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The association between walkable neighbourhoods and physical activity across the lifespan

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Abstract

Background: Walkability is positively associated with physical activity in adults. Walkability is more consistently associated with walking for transportation than recreational walking. The purpose of this study is to examine how the association between walkable neighbourhoods and physical activity varies by age and type of physical activity using a new Canadian walkability database.

Data and methods: The 2016 Canadian Active Living Environments (Can-ALE) database was attached to two cross-sectional health surveys: the Canadian Health Measures Survey (CHMS; 2009 to 2015) and the Canadian Community Health Survey (CCHS; 2015 to 2016). Physical activity was measured in the CHMS using the Actical accelerometer (n = 10,987; ages 3 to 79). Unorganized physical activity outside of school among children aged 3 to 11 was reported by parents in the CHMS (n = 4,030), and physical activity data by type (recreational, transportation-based, school-based, and household and occupational) was self-reported by respondents in the CCHS (n = 105,876; ages 12 and older).

Results: Walkability was positively associated with accelerometer-measured moderate-to-vigorous physical activity in youth ($p < 0.05$), younger adults ($p < 0.0001$) and older adults ($p < 0.05$), while walkability was negatively associated with light physical activity in youth (ages 12 to 17) and older adults (ages 60 to 79) ($p < 0.05$). Walkability was positively associated with self-reported transportation-based physical activity in youth ($p < 0.001$) and adults of all ages ($p < 0.0001$). Walkability was negatively associated with parent-reported unorganized physical activity of children aged 5 to 11, and children living in the most walkable neighbourhoods accumulated 10 minutes of physical activity less—on average—than those living in the least walkable neighbourhoods.

Interpretation: The results of this study are consistent with previous studies indicating that walkability is more strongly associated with physical activity in adults than in children and that walkability is associated with transportation-based physical activity. Walkability is one of many built environment factors that may influence physical activity. More research is needed to identify and understand the built environment factors associated with physical activity in children and with recreational or leisure-time physical activity.

Keywords: exercise, built environment, walkability, walking, transportation
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Physical activity is positively associated with a wide range of physical, psychological, social and cognitive health outcomes in children, youth and adults.[1-4] The most recent national statistics indicate that the majority of Canadians do not achieve the recommended levels of physical activity[5,6] and that levels of physical activity have remained stable over the past decade.[7,8] The need to increase levels of physical activity among the population has resulted in calls to identify features of the built environment that contribute positively to physical activity and health.[9,10] The activity friendliness of a neighbourhood is commonly assessed using walkability, which is a measure of how well a neighbourhood's built form promotes walking. Walkability generally consists of multiple subcomponents, including proximity to destinations of interest (e.g., shops, services, workplaces, schools), street connectivity (number of intersections, route options, directness of routes) and residential density (which can support destinations of interest). A newly developed walkability index—the Canadian Active Living Environments (Can-ALE) database—is a geography-based set of measures that represents the active living friendliness or walkability of Canadian communities.[11]

Systematic reviews report consistent evidence of an association between features of the built environment and physical activity in adults,[12-15] and this association is evident in the Canadian context.[16-24] The link between the built environment and physical activity is more often reported for transportation-based or utilitarian walking than for recreational walking.[13,15-17,19,22-24] A limitation of previous research is a reliance on subjective measures of physical activity that do not always delineate between various types and domains of physical activity. Two health surveys at Statistics Canada—the Canadian Community Health Survey (CCHS) and the Canadian Health Measures Survey (CHMS)—use a common physical activity questionnaire that asks Canadians to report time spent engaging in physical activity across a range of domains, including transportation-based, recreational, school-based (where applicable), and occupational and household. These questionnaire data, combined with accelerometer-measured physical activity data in the CHMS, create a unique opportunity to closely examine associations between walkability and physical activity.

The majority of the evidence linking the built environment with physical activity and health relates to adults and older adults, and less is understood about these relationships in children and youth. D'Haese and colleagues reported no association between neighbourhood walkability and physical activity in Belgian children.[25] McGrath and colleagues reported that children living in neighbourhoods with more green space, attractive streets and lower walkability scores accumulated more moderate-to-vigorous physical activity (MVPA).[26] Janssen and King reported that Canadian children living in low walkability neighbourhoods

Authors: Rachel C. Colley (rachel.colley@canada.ca), Tanya Christidis and Michael Tjepkema are with the Health Analysis Division, and Isabelle Michaud is with the International Cooperation and Methodology Innovation Centre at Statistics Canada, Ottawa, Canada. Nancy A. Ross is with the Geo-Social Determinants of Health Research Group in the Department of Geography at McGill University, Montréal, Quebec.

were more likely than children living in high walkability neighbourhoods to engage in free-time physical activity outside of school and achieve the recommended levels of physical activity.[27] Mixed findings have been reported for Canadian youth—for example, walkability and park space were negatively associated with physical activity,[28] and urban sprawl (a pattern of development associated with lower physical activity in adults) was positively associated with physical activity.[29]

The purpose of this study is to examine how the association between walkability (or an "activity friendly environment") and physical activity varies across the lifespan and by the various domains of physical activity in Canadians by combining Can-ALE with two nationally representative health surveys.

What is already known on this subject?

- Physical activity is positively associated with health.
- Many Canadians do not meet the current physical activity guidelines.
- Features of the built environment such as street connectivity, proximity to services and residential density have been associated with increased physical activity.

What does this study add?

- Using a new Canadian measure of walkability or "activity friendliness", this study confirms previous research that has reported a positive association between walkability and physical activity in adults as well as a positive association between walkability and transportation-based physical activity.
- Walkability was not associated with physical activity in children aged 3 to 11. Children living in the least walkable neighbourhoods accumulated, on average, 10 minutes more unorganized physical activity per day than children living in the most walkable neighbourhoods.

Methods

The Postal Code Conversion File Plus (PCCF+ 7A) was used to attach the 2016 Canadian Active Living Environments (Can-ALE) database (limited to non-rural areas) to the accelerometer subsample of cycles 2, 3 and 4 of the Canadian Health Measures Survey (CHMS; 2009 to 2015). PCCF+ was used to have a dissemination area (DA) vintage (2016) more closely aligned with the survey than what was available on the survey file (2011). The present analysis is based on a sample of 10,987 respondents with valid accelerometer-measured physical activity and Can-ALE data. Physical activity was measured in the CHMS using the Actical accelerometer. A separate sample of the parent-reported physical activity data (unorganized, organized and school-based) for children aged 3 to 11 (n = 4,030) was created from the original household and clinic CHMS sample of this age group (n = 4,883).

PCCF+ 7A was used to attach the 2016 Can-ALE database (limited to non-rural areas) to the Canadian Community Health Survey (CCHS; 2015 to 2016). Of the original CCHS sample (n = 110,095), about 4% had either missing (n = 3,248) or invalid (n = 971) physical activity data. This analysis is based on 105,876 respondents aged 12 and older with valid self-reported physical activity data. Self-reported physical activity data by type (transportation-based, recreational, school-based, and household and occupational) for youth and adults (aged 12 and older) were used from the CCHS.

Canadian Health Measures Survey and Canadian Community Health Survey

The CHMS is an ongoing cross-sectional survey conducted by Statistics Canada that collects measured and reported health information from a representative sample (representing approximately 97% of the population) of the Canadian household-dwelling population aged 3 to 79 using mobile examination centres that travel to multiple sites (Cycle 2: 18 sites; Cycle 3: 16 sites; Cycle 4: 16 sites) across the country, except the territories.[30-32] The CCHS is an ongoing cross-sectional survey conducted by Statistics Canada that collects self-reported information related to health status, health care utilization and determinants of health for the Canadian population and covers approximately 98% of the Canadian population aged 12 and older.[33]

Canadian Active Living Environments (Can-ALE) database

The Can-ALE database is a geography-based set of measures that represents the active living friendliness of Canadian communities.[11,34] The z-scores of three factors were included in the 2016 Can-ALE database: intersection density, dwelling density and points of interest. A summarized index measure (the sum of z-scores for each ALE measure—the ALE index) and a categorical measure of the favourability of the active living environment (from 1, the least active living friendly and walkable, to 5, the most active living friendly and walkable—the ALE class) are also included in the database. A cluster analysis (k-medians approach) was used to assign each DA to one of the five groups. The measures are based on one-kilometre buffers drawn from the centroids of DAs from the 2016 Census. DAs are small geographic units defined by Statistics Canada that typically encompass a population of between 400 and 700 people. Intersection density was derived using road and footpath features from Statistics Canada's Road Network File and OpenStreetMap and represents the number of three-way (or more) intersections within a one-kilometre buffer around the DA centroid. Dwelling density was calculated using Statistics Canada census data and captures the average dwelling density of the DAs within the buffer area. The points of interest measure captures the number of potential walking destinations (e.g., parks, schools, shops, places of business and landmarks) within a one-kilometre buffer. A description of the different Can-ALE classes is provided in Table 1.

Postal Code Conversion File Plus (PCCF+)

The Postal Code Conversion File Plus (PCCF+) is a SAS© control program and set of associated datasets from the Postal Code Conversion File (PCCF), a postal code population weight file, the Geographic Attribute File, health region boundary files and other supplementary data. PCCF+ Version 7A[35] was used to assign a 2016 DA to each CCHS and CHMS respondent's postal code to link it to the Can-ALE database. Because of precision issues with geocoding in rural areas,[35,36] respondents living in a rural area or small town were excluded from this analysis using the community size variable (CSize < 5). Community size is defined in terms of the 2016 Census population in each census metropolitan area (CMA) or census agglomeration (CA). Community size 1 includes Toronto, Montréal and Vancouver; community size 2 includes Ottawa–Gatineau, Edmonton, Calgary, Québec, Winnipeg and Hamilton; community size 3 includes all 18 other CMAs and seven of the larger CAs; community size 4 includes all 106 other CAs; and community size 5 includes all places not included in a CMA or CA and is representative of rural and small-town Canada.

Accelerometer-measured physical activity (Canadian Health Measures Survey)

Following a household questionnaire, participants reported to the mobile examination centre located in or near their hometown to complete a series of physical measures. Upon completion of the mobile examination centre visit, ambulatory respondents were asked to wear an Actical accelerometer (Phillips Respironics, Oregon, United States) over their right hip on an elasticized belt during waking hours for seven consecutive days. All respondents were blind to the data while they wore the device. The Actical measures and records time-stamped acceleration in all directions, providing an index of physical activity intensity using a count value for each minute. A valid day was defined as having 10 or more hours of wear time and a valid respondent was defined as having a minimum of four valid days.[37] Wear time was determined by subtracting non-wear time from 24 hours. Non-wear time was defined as at least 60 consecutive minutes of zero counts, with allowance for one to two minutes of counts between 0 and 100. Published movement intensity thresholds were applied to the data to derive time spent in light physical activity (LPA) and moderate-to-vigorous physical activity (MVPA).[38-40] A complete description of the accelerometer data reduction procedures is available elsewhere.[37]

Self-reported physical activity (Canadian Community Health Survey)

CCHS respondents aged 12 and older were asked to provide estimates of time spent in the past seven days engaged in transportation-based, recreational, school-based, and occupational and household physical activity. The reported values by domain were summed to determine their total physical activity. An examination of how this self-reported questionnaire module relates to accelerometer-measured physical activity is available elsewhere for adults[41] and youth.[42]

Parent-reported physical activity (Canadian Health Measures Survey)

Parents of CHMS respondents aged 3 to 11 were asked to estimate the number of hours per week their child usually takes part in physical activity that makes them out of breath or warmer than usual in their free time outside of school while participating in unorganized activities on their own or with friends. An examination of how this parent-reported questionnaire module relates to accelerometer-measured physical activity is available elsewhere.[43]

Statistical analysis

Unadjusted descriptive statistics were used to calculate the means and 95% confidence intervals of each physical activity variable by Can-ALE class. Pairwise contrasts were used to make comparisons of physical activity between Can-ALE classes. Trend analyses were used to assess upward or downward linear trends in physical activity across the five categories of walkability. Separate linear regression models for each physical activity variable (accel-

Table 1
Description of Can-ALE subcomponents across Can-ALE categories

	Can-ALE Class 1	Can-ALE Class 2	Can-ALE Class 3	Can-ALE Class 4	Can-ALE Class 5
Connectivity relative to national average	-85%	0	+54%	+105%	+256%
Destinations relative to national average	-91%	-31%	+21%	+127%	+637%
Population density relative to national average	-93%	-30%	+35%	+170%	+470%
Example neighbourhoods	Fort Langley, B.C.	Cowansville, Que.	Brossard, Que.	South End, Halifax, N.S.	Plateau, Montréal, Que.
	Caledon, Ont.	Kanata, Ont.	Holliston, Saskatoon, Sask.	Woodfield, London, Ont.	The Annex, Toronto, Ont.
	Bay Roberts, N.L.	Moose Jaw, Sask.	Steveston, Richmond, B.C.	Bridgeland, Calgary, Alta.	Kitsilano, Vancouver, B.C.

Adapted from Ross et al., *Report on the Utilitarian Walking, Active Transportation, and Physical Activity of Canadians* (see reference 11 and 34).
Note: +/- signify difference from national average.

erometer-measured, self-reported and parent-reported) were created for all age groups (3 to 4, 5 to 11, 12 to 17, 18 to 39, 40 to 59, and 60 to 79 in the CHMS and 60 and older in the CCHS) to assess the association between the walkability index (ALE_index; continuous variable) and physical activity. The CHMS linear regression models (i.e., accelerometer-measured and parent-reported physical activity data) were controlled for age, sex, household income and household education. The CCHS linear regression models were controlled for age, sex, household income and household education, with the exception of the youth sample (aged 12 to 17), which was controlled for age, sex and household income only. MVPA—but not LPA or step counts—was log-transformed in the CHMS models. All self-reported physical activity variables were log-transformed in the CCHS models. All analyses were weighted using the combined cycle survey weights generated by Statistics Canada for cycles 2, 3 and 4 of the CHMS[30-32] and for the 2015 to 2016 CCHS.[33] Analyses using the accelerometer data were weighted with specific subsample weights, while parent-reported and self-reported data were weighted using the full household weights. The data were analyzed with SAS 9.3 (SAS Institute, Cary, North Carolina) and SUDAAN 11.0 using denominator degrees of freedom (DDF = 35) in the SUDAAN procedure statements for the CHMS analyses. To account for survey design effects, 95% confidence intervals were estimated using the bootstrap technique. Of the households selected in cycles 2, 3 and 4 of the CHMS, between 74.1% and 76.4% provided information about the composition of their household, between 88.4% and 91.5% participated in the household survey, and between 77.2% and 81.7% attended the mobile examination centre for physical measurements, resulting in an overall combined response rate of between 51.7% and 55.5%. The response rate for the accelerometer subsample (reflecting the analytical requirement of having at least four valid days of accelerometer data)[30-32] was about 40% for all cycles. The response rate for the 2015 to 2016 CCHS was 57.5%.[33]

Results

An overview of the physical activity variables and the distribution across Can-ALE categories is presented by age

Table 2
Descriptive physical activity results and the distribution across Can-ALE categories for the Canadian Health Measures Survey and Canadian Community Health Survey samples

	Ages 3 to 4			Ages 5 to 11			Ages 12 to 17		
		95% confidence interval			95% confidence interval			95% confidence interval	
	Estimate	from	to	Estimate	from	to	Estimate	from	to
Canadian Health Measures Survey (n = 10,987)									
Accelerometer-measured physical activity (n = 10,987)									
Moderate-to-vigorous physical activity (minutes/day)	69.7	67.1	72.4	63.1	59.9	66.3	47.4	44.0	50.8
Light physical activity (minutes/day)	208.8	203.6	214.1	269.1	263.5	274.6	207.8	203.3	212.3
Step counts per day	10,279	9,866	10,691	11,576	11,174	11,978	9,681	9,227	10,135
Parent-reported physical activity (n = 4,030; ages 3 to 11)									
Physical activity at school during free time (minutes/day)	...	...	...	48.5	46.0	51.0	...	...	...
Physical activity at school during class time (minutes/day)	...	...	...	26.3	25.1	27.5	...	...	...
Physical activity during lessons, leagues and team sports (minutes/day)	6.8	5.6	7.9	17.4	15.7	19.0	...	...	...
Unorganized physical activity outside of school (minutes/day)	44.7	42.4	46.9	35.9	33.9	37.9	...	...	...
Distribution across Can-ALE classes (n = 10,987)									
Can-ALE Class 1 (%)	15.6	11.0	21.8	18.8	13.7	25.2	18.6	13.1	25.7
Can-ALE Class 2 (%)	33.2	26.0	41.4	37.4	31.3	44.0	33.4	27.6	39.8
Can-ALE Class 3 (%)	35.2	27.9	43.3	28.8	23.6	34.6	33.1	27.0	39.9
Can-ALE Class 4 (%)	9.4	5.8	15.0	12.3	7.9	18.5	12.6	7.7	20.0
Can-ALE Class 5 (%)	6.5	3.1	12.8	2.8	1.3	5.9	2.3	1.0	5.0
Canadian Community Health Survey (n = 105,876)									
Self-reported physical activity									
Transportation-based physical activity (minutes/day)	...	...	...	...	...	...	27.3	25.9	28.6
Recreational physical activity (minutes/day)	...	...	...	...	...	...	34.6	33.2	36.0
School-based physical activity (minutes/day)	...	...	...	...	...	...	31.8	30.2	33.4
Household and occupational physical activity (minutes/day)	...	...	...	...	...	...	6.4	5.6	7.2
Total physical activity (minutes/day)	...	...	...	...	...	...	100.1	97.0	103.2
Distribution across Can-ALE classes									
Can-ALE Class 1 (%)	...	...	...	...	...	...	22.4	21.1	23.7
Can-ALE Class 2 (%)	...	...	...	...	...	...	36.3	34.7	38.0
Can-ALE Class 3 (%)	...	...	...	...	...	...	29.9	28.1	31.7
Can-ALE Class 4 (%)	...	...	...	...	...	...	8.5	7.4	9.7
Can-ALE Class 5 (%)	...	...	...	...	...	...	2.9	2.3	3.8

Table 2
Descriptive physical activity results and the distribution across Can-ALE categories for the Canadian Health Measures Survey and Canadian Community Health Survey samples

	Ages 18 to 39			Ages 40 to 59			Ages 60 to 79		
		95% confidence interval			95% confidence interval			95% confidence interval	
	Estimate	from	to	Estimate	from	to	Estimate	from	to
Canadian Health Measures Survey (n = 10,987)									
Accelerometer-measured physical activity (n = 10,987)									
Moderate-to-vigorous physical activity (minutes/day)	30.3	27.5	33.2	23.1	21.3	24.9	15.3	13.9	16.7
Light physical activity (minutes/day)	229.2	221.4	236.9	229.6	224.7	234.5	186.9	181.2	192.7
Step counts per day	8,911	8,537	9,285	8,508	8,199	8,818	6,892	6,659	7,125
Parent-reported physical activity (n = 4,030; ages 3 to 11)									
Physical activity at school during free time (minutes/day)	...	...	...	...	...	...	...	...	...
Physical activity at school during class time (minutes/day)	...	...	...	...	...	...	...	...	...
Physical activity during lessons, leagues and team sports (minutes/day)	...	...	...	...	...	...	...	...	...
Unorganized physical activity outside of school (minutes/day)	...	...	...	...	...	...	...	...	...
Distribution across Can-ALE classes (n = 10,987)									
Can-ALE Class 1 (%)	14.5	10.3	20.1	18.3	13.6	24.2	20.7	15.3	27.4
Can-ALE Class 2 (%)	31.3	25.4	37.8	34.7	28.3	41.7	32.5	27.1	38.3
Can-ALE Class 3 (%)	31.8	26.3	37.8	30.6	25.4	36.4	30.5	25.4	36.1
Can-ALE Class 4 (%)	12.7	8.8	18.0	11.1	7.2	16.8	11.7	7.2	18.5
Can-ALE Class 5 (%)	9.8	5.4	17.1	5.3	2.3	11.6	4.6	2.4	8.5
Canadian Community Health Survey (n = 105,876)									
Self-reported physical activity									
Transportation-based physical activity (minutes/day)	16.8	16.2	17.4	12.6	12.1	13.1	11.4	10.9	11.8
Recreational physical activity (minutes/day)	18.9	18.3	19.5	14.0	13.5	14.5	11.2	10.7	11.7
School-based physical activity (minutes/day)	...	...	...	...	...	...	...	...	...
Household and occupational physical activity (minutes/day)	28.6	27.0	30.1	24.8	23.4	26.2	15.4	14.3	16.5
Total physical activity (minutes/day)	64.3	62.5	66.1	51.4	49.8	52.9	37.9	36.6	39.2
Distribution across Can-ALE classes									
Can-ALE Class 1 (%)	16.9	15.8	18.0	20.5	19.4	21.7	21.3	20.2	22.5
Can-ALE Class 2 (%)	33.6	32.1	35.1	36.0	34.4	37.5	35.1	33.7	36.6
Can-ALE Class 3 (%)	29.3	27.7	31.0	28.1	26.5	29.6	28.0	26.5	29.5
Can-ALE Class 4 (%)	11.7	10.5	13.0	10.6	9.6	11.7	10.7	9.6	11.9
Can-ALE Class 5 (%)	8.5	7.7	9.4	4.9	4.3	5.6	4.9	4.2	5.7

... not applicable
Notes: Can-ALE stands for Canadian Active Living Environments. CI stands for confidence interval.
Sources: Canadian Health Measures Survey, 2009 to 2015; Canadian Community Health Survey, 2015 to 2016.

group in Table 2 for both the CHMS and CCHS. Physical activity generally decreases with age and is higher in self-reported data than in accelerometer-measured data. The distribution across Can-ALE classes was relatively consistent across age groups for both samples.

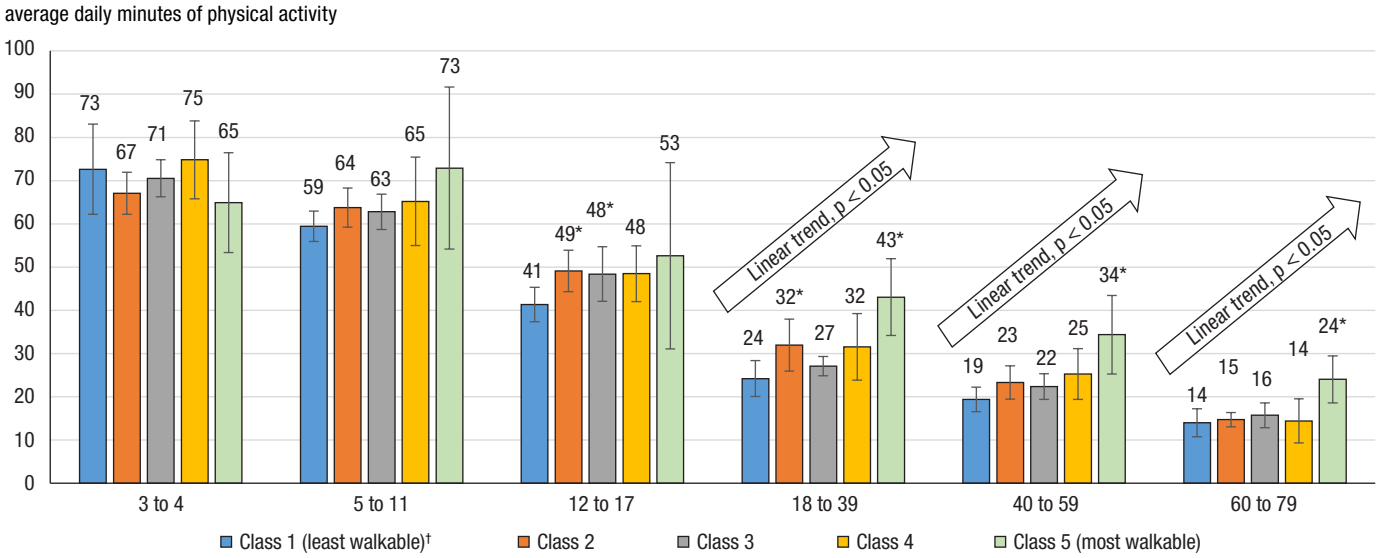
Accelerometer-measured physical activity

A significant upward linear trend was evident for MVPA across Can-ALE categories for adults but not for children or youth (Figure 1). Pairwise contrasts between MVPA in Can-ALE classes 2, 3, 4 and 5 and MVPA in Class 1 are noted in Figure 1. LPA did not vary across Can-ALE categories, with the exception of a significant downward linear trend in LPA for youth aged 12 to 17 (data not shown). Average daily step counts did not vary across Can-ALE categories in any age group (data not shown). Linear regression models (controlled for age, sex, income and education) indicated that walkability (Can-ALE index) was positively associated with MVPA in youth and adults (Table 3). Walkability was negatively associated with LPA in youth and older adults and was positively associated with average daily step counts in middle-aged adults only (Table 3).

Self-reported physical activity of youth and adults

An upward linear trend across Can-ALE categories in self-reported transportation-based physical activity was evident for youth and adults (Figure 2a). No linear trend across Can-ALE categories was evident for self-reported recreational physical activity (Figure 2b). A downward linear trend across Can-ALE categories in self-reported household and occupational physical activity was evident for youth and adults (Figure 2c). There was no overall linear trend in either direction for total self-reported physical activity (Figure 2d). Linear regression models (controlled for age, sex, income

Figure 1
Average daily minutes of accelerometer-measured moderate-to-vigorous physical activity, by Can-ALE category (walkability)



* significantly different from reference category ($p < 0.0125$)
† reference category
Sources: Canadian Health Measures Survey, 2009 to 2015; Canadian Active Living Environments (Can-ALE) database, 2016.

and education) indicated that walkability was positively associated with transportation-based physical activity for both youth and adults, but was positively associated with total physical activity in adults only (Table 3). Walkability was negatively associated with occupational and household physical activity among adults. Walkability was not associated with recreational physical activity.

Parent-reported physical activity of children aged 3 to 11

There were no differences in parent-reported physical activity across Can-ALE categories for preschool-aged children (ages 3 to 4) (data not shown). In children aged 5 to 11, a downward linear trend across Can-ALE categories was evident in unorganized physical activity outside of school (Figure 3). Children living in the most walkable Can-ALE category accumulated 10 minutes of unorganized physical activity less than those living in the least walkable Can-ALE category. Linear regression models (controlled for age, sex, income and education) indicated that walkability was negatively associated with parent-reported physical activity in children aged 5 to 11 (Table 3).

Discussion

By combining accelerometer-measured, self-reported and parent-reported physical activity data from two large, nationally representative Canadian health surveys with a new Canadian measure of walkability (Can-ALE), this study confirmed that the association between walkability and physical activity varies by age and domain of activity. Walkability was positively associated with accelerometer-measured MVPA in youth and adults, while it was negatively associated with LPA in youth and older adults. Walkability was positively associated with self-reported transportation-based physical activity in youth and adults. Walkability was negatively associated with parent-reported unorganized physical activity among children aged 5 to 11, and children living in the most walkable neighbourhoods were accumulating 10 minutes of physical activity less—on average—than those living in the least walkable neighbourhoods.

Using accelerometer-measured physical activity data, this study corroborates a body of Canadian literature that supports a positive association between walkability and physical activity in adults[16-24] and a less conclusive relationship in children.[25-29] A paper published by Janssen and King in 2015, "Walkable school neighborhoods are not playable neighborhoods," noted that the features that make a neighbourhood highly walkable (e.g., high density, mixed residential and commercial area) may present barriers to children's outdoor free play.[27] Accelerometer-measured MVPA was not associated with walkability in children in the present study. Furthermore, unorganized physical activity outside of school (i.e., free play) decreased with each increasing step on the walkability scale. Walkability—as typically defined at present (e.g., density, connectivity and destinations)—may not be a relevant construct for children. Other features of the built environment that support playability (e.g., presence of parks, green space, open space, quiet roads) are likely more appropriate for explaining physical activity in children.[26] As highlighted by Janssen and King, more research is needed to identify and study built environment features and designs that support physical activity in all age groups.[27] Moreover, the contribution of the built environment in terms of effect size relative to other predictors of physical activity behaviour in children

Table 3
Association between walkability and accelerometer-measured and self-reported physical activity

Data source	Physical activity variable	Age group (years)	Beta	Standard error	95% confidence interval from	95% confidence interval to	Statistical significance (p)
Canadian Health Measures Survey	Accelerometer-measured moderate-to-vigorous physical activity[1]	3 to 4	0.00	0.01	-0.02	0.02	0.985
		5 to 11	0.01	0.01	-0.02	0.03	0.630
		12 to 17	0.04	0.01	0.01	0.06	0.013
		18 to 39	0.07	0.01	0.04	0.09	0.000
		40 to 59	0.05	0.01	0.03	0.08	0.000
		60 to 79	0.06	0.02	0.02	0.10	0.009
	Accelerometer-measured light physical activity	3 to 4	0.29	0.76	-1.26	1.83	0.709
		5 to 11	0.52	1.13	-1.77	2.81	0.649
		12 to 17	-3.45	1.39	-6.26	-0.63	0.018
		18 to 39	-1.78	2.50	-6.86	3.30	0.481
		40 to 59	-0.47	1.13	-2.76	1.82	0.680
		60 to 79	-2.20	0.93	-4.07	-0.32	0.023
	Accelerometer-measured step counts	3 to 4	174.04	116.58	-62.62	410.70	0.144
		5 to 11	-17.26	79.63	-178.91	144.39	0.830
		12 to 17	34.47	131.56	-232.62	301.55	0.795
		18 to 39	106.55	57.48	-10.15	223.25	0.072
		40 to 59	116.48	45.20	24.72	208.25	0.014
		60 to 79	61.64	60.15	-60.47	183.76	0.312
	Parent-reported unorganized physical activity	3 to 4	-0.28	0.69	-1.68	1.11	0.681
		5 to 11	-1.37	0.45	-2.28	-0.45	0.005
Canadian Community Health Survey	Self-reported transportation-based physical activity[1]	12 to 17	0.03	0.01	0.02	0.05	0.000
		18 to 39	0.02	0.00	0.01	0.03	0.000
		40 to 59	0.02	0.00	0.02	0.03	0.000
		60 and older	0.03	0.00	0.03	0.04	0.000
	Self-reported recreational physical activity[1]	12 to 17	-0.01	0.01	-0.04	0.01	0.387
		18 to 39	0.00	0.00	0.00	0.01	0.130
		40 to 59	0.01	0.00	0.00	0.02	0.064
		60 and older	0.00	0.01	-0.02	0.01	0.754
	Self-reported household and occupational physical activity[1]	12 to 17	-0.05	0.03	-0.11	0.01	0.092
		18 to 39	-0.02	0.01	-0.03	0.00	0.012
		40 to 59	-0.02	0.01	-0.03	-0.01	0.001
		60 and older	-0.03	0.01	-0.05	-0.01	0.004
	Self-reported total physical activity[1]	12 to 17	0.00	0.01	-0.02	0.02	0.798
		18 to 39	0.01	0.00	0.00	0.02	0.032
		40 to 59	0.01	0.00	0.00	0.02	0.048
		60 and older	0.01	0.00	0.00	0.02	0.002
	Self-reported school-based physical activity[1]	12 to 17	0.01	0.02	-0.02	0.04	0.693

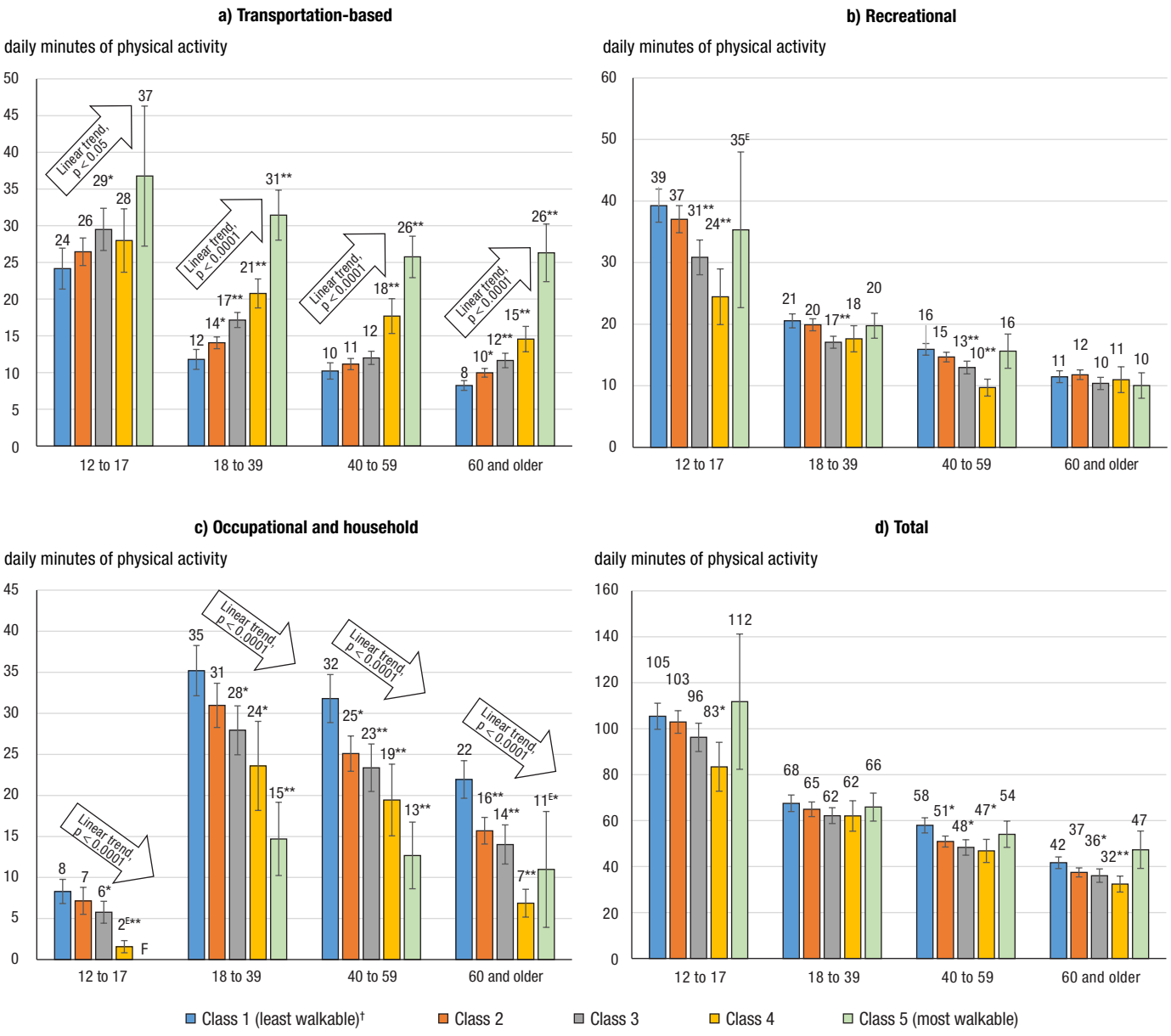
1. Variables were log-transformed in the linear regression models.
Note: Models controlled for age, sex, household education and household income. The CCHS youth models were adjusted for age, sex and household income only.
Sources: Canadian Health Measures Survey, 2009 to 2015; Canadian Community Health Survey, 2015 to 2016.

(e.g., parental role models and support) is an important consideration.[25,44]

The relationship between walkability and physical activity was stronger in younger adults than in older adults. Furthermore, walkability was negatively associated with LPA in older adults. A systematic review focused on older adults suggested that many built environment correlates of physical activity relevant to older adults are not currently captured in traditional definitions of walkability, including safety, crime, access to recreational facilities, access to parks and public open spaces, greenery and aesthetically pleasing scenery, walking-friendly infrastructure, and access to public transportation.[12] A potential focus of future research would be the identification of unique built environment features conducive to physical activity—including LPA—in older adults.

The finding that walkability was not associated with recreational physical activity is consistent with other findings.[13,15-17,19,22-24] A recent Canadian systematic review reported that the majority of studies included in the review found null (97% of studies) or negative (3% of studies) associations between recreational physical activity and walkability.[19] This same review found that the majority (67%) of studies included in

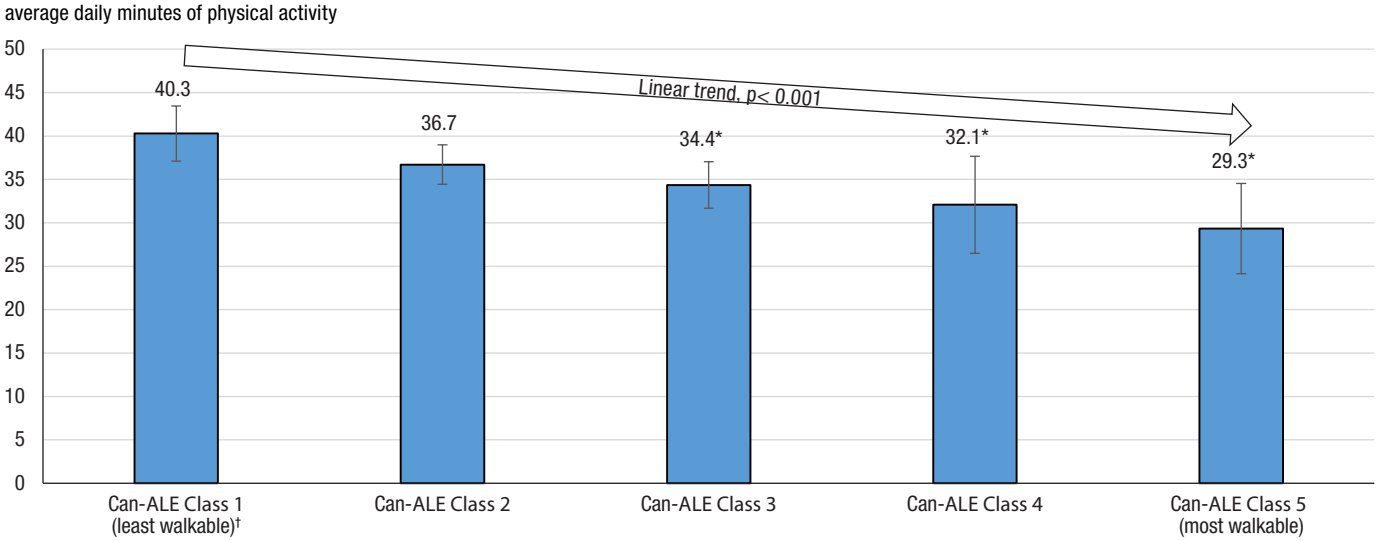
Figure 2
Average daily minutes of self-reported physical activity in youth and adults, by type, by Can-ALE category (walkability)



E use with caution
F too unreliable to be published
* significantly different from reference category ($p < 0.0125$)
** significantly different from reference category ($p < 0.0002$)
† reference category
Total physical activity = transportation-based + recreational + household and occupational
Note: No linear trends were observed in b) and in d).
Sources: Canadian Community Health Survey, 2015 to 2016; Canadian Active Living Environments (Can-ALE) database, 2016.

the review found a positive association between walkability and transportation-based physical activity. This is also consistent with Thielman and colleagues, who reported a similar discrepancy between recreational and transportation-based physical activity and suggested that the gains in daily energy expenditure obtained from active transportation may be negated by lower recreational physical activity among some age groups.[24] The construct of walkability was designed to include features of the built environment that facilitate physical activity for the purposes of transportation. These features are likely very different from those associated with recreational or leisure-time physical activity, such as aesthetically pleasing walking trails and reduced traffic. The inconsistent findings with regard to walkability and physical activity have led to research that explores novel built environment features, such as reducing parking lots and setbacks and

Figure 3
Parent-reported unorganized physical activity outside of school in children aged 5 to 11



* significantly different from reference category ($p < 0.0125$)
† reference category
Sources: Canadian Health Measures Survey, 2009 to 2015; Canadian Active Living Environments (Can-ALE) database, 2016.

increasing street-level tree canopies.[45] Future walkability indices are likely to include additional or different built environment features, which may change the strength and direction of the associations with physical activity.

It is difficult to place the finding that walkability was negatively associated with occupational and household physical activity in context with previous work, as there is not much research with which to draw comparisons. This is partly because of the unique question on the questionnaire that places the occupational and household domains together. This combined domain in the physical activity questionnaires used by Statistics Canada was included in response to surveillance needs for understanding the distribution of physical activity across the various domains of life (recreation, transportation, and household and occupation). Previous work indicated that the household and occupation domain did not correlate well with accelerometer-measured MVPA and was correlated with measured LPA.[41] Further research is needed to understand this domain and whether occupation and household should be collapsed into a single category as they are currently. It is possible that household physical activity (e.g., chores and gardening) may be lower in urban areas where residences and properties are typically smaller in size. Speculating on why occupational physical activity would be lower in more walkable areas is difficult, and further work examining more individual-level and neighbourhood-level covariates would be needed. In addition, it would be interesting to examine whether individuals who engage in certain types of physical activity are more or less likely to engage in physical activity from other domains. For example, are individuals who participate in recreational physical activity regularly more or less likely to walk or cycle to work, or are individuals with very active jobs more or less likely to engage in transportation-based and recreational physical activity?

Strengths and limitations

To date, the majority of the research done on the association between walkability and physical activity has been focused on either adults or children, has been limited to small geographic areas, or has relied on reported physical activity data.[19] The present study examined this relationship in a single analysis across a wide age range using two nationally representative samples of Canadians that used both direct and reported physical activity measurement approaches. The Can-ALE dataset is a new Canadian geography-based set of measures that incorporates high-quality data sources that are open and free to use. Descriptive physical activity epidemiology work using this new walkability measure is not yet available in the published literature. This study provides a broad overview of how the new measure of walkability or activity friendliness relates to physical activity in Canadians. A strength of the current study is that it uses both self-reported and accelerometer-measured approaches. The accelerometer results provided a robust and unbiased account of the relationship between walkability and physical activity, while the self-reported information is critical to understand the contextual nuances evident in the relationship between the two.

The present study examined the relationship between walkability and physical activity using both unadjusted trend analyses and adjusted regression models. The covariates included in the regression models in this study were limited to age, sex, income and education.

For the most part, the adjusted regression models corroborated the unadjusted trend analyses. It would be important for a future study to identify and examine other individual-level covariates. In addition, more work is needed to examine how the association between walkability and physical activity is affected by neighbourhood-level variables related to income, safety and demographics. A subject worth exploring further is the highest walkability class, as it had a relatively smaller number of respondents and they have physical activity habits that are very different from the rest of the population. Another limitation of both this study and previous work is the cross-sectional design and lack of adjustment of residential self-selection.[19] If people choose to live in a neighbourhood that supports their existing physical activity habits, this may lead to an overestimation of the strength of association between walkability and physical activity.[46] Longitudinal research that follows people who move from less walkable areas to highly walkable areas (and vice versa) would help to shed light on this issue. Other limitations of this study include possible residual confounding from unmeasured variables and the fact that the results cannot be generalized for rural areas in Canada.

Conclusion

The notion of walkability comprises a very specific set of factors that appears to support walking for the purpose of transportation in adults. Further research is needed to identify and examine other built environment characteristics that support physical activity in children (e.g., playability, parks, safety) and recreational physical activity in adults (e.g., greenness, presence of trails). Research focused specifically on older adults is also needed. ■

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