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Residents of highly walkable neighbourhoods in Canadian urban areas do substantially more physical activity: a cross-sectional analysis

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Abstract

Background: Research has shown that neighbourhood walkability is associated with small differences in physical activity; however, the health impacts of these small differences have been questioned. We examined the size of the association of walkability with accelerometer-measured physical activity in a large, national-level Canadian population, and compared results to physical activity levels recommended in international guidelines. Our primary objective was to investigate the direction and size of the differences in physical activity that were related to walkability, and whether these differences depended on age.

Methods: Participants were included from among respondents to the 2007–2011 Canadian Health Measures Surveys who lived in urban areas and were aged 6–79 years. The Canadian Health Measures Surveys are ongoing cross-sectional surveys of a Canada-wide population. Respondents were divided into quintiles based on Street Smart Walk Score® values of their census dissemination areas. For all respondents and age subgroups, we used covariate-adjusted generalized linear models to estimate differences between quintiles in accelerometer-measured moderate-to-vigorous physical activity (MVPA) and sedentary time.

Results: We included 7180 respondents. Differences in participant MVPA between highest and lowest Street Smart Walk Score quintiles were 3.2 (95% confidence interval [CI] –3.2 to 9.6) minutes/day for ages 6–11 years, 11.4 (95% CI 5.3 to 17.4) minutes/day for ages 12–17 years, 9.9 (95% CI 2.4 to 17.4) minutes/day for ages 18–29 years, 14.9 (95% CI 10.2 to 19.6) minutes/day for ages 30–44 years, 11.5 (95% CI 6.7 to 16.3) minutes/day for ages 45–64 years and 6.9 (95% CI 3.1 to 10.8) minutes/day for ages 65–79 years. There were no significant differences in sedentary time in any age group.

Interpretation: In all groups except the youngest, participants in the most walkable areas did significantly more MVPA than those in the least walkable areas. For several age groups, this difference was approximately one-half to two-thirds of the amount recommended in guidelines for physical activity. Substantially higher MVPA levels suggest that residents of highly walkable areas may have greater health benefits.

Physical inactivity is a widespread problem, with serious negative health consequences.[1] International guidelines recommend adults do at least 150 minutes of moderate-to-vigorous physical activity (MVPA) per week and that children do at least 60 minutes of MVPA per day.[2,3] Recent research has shown most Canadians do not meet these guidelines.[4,5] Public health professionals have increasingly focused on improving neighbourhood walkability as a potential means of increasing physical activity.[6,7] Walkable neighbourhoods are those with a variety of destinations in close proximity, well-connected streets and adequate green space.[8] If walkability influences physical activity behaviours, there may be far-reaching health implications across a broad population.

Concerns have arisen that walkability's association with physical activity may be too small to have a meaningful impact on health.[9–11] Research shows, in addition to frequency and duration, higher intensities of physical activity produce greater health gains; hence, the guidelines' focus on minimum MVPA levels.[12,13] Research also shows consistent positive associations between walkability and active transport.[14,15] As active transport is classified as MVPA,[16] positive associations between walkability and MVPA can be anticipated. Additionally, sedentary time, defined as waking time spent at an intensity below light physical activity,[17] may have health consequences independent of MVPA.[18] Furthermore, walkability may have associations with sedentary time unique from its associations with MVPA; for instance, in less walkable environments people may be more likely to use sedentary modes of transportation such as driving.[16,19]

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Considering international guidelines, we aimed to investigate whether differences in physical activity related to walkability are large enough to have a meaningful impact on health. We also considered that the mixed results reported in previous studies may be due to methodological issues such as small sample sizes, subjective measures of physical activity and differential associations in various age groups (i.e., effect modification by age).[9,15,20,21] Therefore, we attempted to answer the following primary research question in a large Canada-wide sample: What are the sizes of associations between walkability and objectively measured MVPA and how does age modify these associations? We also sought to answer the following secondary research question related to sedentary time: What are the magnitudes of associations between walkability and sedentary time, and how does age modify these associations?

Methods

Study design

We used the Canadian Health Measures Survey for the periods March 2007–February 2009 and August 2009–November 2011. We used the first 2 cycles of this national-level, cross-sectional survey that collected both self-reported and direct measures of Canadians' health and health determinants.[22,23] It used a 3-stage stratified sampling design to obtain a sample representative of about 96% of the population of Canada (people in institutions, full-time members of the Canadian Armed Forces, and people living in reserves, other Aboriginal settlements or certain remote areas were excluded). Additional information on this survey design is available from Statistics Canada.[22,23]

Setting

The Canadian Health Measures Survey included a questionnaire conducted in person at respondents' households using computer-assisted interviewing, followed by visits to nearby mobile examination centres where direct measures were taken, followed by collection of physical activity monitor data over a 7-day period.

Population

Respondents of all ages (except those in wheelchairs) were asked to wear activity monitors during waking hours for 7 days for data collection.[22,23] A minimum of 4 valid days (days with 10 or more hr of wear time) of activity monitor data were needed for accurate measures of average physical activity. The Canadian Health Measures Survey reweighted the subsample of respondents with at least 4 valid days to improve representativeness. We further restricted the activity monitor subsample to those residing in urban areas (defined by Statistics Canada as contiguously built up areas with at least 400 people/km^2 and total populations of at least 1000).[24] We also excluded respondents with missing data for walkability and key sociodemographic characteristics.

Source of exposure data: walkability

The Street Smart Walk Score® (hereinafter referred to as Walk Score) metric was our neighbourhood walkability indicator.[25] This metric has been validated,[26–28] and previous studies have identified associations with outcomes such as utilitarian walking, obesity and hypertension.[29–31] Walk Score values were calculated for specific locations based on the number, variety and proximity of various amenities (e.g., restaurants/bars, parks, schools), and connectivity of surrounding streets. Values ranged from 0 to 100, with higher values indicating greater amenity density, more connected streets and, therefore, a more walkable location. Additional information on Walk Score methodology can be found at www.walkscore.com.

We used population-weighted latitude/longitude coordinates of census dissemination areas assigned to survey respondents as proxies for primary residences. Dissemination areas are designed to cover areas with 400–700 people.[32] Therefore, in urban areas, dissemination areas are small enough to reasonably correspond with residential location. In 2014, we sent these latitude/longitude coordinates to the Walk Score developers, who provided Walk Score values for each coordinate. Data files for the Canadian Health Measures Survey included postal codes for respondents but not dissemination areas; therefore, we matched dissemination areas (and their calculated Walk Scores) to the survey respondents' postal codes using Statistics Canada's Postal Code Conversion File.[33]

Source of outcome data: moderate-to-vigorous physical activity and sedentary time

Respondents wore activity monitors on adjustable belts. These monitors were designed to capture movement along 3 vectors (triaxial) to allow acquisition of most types of physical activity as counts.[22] Moderate-to-vigorous physical activity (MVPA, min/d) was calculated as the number of minutes of daily wear time recorded at or above 1500 counts/minute for respondents aged 6–19 years, and at or above 1535 counts/minute for respondents aged 20–79 years.[34,35] These cut points are roughly equivalent to physical activity intensity above 3 metabolic equivalents. Metabolic equivalent values are defined as the ratio of the body's metabolic rate while doing a particular exercise to its metabolic rate while at rest.[16] For example, if the body's metabolic rate while walking is 4 times its metabolic rate while at rest, walking has a metabolic equivalent value of 4. For all ages, sedentary time (min/d) was calculated as the number of minutes of wear time recorded above 0 and below 100 counts/minute.[36] These cut points are roughly equivalent to intensities between 0 and 2 metabolic equivalents. Nonwear time was considered to be 60 or more consecutive minutes with 0 counts (allowing 1–2 min of counts between 0 and 100).[4,5]

Statistical analysis

We divided respondents into quintiles according to Street Smart Walk Score values assigned to them. For each Walk Score quintile and for the total study population, we calculated means and proportions of important sociodemographic characteristics. We built generalized linear models of associations between walkability and MVPA, both unadjusted and adjusted for important confounders, and used generalized estimating equations to account for clustering of multiple respondents within single dissemination areas. To test effect modification by age, we tested interactions between age group and Walk Score quintile in the adjusted models. We built models for all respondents and the following age strata: 6–11, 12–17, 18–29, 30–44, 45–64 and 65–79 years. These strata reflected our estimation of the following life stages: child, youth, young adult, early–middle-aged adult, late–middle-aged adult and older retired/semiretired adult. We built a similar set of models for associations between Walk Score quintiles and sedentary time.

Covariate-adjusted models for respondents overall included the following variables, anticipated to be the most important confounders based on previous research:[4,5,37–40] age category, sex, visible minority status (defined as nonwhite race), immigration to Canada in the past 10 years, postsecondary graduate in the household, household income quintile, number of children under 12 in the household, did respondents work or attend school and activity monitor wear time. The covariate-adjusted models for age subgroups were adjusted for the same variables, except age category.

For all estimates, we accounted for the complex survey design using activity monitor subsample survey weights provided by Statistics Canada. To obtain more accurate variance estimates, we normalized survey weights by dividing each respondent's survey weight by the mean weight for all respondents in our study. We used 95% confidence intervals (CI) to determine statistical significance for all estimates. We used SAS version 9.4 (SAS Institute) for all analyses.

Ethics approval

After reviewing our study protocol, the Ethics Review Board of Public Health Ontario granted ethics approval, and Statistics Canada's Research Data Centre granted access to the Canadian Health Measures Survey.

Results

Population

The percentage of people contacted who completed the household questionnaire, visited the mobile examination centre and returned valid activity monitor data was 42.1% averaged across both Canadian Health Measures Survey cycles; however, these respondents were reweighted to be nationally representative.[22,23] A flow diagram of participant response is in Appendix 1 (available at www.cmajopen.ca/content/4/4/E720/suppl/DC1). Figure 1 provides a flow diagram of our study's

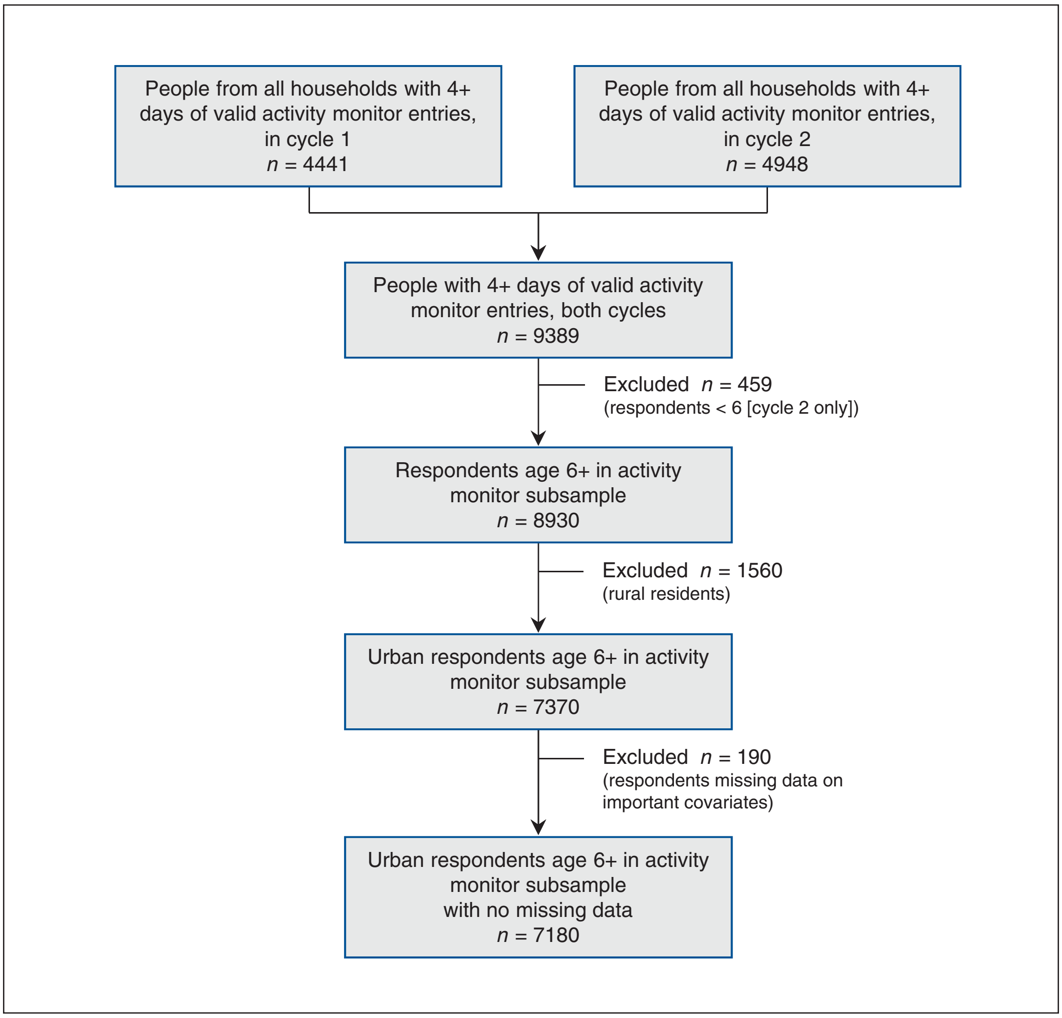

Figure 1: Flow diagram of Canadian Health Measures Survey respondents eligible for the walkability study.

Table 1: Study population characteristics (Canada-wide): overall and by Street Smart Walk Score quintile

Variable	Total no. of respondents for all quintiles (%)	Street Smart Walk Score quintile				
		No. of respondents (%)‡ in Q1, 0–22	No. of respondents (%)‡ in Q2, 23–40	No. of respondents (%)‡ in Q3, 41–58	No. of respondents (%)‡ in Q4, 59–79	No. of respondents (%)‡ in Q5, 80–100
No. of respondents (weighted)	7180	1388	1390	1496	1442	1464
Age category, yr						
6–11	533 (7.4)	135 (9.7)	118 (8.5)	116 (7.8)	92 (6.4)	72 (4.9)
12–17	617 (8.6)	116 (8.4)	151 (10.9)	143 (9.6)	119 (8.3)	89 (6.1)
18–29	1335 (18.6)	226 (16.3)	280 (20.1)	250 (16.7)	273 (18.9)	306 (20.9)
30–44	1815 (25.3)	362 (26.1)	305 (21.9)	368 (24.6)	317 (22.0)	462 (31.6)
45–64	2172 (30.3)	432 (31.1)	423 (30.5)	452 (30.2)	454 (31.5)	410 (28.0)
65–79	707 (9.8)	117 (8.4)	113 (8.1)	166 (11.1)	186 (12.9)	125 (8.5)
Sex						
Male	3540 (49.3)	689 (49.6)	651 (46.8)	705 (47.1)	738 (51.2)	757 (51.7)
Female	3639 (50.7)	699 (50.4)	739 (53.2)	791 (52.9)	703 (48.8)	707 (48.3)
Visible minority status						
Visible minority	1625 (22.6)	184 (13.2)	256 (18.4)	376 (25.1)	415 (28.8)	393 (26.9)
Not a visible minority	5555 (77.4)	1204 (86.7)	1133 (81.6)	1120 (74.9)	1026 (71.2)	1070 (73.1)
Immigrated to Canada in previous 10 yr						
Yes	715 (10.0)	74 (5.3)	64 (4.6)	182 (12.1)	143 (9.9)	251 (17.2)
No	6465 (90.0)	1314 (94.7)	1325 (95.4)	1314 (87.8)	1299 (90.1)	1212 (82.8)
Postsecondary graduate* in household						
Yes	5747 (80.0)	1157 (83.4)	1112 (80.0)	1172 (78.3)	1073 (74.5)	1232 (84.2)
No	1432 (20.0)	231 (16.6)	277 (20.0)	324 (21.7)	368 (25.5)	231 (15.8)
Household income, Can$†						
0–36 000	1416 (19.7)	163 (11.7)	196 (14.1)	239 (16.0)	397 (27.5)	421 (28.8)
36 500–59 500	1370 (19.1)	221 (15.9)	231 (16.6)	324 (21.7)	295 (20.5)	298 (20.4)
60 000–79 500	1175 (16.4)	248 (17.9)	216 (15.5)	254 (17.0)	232 (16.1)	225 (15.4)
80 000–114 000	1755 (24.4)	426 (30.7)	417 (30.0)	357 (23.9)	292 (20.3)	265 (18.1)
> 114 500	1463 (20.4)	331 (23.8)	330 (23.7)	322 (21.5)	225 (15.6)	255 (17.4)
No. of persons < 12 yr of age in household						
0	4811 (67.0)	854 (61.5)	907 (65.3)	984 (65.8)	1036 (71.8)	1030 (70.4)
1	1203 (16.8)	218 (15.7)	246 (17.7)	226 (15.1)	217 (15.0)	296 (20.2)
2 or more	1166 (16.2)	317 (22.8)	236 (17.0)	286 (19.1)	189 (13.1)	138 (9.4)
Works or attends school						
Yes	6075 (84.6)	1176 (84.7)	1230 (88.5)	1220 (81.6)	1155 (80.1)	1294 (88.4)
No	962 (13.4)	191 (13.7)	138 (9.9)	247 (16.5)	246 (17.1)	141 (9.6)
Missing	143	21	22	29	41	29
Has difficulty walking						
Yes	124 (1.7)	24 (1.7)	23 (1.7)	27 (1.8)	36 (2.5)	15 (1.0)
No	7055 (98.3)	1364 (98.3)	1367 (98.3)	1469 (98.2)	1406 (97.5)	1449 (99.0)
Activity monitor wear time, min/d; mean ± SD	835.1 ± 77.1	834.5 ± 68.5	840.0 ± 72.8	842.1 ± 80.7	833.7 ± 80.4	825.3 ± 81.9

Note: Q1 = 1st Street Smart Walk Score quintile, Q2 = 2nd Street Smart Walk Score quintile, Q3 = 3rd Street Smart Walk Score quintile, Q4 = 4th Street Smart Walk Score quintile, Q5 = 5th Street Smart Walk Score quintile (Street Smart Walk Score values are from 2014).
*Includes people with trade certificate/diploma, college or CEGEP certificate/diploma, university certificate/diploma below bachelors degree, bachelors degree and certificate/diploma/degree above bachelors degree.
†Incomes rounded to nearest $500.00.
‡Values have been weighted using Canadian Health Measures Survey sample weights.

exclusions. We included 7180 participants in our final sample population.

Table 1 shows sociodemographic characteristics and activity monitor wear time for the overall sample population and each Walk Score quintile. Our sample population had more postsecondary graduates than the full Canadian Health Measures Survey sample population aged 6–79 years old, a difference of 5.4 percentage points. Differences for all other sociodemographic characteristics in Table 1 were less than 3 percentage points. Sociodemographic characteristics of the full Canadian Health Measures Survey sample population are available in Appendix 2 (available at www.cmajopen.ca/content/4/4/E720/suppl/DC1). Figure 2 shows MVPA (min/d) and sedentary time for each age category.

Table 2 shows which population characteristics had statistically significant differences between Walk Score quintiles. Areas with higher Walk Score quintiles had greater proportions of households with low incomes and smaller proportions of households with high incomes. This is consistent with earlier research showing that lower-income households tend to be in more developed areas, which subsequently have greater walking access to neighbourhood amenities.[41,42]

MVPA

In the unadjusted analysis of all study participants, people living in the highest Walk Score quintile did significantly more MVPA than people in the lowest quintile. Most unadjusted analyses of age subgroups showed significant positive associations when comparing highest to lowest quintiles (Table 3). In the covariate-adjusted analysis of all study participants, the highest quintile did an average of 11.8 minutes more MVPA per day (95% CI 9.1 to 14.5) than the lowest quintile. There was a statistically significant ($p < 0.05$) interaction between the highest quintile and all age groups, except for those aged 18–29 years ($p = 0.07$) and 65 years and older ($p = 0.14$); therefore, we proceeded with the subgroup analysis. Subgroup analysis by age showed significant differences between highest and lowest quintiles in all but the youngest age group (Table 3 and Figure 3). MVPA differences between the 2nd–4th Walk Score quintiles and the lowest quintile were smaller, and most were not significant.

Sedentary time

Covariate-adjusted associations between Walk Score quintiles and sedentary time were not significant when comparing all higher quintiles with the lowest. There were no statistically significant interactions between age group and any Walk Score quintile. Unadjusted and adjusted differences in sedentary time between quintiles are available in Appendix 3 (available at www.cmajopen.ca/content/4/4/E720/suppl/DC1).

Discussion

Analyzing all respondents together, people living in the most walkable neighbourhoods engaged in significantly more objectively measured MVPA than people in the least walkable neighbourhoods. Differences for the highest quintile were markedly larger than those for the 2nd–4th quintiles, a finding consistent with other walkability research.[43] In the subgroup analysis, adults aged 30–44 years showed the strongest association, with the highest quintile doing almost 15 minutes per day more MVPA, on average. This is equivalent to 105 minutes of MVPA per week, or over two-thirds of the weekly recommendation of 150 minutes per week for adults.[2,3] Differences for adults aged 18–29 years and 45–64 years were also large, with the highest quintile doing 70–80 minutes per week more MVPA, which is about half the recommendation for adults. Children aged 6–11 years were the only subgroup without a statistically significant difference in MVPA between quintiles. Perhaps this is because characteristics captured by the Walk Score metric, such as amenity density and street connectivity, do not influence the types of activity children engage in (e.g., active play).

Our study is most comparable to studies assessing MVPA time using accelerometers, because self-reported measures can differ substantially because of poor recall, social desirability and other biases.[44] Accelerometer use increases the resource requirements and participant burden of studies; therefore, most studies using accelerometers have sample populations under 400, which limits their power to detect associations.[9,45]

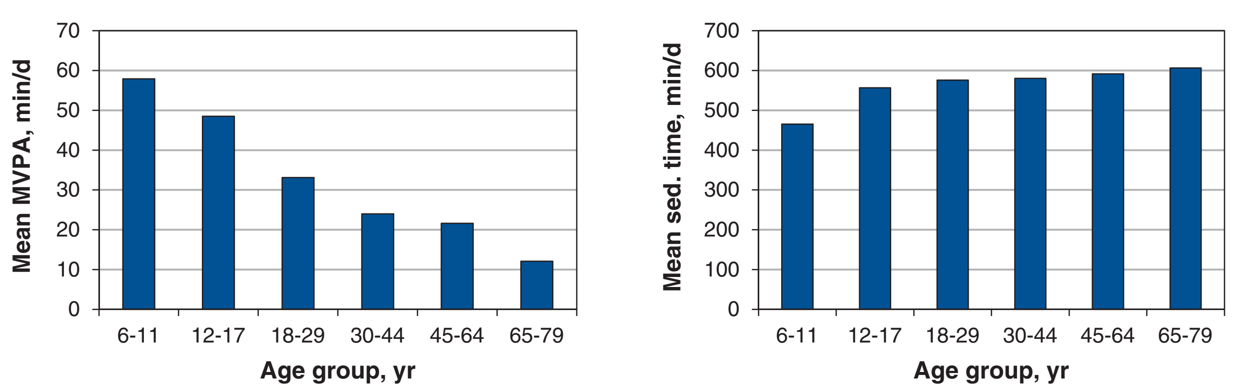

Figure 2: Mean moderate-to-vigorous activity (MVPA; min/d) and sedentary time, by age group ($n = 7180$).

Table 2: Differences in population characteristics across Street Smart Walk Score quintiles	
Population characteristic	*p**
Age category, yr	
6–11	< 0.001
12–17	< 0.001
18–29	0.01
30–44	< 0.001
45–64	0.5
65–79	< 0.001
Sex	
Male	0.2
Female	0.2
Visible minority status	
Visible minority	< 0.001
Not a visible minority	< 0.001
Immigrated to Canada in previous 10 yr	
Yes	< 0.001
No	0.002
Postsecondary graduate† in household	
Yes	< 0.001
No	< 0.001
Household income, Can$‡	
0–36 000	< 0.001
36 500–59 500	< 0.001
60 000–79 500	0.4
80 000 –114 000	< 0.001
≥ 114 500	< 0.001
No. of persons < 12 yr of age in household	
0	0.005
1	0.002
2 or more	< 0.001
Works or attends school	
Yes	0.04
No	< 0.001
Has difficulty walking	< 0.001
Yes	0.06
No	1.0
Activity monitor wear time, min/d	< 0.001

*p values are for χ^2 goodness-of-fit tests across Street Smart Walk Score quintiles, except activity monitor wear time, where p values are for 1-way ANOVA across quintiles.
†Includes people with trade certificate/diploma, college or CEGEP certificate/diploma, university certificate/diploma below bachelors degree, bachelors degree, certificate/diploma/degree above bachelors degree.
‡Incomes rounded to nearest $500.00.

Our findings are similar to 3 studies in the US that are among the largest studies that used objective MVPA measures in their respective age categories. In a study by Sallis and colleagues that involved 2199 adults aged 20–65 years, residents of highly walkable neighbourhoods did 5.8 minutes per day more MVPA than those in less walkable neighbourhoods.[46] Carlson and colleagues' study involving 687 adults aged 65 years and older also identified a positive walkability–MVPA association.[47] In a study involving 770 youth aged 11–15 years, Norman and colleagues found that MVPA was associated with certain features of walkability, such as nearby parks and retail floor area ratio but not with an overall index of walkability.[48]

The studies by Sallis, Carlson, and Norman and their respective colleagues were confined to 1 or 2 major American cities and may not be generalizable to smaller municipalities or other countries. Two recent studies in Canada analyzed national-level populations using the Walk Score metric to assess walkability.[31,49] Thielman and colleagues found positive associations between walkability and self-reported total physical activity among people aged 30–64 years, but they did not find associations among those aged 12–17, 18–29 or 65 years and older.[31] Hajna and colleagues examined adult respondents to the Canadian Health Measures Survey cycle 1, a subset of our study population, but they did not find significant associations between walkability and objectively measured step counts.[49] Our positive results differ from these null findings, possibly because of the following: the majority of daily physical activity is light physical activity; therefore, studies that assessed "total physical activity" or "step counts" captured mostly light physical activity.[4,5] Common light physical activities include light household cleaning and walking around workplaces,[16] which are not expected to be associated with neighbourhood walkability. The physical activities most commonly associated with walkability are transport walking and cycling, which are MVPA.[14–16] Therefore, walkability may be associated with MVPA (e.g., through active transport) but not with light physical activity, and our study isolated the association with MVPA.

Our null findings on walkability and objectively measured sedentary time add to a smaller body of literature in this area, most of which assessed sedentary time using self reporting.[19] A systematic review of studies involving adults found only 28% of the comparisons between environmental attributes and sedentary time were significant in the expected direction.[19] A study in Australia (n = 1072) of self-reported television viewing time by older adults identified a significant positive association with only 1 of 7 perceived environmental attributes;[50] however, a large (n = 3105) British study involving youth aged 11–12 years found greater walkability or cycleability was associated with less self-reported sedentary time.[51]

Our study's large national-level study sample population and objective measures are major strengths; however, some limitations must be considered. Although our analysis accounts for differences in many sociodemographic covariates and accelerometer wear time, it does not include variables such as neighbourhood safety, weather or self-selection of participants into neighbourhoods amenable to their level of physical activity. There was also a time lag between assessment of MVPA and sedentary time, which occurred from 2007 to 2011, and assessment of neighbourhood walkability, which was done in 2014. However, as most built environments do not change rapidly,[52] we expected minimal misclassification into Walk Score quintiles. Additionally, there may have been selection bias if people who were less physically

Table 3: Unadjusted and covariate-adjusted differences from lowest Street Smart Walk Score quintile in MVPA for respondents, overall and by age group

Age group, yr	Quintile (Walk Score range)	MVPA, min/d; weighted mean ± SD	Unadjusted difference (95% CI)	Adjusted* difference (95% CI)
All participants	Q5 (80–100)	35.1 ± 27.9	**9.7 (6.7 to 12.8)**	**11.8 (9.1 to 14.5)†**
	Q4 (59–79)	25.9 ± 23.1	0.5 (–2.2 to 3.3)	2.2 (–0.3 to 4.7)†
	Q3 (41–58)	28.0 ± 26.5	2.6 (–0.9 to 6.2)	**3.6 (0.5 to 6.7)†**
	Q2 (23–40)	27.5 ± 25.6	2.2 (–0.5 to 4.9)	1.5 (–1.0 to 4.0)†
	Q1 (0–22)	25.3 ± 21.9	Ref.	Ref.†
6–11	Q5 (80–100)	56.8 ± 15.3	–0.1 (–6.7 to 6.5)	3.2 (–3.2 to 9.6)
	Q4 (59–79)	57.3 ± 15.6	0.4 (–5.4 to 6.3)	1.5 (–4.5 to 7.5)
	Q3 (41–58)	58.6 ± 18.0	1.6 (–4.7 to 8.0)	3.2 (–2.8 to 9.2)
	Q2 (23–40)	59.4 ± 18.2	2.5 (–3.9 to 8.8)	2.2 (–3.6 to 7.9)
	Q1 (0–22)	56.9 ± 15.8	Ref.	Ref.
12–17	Q5 (80–100)	54.6 ± 19.6	**10.5 (3.4 to 17.6)**	**11.4 (5.3 to 17.4)**
	Q4 (59–79)	46.4 ± 18.2	2.3 (–3.9 to 8.4)	3.5 (–2.2 to 9.1)
	Q3 (41–58)	49.9 ± 22.5	5.8 (–0.8 to 12.3)	**6.5 (0.8 to 12.2)**
	Q2 (23–40)	48.5 ± 25.4	4.4 (–2.3 to 11.0)	**6.9 (0.7 to 13.0)**
	Q1 (0–22)	44.1 ± 15.9	Ref.	Ref.
18–29	Q5 (80–100)	40.8 ± 26.8	**9.9 (1.0 to 18.8)**	**9.9 (2.4 to 17.4)**
	Q4 (59–79)	31.1 ± 28.5	0.2 (–9.4 to 9.9)	–1.4 (–9.7 to 7.0)
	Q3 (41–58)	34.6 ± 38.7	3.8 (–11.6 to 19.2)	3.1 (–9.0 to 15.1)
	Q2 (23–40)	27.0 ± 27.6	–3.9 (–12.8 to 5.0)	–5.6 (–13.5 to 2.3)
	Q1 (0–22)	30.9 ± 29.0	Ref.	Ref.
30–44	Q5 (80–100)	34.3 ± 27.9	**16.9 (11.5 to 22.3)**	**14.9 (10.2 to 19.6)**
	Q4 (59–79)	21.4 ± 17.0	4.0 (–0.3 to 8.3)	3.1 (–0.9 to 7.0)
	Q3 (41–58)	21.7 ± 19.3	4.3 (–0.4 to 9.0)	3.7 (–0.3 to 7.8)
	Q2 (23–40)	21.8 ± 15.5	**4.4 (0.5 to 8.3)**	**3.4 (0.0 to 6.8)**
	Q1 (0–22)	17.4 ± 15.2	Ref.	Ref.
45–64	Q5 (80–100)	29.4 ± 35.0	**11.0 (5.9 to 16.1)**	**11.5 (6.7 to 16.3)**
	Q4 (59–79)	19.3 ± 20.8	0.9 (–2.5 to 4.3)	1.0 (–2.7 to 4.7)
	Q3 (41–58)	20.8 ± 23.3	2.4 (–1.5 to 6.3)	2.9 (–0.9 to 6.7)
	Q2 (23–40)	20.5 ± 27.7	2.1 (–2.0 to 6.3)	1.7 (–2.2 to 5.6)
	Q1 (0–22)	18.4 ± 20.5	Ref.	Ref.
65–79	Q5 (80–100)	16.1 ± 13.3	**6.2 (2.2 to 10.2)**	**6.9 (3.1 to 10.8)**
	Q4 (59–79)	13.4 ± 19.2	3.5 (–1.3 to 8.4)	4.3 (–0.1 to 8.7)
	Q3 (41–58)	11.1 ± 15.3	1.2 (–2.5 to 4.9)	1.2 (–2.4 to 4.8)
	Q2 (23–40)	9.3 ± 13.3	–0.6 (–4.1 to 3.0)	–0.3 (–3.7 to 3.2)
	Q1 (0–22)	9.9 ± 10.7	Ref.	Ref.

Note: CI = confidence interval, MVPA = moderate-to-vigorous physical activity, Q1 = 1st Street Smart Walk Score quintile, Q2 = 2nd Street Smart Walk Score quintile, Q3 = 3rd Street Smart Walk Score quintile, Q4 = 4th Street Smart Walk Score quintile, Q5 = 5th Street Smart Walk Score quintile, Ref. = reference. Statistically significant estimates at $p < 0.05$ are in boldface type.
*All estimates adjusted for sex, visible minority status, immigration to Canada in the past 10 yr, having a postsecondary graduate in the household, household income quintile, number of children under 12 in the household, whether respondents work or attend school, whether respondents have difficulty walking and activity monitor wear time.
†Analyses of all respondents also adjusted for age category. Street Smart Walk Score values are from 2014. Remaining variables from the 2007 to 2011 Canadian Health Measures Survey.

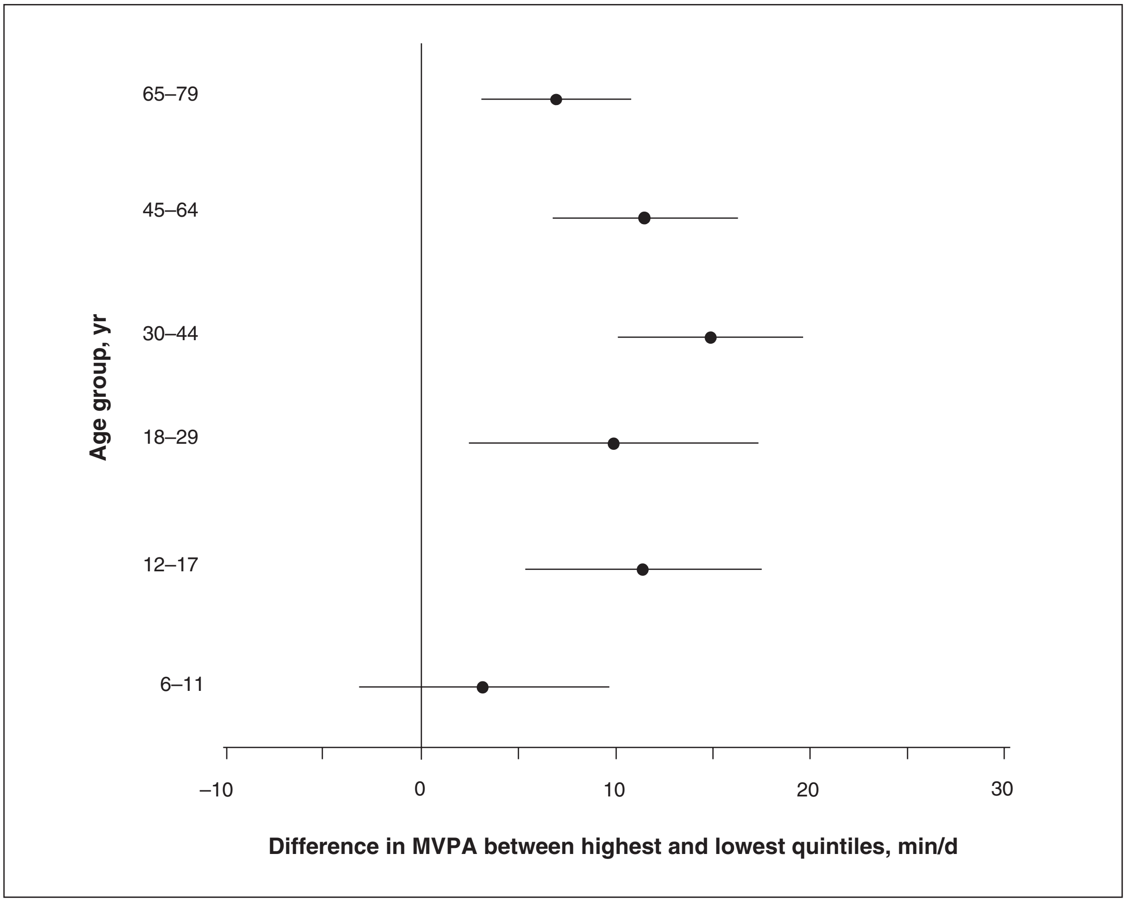

Figure 3: Covariate-adjusted difference in moderate-to-vigorous physical activity (MVPA; min/d) between highest and lowest Street Smart Walk Score quintiles, by age group.

active were less likely to return valid activity monitor data. Furthermore, the 4–7 day wear period may not be representative of typical activity levels for some people, and the minimum 10-hour wear protocol may have missed important activity information. Another limitation is the cross-sectional study design, which limits conclusions about the temporality of the associations assessed.

Conclusion

In all but the youngest age group, people living in the most walkable urban neighbourhoods did significantly more MVPA than people in the least walkable urban neighbourhoods. Furthermore, the higher MVPA in several age groups made up a substantial portion of the international physical activity guidelines, suggesting the higher MVPA levels in highly walkable areas can have a meaningful impact on risk of chronic disease. These findings add to a body of walkability research that has shown mixed results when examining MVPA and sedentary time, which may be due to methodologic issues in many of these studies.[9,19] Future studies should aim to maintain the use of objective measures and large sample sizes, while using longitudinal designs that allow the temporality of this relationship to be examined. If such studies identify walkability–MVPA associations of a similar size as our study, this will suggest that improving walkability is a promising means of achieving meaningful increases in physical activity across a broad population.

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