health in Ambulatory Care Research Team (www.canheart.ca). The Institute for Clinical Evaluative Sciences (ICES) is funded by the Ontario Ministry of Health and Long-Term Care (MOHLTC). The results and conclusions should not be attributed to any of the funding agencies, sponsoring agencies, or Walk Score®. No endorsement by ICES or the MOHLTC is intended or should be inferred. All decisions about study design, publication, and data analysis were made independent of Walk Score® and the funding agencies.

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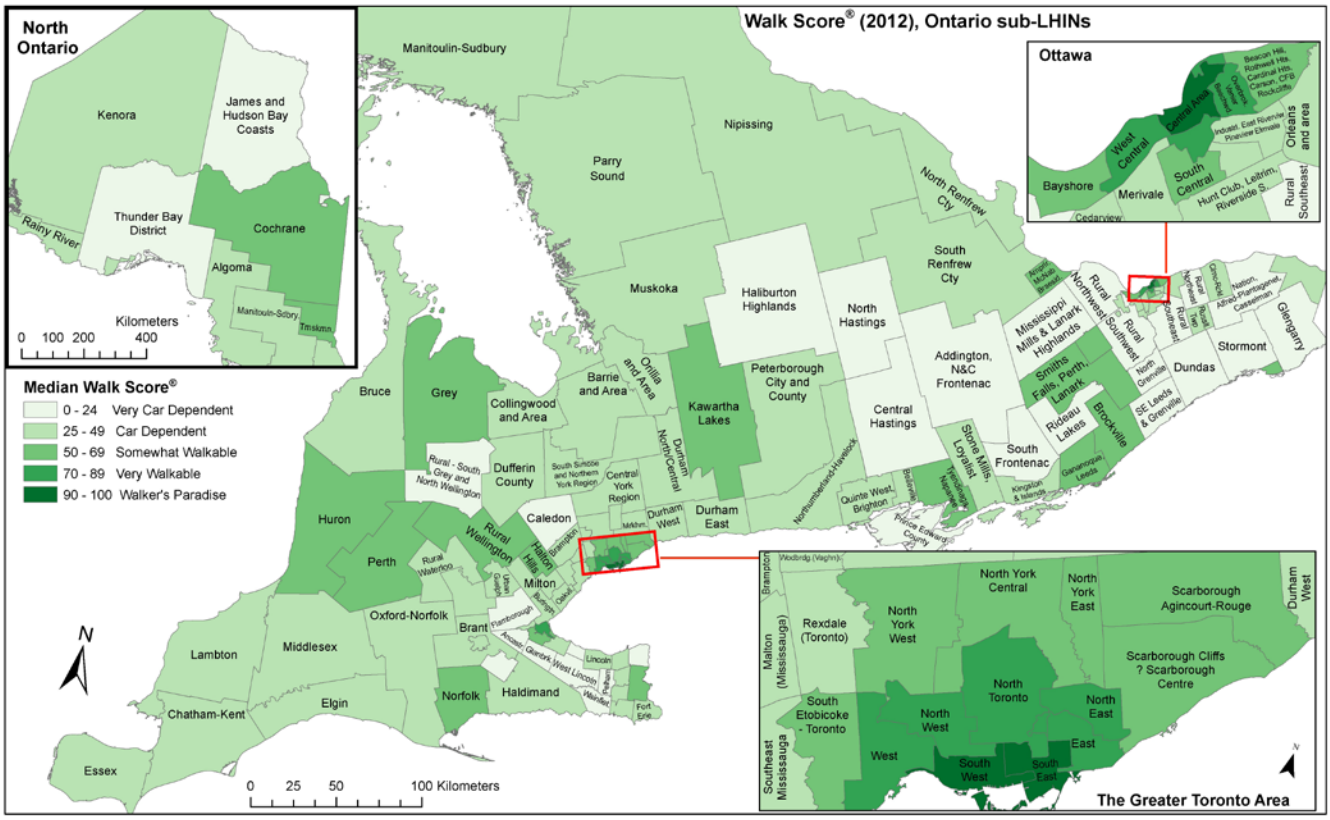
Appendix

Ontario sub-Local Health Integration Networks (sub-LHINs), by median Street Smart Walk Score® category



For illustrative purposes, this map was created at the sub-LHIN level. Sub-LHINs are subdivisions of Local Health Integration Networks (LHINs) defined by the Ontario Ministry of Health and Long-term Care for health system evaluation and planning (http://www.lhins.on.ca). The 14 LHINs and 141 sub-LHINs cover the entire province, including rural areas. Walk Scores vary within each sub-LHIN; the median Walk Score for each sub-LHIN was calculated using Walk Scores of the postal codes within each sub-LHIN. The analysis in the current study was performed at the level of postal codes, which are much smaller geographic areas than sub-LHINs.