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Evidence synthesis

A systematized literature review on the associations between neighbourhood built characteristics and walking among Canadian adults

Brenlea Farkas, MSc (1); Daniel J. Wagner, MSc (1); Alberto Nettel-Aguirre, PhD (1, 2, 3); Christine Friedenreich, PhD (1, 4, 5); Gavin R. McCormack, PhD (1)

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Abstract

Introduction: Evidence to date suggests that the built environment has the potential to facilitate and even discourage physical activity. A limitation of previous reviews is that they have typically not been country-specific. We conducted a systematized literature review of quantitative studies that estimated associations between the built environment—which were objectively measured—and walking among Canadian adults.

Methods: Five scientific databases were searched for peer-reviewed studies published in all years up to December 31, 2016, that estimated the association between the built environment (i.e. objectively measured using audits and Geographic Information Systems [GIS]) and physical activity among a sample of Canadian adults. The database searches, title and abstract screen, full-text review and data extraction were undertaken by two reviewers.

Results: Of 4140 articles identified, 25 met the inclusion criteria. Most studies included data from a single Canadian province. All but two studies were cross-sectional. Most studies captured self-reported walking for transportation and walking for any purpose. Overall walkability and land use were consistently associated with walking for transportation, while proximity to destinations was associated with walking for any purpose.

Conclusions: Our review findings suggest that the built environment is potentially important for supporting adult walking. Overall walkability, land use and proximity to destinations appear to be important given their association with transportation walking and walking for any purpose.

Keywords: *built environment, walking, pedestrian, neighbourhood, physical activity, walkability, transportation, recreation*

Highlights

- Among Canadian studies investigating the association between the objectively measured built environment and walking, recreational walking is studied less frequently than transportation walking or walking for any purpose.
- Objectively measured walkability, land use mix and destination proximity are associated with walking outcomes among Canadian adults.
- In Canadian neighbourhoods, objectively measured built characteristics are more consistently associated with transportation walking than with recreational walking.
- Except for two longitudinal studies, all Canadian studies investigating the association between the objectively measured built environment and walking are cross-sectional.

Introduction

Walking is a popular physical activity that requires no special ability, skill or equipment and incurs a minimal cost to undertake. By contributing to physical activity levels, walking helps to reduce the risk of chronic health conditions including cardiovascular disease,[1] diabetes,[1] hypertension,[2] depression,[3] cancer,[4,5] and obesity.[6,7] The treatment and management of chronic health conditions resulting from a lack of physical activity place a significant economic burden on Canada's health care system[7-9] and elsewhere. Despite the known health benefits,[10, 11] many Canadian adults do not undertake enough physical activity.[12] Creating neighbourhood built environments that support physical activity may be one approach to increasing physical activity at the population level and, in turn, decrease the economic burden of chronic health conditions in Canada.

The built environment includes all characteristics of the physical environment that

Author references:

1. Department of Community Health Sciences, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada
2. Department of Pediatrics, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada
3. Alberta Children's Hospital Research Institute, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada
4. Department of Oncology, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada
5. Department of Cancer Epidemiology and Prevention Research, CancerControl Alberta, Alberta Health Services, Calgary, Alberta, Canada

Correspondence: Gavin McCormack, Department of Community Health Sciences, Cumming School of Medicine, University of Calgary, 3280 Hospital Drive, N.W. Calgary, AB T2N 4Z6; Tel: 403-220-8193; Email: gmccorma@ucalgary.ca

have been planned, constructed or modified by humans.[13] Evidence from systematic reviews suggests that the neighbourhood built environment is associated with physical activity.[14-16] Findings from these reviews also suggest that the neighbourhood built environment is more supportive of walking than of any other physical activity, and that built environment correlates may differ depending on the purpose of walking (e.g. transportation walking, recreational walking, dog walking).[14,16,17] Studies have consistently found an association between land use mix, destination mix and proximity, residential or population density, street and pedestrian connectivity, and overall levels of walkability and walking.[14,16,18-22] However, it is not known whether there is a link between these findings and the exact geographical location or region (e.g. city or country) in which the study was undertaken.

To date, systematic reviews exploring the relationship between the built environment and physical activity have typically combined findings from studies undertaken in multiple geographical contexts.[14,19,21] The findings from these literature reviews have been heavily informed by studies undertaken in Australia, European countries, and the United States; these studies suggest that the findings may not be generalizable to a specific geographic location. Given that the prevalence of physical activity differs between countries,[23-25] we might also expect that the same built characteristics have different impacts on physical activity depending on the geographical location and context. Pucher and Buehler[25] found higher levels of cycling among Canadians than Americans, and concluded that this difference was the result of the differences in the built environment (levels of residential density and land use mix, safer cycling conditions and difference in cycling infrastructure), incomes, costs associated with car ownership and cycling training programs. While Sugiyama et al.[26] found consistent associations between several self-reported built characteristics and walking among people in 12 countries, the authors also noted that the relationship between self-reported neighbourhood aesthetics and recreational walking differed between countries. Cerin et al.[27] also found that associations between self-reported aesthetics and street connectivity and objectively measured physical activity differed between countries. Moreover, Ding et al.[28] found some differences across countries between self-reported residential density, proximity to transit, bicycle facilities and safety from crime and the likelihood of meeting physical activity recommendations. These findings suggest that consideration should be given to the country in which the evidence is derived, especially if this evidence is used to inform local urban policy or practice.

Given that the associations between the built environment and physical activity are likely country-specific, it might be useful to review the evidence and develop recommendations that can help inform local urban and transportation policy and planning decisions. The strong emphasis on self-reported measures of the built environment[16,19,22] in some studies is also cause for concern, as self-report and objective measures of the same built environment characteristics do not always correspond.[29,30] Thus, the aim of this study was to undertake a systematized literature review of quantitative studies that estimate the associations between the objectively measured built environment and walking for different purposes among Canadian adults.

Methods

Search strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines[31] informed the methods used for this investigation. Given that not all elements of a systematic review, such as a quantitative assessment of each study's internal validity, were included, this review is referred to as a "systematized literature review."[32] To identify relevant literature, queries were developed for five databases that had been used in previous built environment–physical activity reviews:[14,16,19] MEDLINE; Cumulative Index to Nursing and Allied Health Literature (CINAHL); SPORTDiscus; Transport Research International Documentation (TRID); and Environment Complete. Our broad and comprehensive search of peer-reviewed articles spanning all years up to December 31, 2016, covered all relevant studies that looked at the association between the built environment and all types of physical activity, and not only walking.

As per best-practice recommendations for systematic reviews of observational studies, a standardized approach was used to identify potentially relevant studies. [18] The database search comprised three components: (1) identifying relevant terms related to the built environment, with the first Boolean search using "or" to explode (search by subject heading) and map (search by keyword) the medical subject headings "built environment," "urban design," "urban form" or "neighbourhood" or "landscape architecture"; (2) identifying relevant terms related to the physical activity, with the second Boolean search using "or" to explode and map the terms "physical activity," "recreation," "leisure," "transportation," "physical exertion," "exercise," "walking," "cycling" or "jogging"; and (3) identifying studies in the Canadian context, using a final Boolean search using "or" to explode and map the medical subject headings, with keywords that included "Canada," "Canadian," "Alberta," "British Columbia," "Manitoba," "New Brunswick," "Newfoundland and Labrador," "Nova Scotia," "Northwest Territories," "Nunavut," "Ontario," "Prince Edward Island," "Quebec," "Saskatchewan" or "Yukon." These three search strings were then combined using the Boolean operator "and" for all possible combinations.

In addition to the database searches, we scanned the reference lists of relevant literature reviews as well as all articles that were deemed eligible for a comprehensive review.

Study selection

One reviewer (BF) screened the titles of identified abstracts (n = 4140) to exclude non-relevant articles. Of those identified, 796 abstracts were initially reviewed. Abstracts reporting on the association between the built environment and physical activity were selected for full-text review. Comprehensive reviews were also done on articles where the abstracts were unclear. A random sample of 270 abstracts were double screened (by BF and DW) to estimate interrater agreement of included studies (percent of overall agreement = 87.0%) and to validate inclusion criteria. Both researchers then independently reviewed half (n = 263) of the remaining 526 abstracts. Literature reviews, commentaries, conference abstracts and proceedings, and pilot studies identified at the abstract or full-text screening stages were excluded from the review.

Articles were retained if they met the inclusion criteria for research design (quantitative), study population (Canadian

adults aged ≥ 18 years), exposure (objectively measured built characteristics related to destinations or land uses, population or residential density, pedestrian amenities or infrastructure, pedestrian or street connectivity, personal or traffic safety, aesthetics, neighbourhood typology or walkability) and outcome (any self-reported or objectively measured physical activity such as walking, running, cycling, sports or overall measures of physical activity, such as moderate-to-vigorous physical activity). The final inclusion criterion for the review was that a study had to have estimated an association between an objective measure of the built environment and physical activity. For the full-text review, interrater agreement was acceptable (percent of overall agreement = 87.0%). Articles that included studies measuring self-reported built characteristics only were excluded from the review.

Data extraction

From each eligible article, the two reviewers (BF and DW) extracted author details (name and year of publication), study design (cross-sectional, longitudinal, experiment), sample design (random or non-random and size), geographical location of data collection, sample characteristics (demographic and socioeconomic), physical activity outcomes, built environment characteristics, estimated associations between built environment characteristics and physical activity outcomes and, where applicable, details on the confounders adjusted for in the analysis. Where possible, the final model, or the most (or fully) covariate-adjusted estimates of association between the built environment and physical activity, were extracted. The estimated associations between each built environment characteristic and physical activity outcome were coded as follows: null, for non-significant associations; or positive or negative, for significant associations based on the direction of association. Purely descriptive statistics that did not include (inferential) tests of statistical significance were not extracted or synthesized in this review.

Where available, we extracted all information on physical activity participation or prevalence including achievement of physical activity recommendations or guidelines (e.g. 150 minutes of moderate to vigorous physical activity per week[33] or reaching recommended number of steps/day), frequency (e.g. number of walking trips per week), duration and volume (e.g. number of steps per day or energy expenditure). To help in the extraction and synthesis of the built environment characteristics,[34] we used an existing framework that combines built environment characteristics posited to be associated with walking into four broad categories or features: functional, safety, aesthetic and destination. These features—functional, destination, safety and aesthetic—have been used in previous literature reviews:[35-38]

- Functional features include characteristics such as overall walkability (e.g. summary indices, Walk Score) and neighbourhood typology (e.g. urban, suburban, new urbanist), pedestrian and street connectivity (e.g. density of intersections, street pattern) and residential or population density.
- Destination features included characteristics such as land use or destination mix, proximity to transportation or recreational destinations and quality of destinations.
- Safety features included measures of traffic (e.g. speed, volume) and personal or crime-related (e.g. evidence of disorder or incivilities) safety.
- Aesthetic features included measures of attractive, interesting or comfort-related built characteristics (e.g. manicured gardens and lawns, architecture, monuments, water features).

Although we allocated each association between the built environment and walking into one of these features, we acknowledge that in some cases built characteristics could fall into more than one feature. For example, the presence of a park could be considered as either an aesthetic or destination feature. To determine the most appropriate category, we considered what element of the built characteristic had been assessed. For example, a park described as a component of land use mix was categorized as a destination feature,[39] whereas a park described in terms of attractiveness or aesthetics was categorized as an aesthetic feature.[40]

Synthesis and analysis

Descriptive statistics (counts and frequencies) in addition to a narrative description were used where possible to summarize the study's methodological strengths and limitations as well as the association between built characteristics and walking. Built environment and walking associations were summarized by feature (functional, destination, safety and aesthetic) and walking outcome (i.e. participation, frequency, achievement of sufficient physical activity, duration and volume). Our summary findings are presented in tabular and graphical form. Given the heterogeneity of the study designs, the built environment and walking variables, and the statistical procedures used, a meta-analysis of our review findings was not possible.

Results

Identification of studies

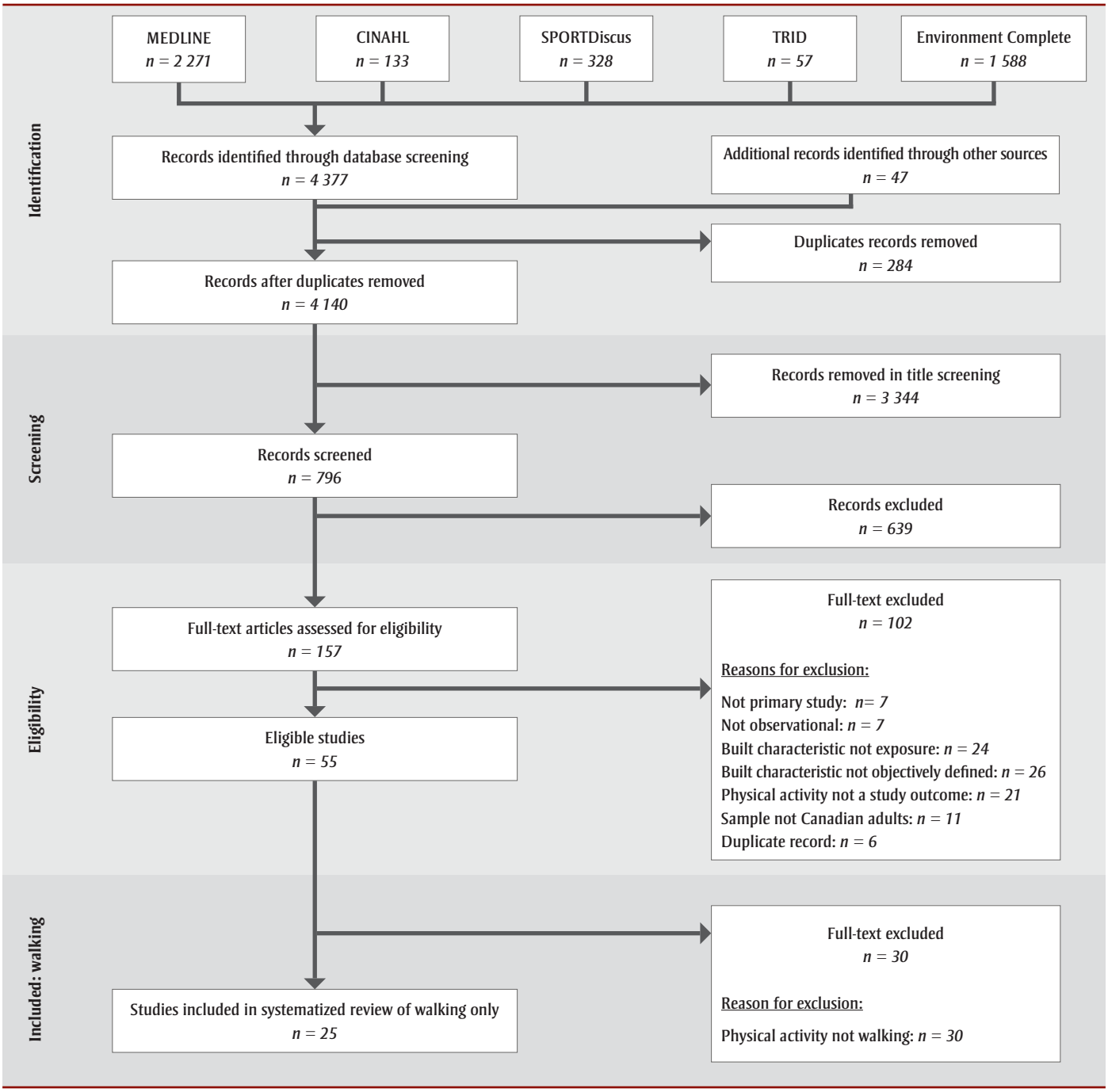
The initial search yielded 4140 unique records (Figure 1). After completion of title and abstract screening, 157 articles underwent full-text review, with 55 studies identified as satisfying the inclusion criteria review. Thirty of these 55 studies, which looked at non-walking physical activity (e.g. total physical activity, moderate to vigorous intensity physical activity, cycling, and walking and cycling combined), were subsequently excluded—leaving only 25 studies that met the inclusion criteria (Table 1).

Summary of study characteristics

Samples

Included studies were published between 2002 and 2016, with more than 80% (n = 21) published in 2011 or later. Most studies were undertaken in a single province (n = 20); two studies included data from multiple provinces;[41,42] and three studies included national data.[43-45] Quebec was the most frequent study location (n = 13), followed by Alberta and British Columbia (n = 9) and Ontario (n = 6). Three studies included data from each Saskatchewan, Manitoba, Newfoundland, Nova Scotia, PEI and New Brunswick. No studies were specifically undertaken in the three territories (Nunavut, Northwest Territories or Yukon), though data from the territories were included in two studies that used national data.[43,44] Among studies that reported mean age (n = 11), the lowest mean age was 33.6 years[46] and the highest mean age was 75 years.[47] Six study samples involved only older adults (≥50 years). Of the studies that reported response rate, the lowest rate was 8%[48] and the highest was 74%.[47] Sample sizes ranged from n = 77[49] to n = 151 318.[44]

FIGURE 1
Details of selection of studies for review



Most studies used a simple random sampling strategy (n = 20); three studies used stratified sampling;[45,49,50] and two studies used automated pedestrian count data.[51,52]

Study design

Most studies used a cross-sectional design (n = 23). Two longitudinal studies were included. A longitudinal study conducted by Gauvin et al.[50] captured changes in the built environment and walking among older adults over a three-year period. Wasfi et al.[45] examined how residential relocation (e.g. moving to a neighbourhood with a higher or lower Walk Score) was associated with duration of transportation walking. The authors explored transportation walking and neighbourhood exposure time over the same 12-year period.[45] Of the 14 studies that indicated the dates of data collection, ten studies captured the walking and built environment data within three years of each other.[40-42,44,46,49,56,58,60,63]

Measurement of walking

Walking was assessed most frequently using self-report (n = 22). Five studies measured walking using the International Physical Activity Questionnaire (IPAQ), which captured physical activity in the past seven days;[40,54-57] two used the Neighbourhood Physical Activity Questionnaire (NPAQ), which captured neighbourhood-based physical activity undertaken in a usual week.[17,42] Other studies included

TABLE 1
Summary of demographic and study characteristics for the 25 included studies

Study	Design	Province	Sample size	Age range (years)	Female (%)	Built environment characteristics[a]	Type of walking[a]
Chiu et al. (2015)[53]	Cross-sectional	ON	106 337	20+	51.2	Walkability *(2005–2008)*	Walk for transportation *(1996, 1997, 2001, 2003, 2005, 2007, 2008)*
Chudyk et al. (2015)[48]	Cross-sectional	BC	150	70–79	66	Walkability	Walk for transportation
Craig et al. (2002)[41]	Cross-sectional	ON, QC, AB	10 983	NR	NR	Walkability *(1999–2000)*	Walk for transportation *(1996)*
Frank et al. (2015)[42]	Cross-sectional	BC, ON	2 748	25+	58.2	Walkability *(2011)*	Walk for recreation, walk for transportation *(2011)*
Gauvin et al. (2008)[54]	Cross-sectional	QC	2 614	44–65+	61.1	Proximity to destination, connectivity, personal safety	Walk for recreation, walk for any purpose *(2005)*
Gauvin et al. (2012)[50]	Cohort	QC	521	67–84	53.4	Proximity to destination	Walk for any purpose *(2006)*
Hajna et al. (2015)[43]	Cross-sectional	All (excluding Nunavut)	2 949	18+	51.4	Walk Score and Walkability *(2006, 2009, 2015)*	Walk for any purpose, walk for transportation *(2007–2009)*
Hajna et al. (2016)[60]	Cross-sectional	QC	201	18+	48.1	Walk Score and Walkability *(2006, 2008, 2009)*	Walk for any purpose *(2006–2008)*
Hirsch et al. (2016)[49]	Cross-sectional	BC	77	65–80+	66.2	Land use, proximity to destination *(2013)*	Walk for any purpose *(2012)*
Jack et al. (2014)[55]	Cross-sectional	AB	1 875	18–60+	62.2	Walkability	Walk for transportation, walk for recreation *(2007–2008)*
Manaugh et al. (2011)[59]	Cross-sectional	QC	17 394	NR	NR	Walk Score and Walkability	Walk for transportation *(2003)*
McCormack et al. (2012)[17]	Cross-sectional	AB	4 034	18+	59.7	Walkability	Walk for transportation, walk for recreation *(2007–2008)*
McCormack et al. (2011)[62]	Cross-sectional	AB	506	18+	64.2	Walkability, proximity to destination	Walk for recreation *(2007–2008)*
Miranda-Moreno et al. (2013)[51]	Cross-sectional	QC	NR[b]	NR	NR	Land use	Walk for any purpose *(2010–2011)*
Miranda-Moreno et al. (2011)[52]	Cross-sectional	QC	NR[b]	NR	NR	Connectivity, population density, land use, proximity to destination	Walk for any purpose *(2011)*
Moniruzzaman et al. (2015)[58]	Cross-sectional	QC	13 127	55+	NR	Proximity to destination, land use, population density *(2009)*	Walk for transportation *(2008)*
Oliver et al. (2011)[61]	Cross-sectional	BC	1 602	19+	61.8	Land use	Walk for transportation, walk for recreation *(2006)*
Oliver et al. (2007)[63]	Cross-sectional	BC	1 311	20–60	61.4	Land use *(2006)*	Walk for transportation, walk for recreation *(2006)*
Riva et al. (2009)[57]	Cross-sectional	QC	2 923	45–65+	61.8	Walkability	Walk for transportation, walk for recreation, walk for any purpose *(2005)*

Continued on the following page

TABLE 1 (continued)
Summary of demographic and study characteristics for the 25 included studies

Study	Design	Province	Sample size	Age range (years)	Female (%)	Built environment characteristics[a]	Type of walking[a]
Schopflocher et al. (2014)[40]	Cross-sectional	AB	2 042	NR	NR	Connectivity, land use, proximity to destination, aesthetics, personal safety, traffic safety *(2008)*	Walk for transportation, walk for recreation, walk for any purpose *(2010)*
Thielman et al. (2015)[44]	Cross-sectional	All	151 318	12–65+	48.4	Walk Score *(2012, 2014)*	Walk for transportation *(2007–2012)*
Toohey et al. (2013)[56]	Cross-sectional	AB	884	50+	60.1	Walkability, population density, aesthetics *(2006)*	Walk for any purpose *(2007)*
Wasfi et al. (2013)[46]	Cross-sectional	QC	6 913	18+	57	Connectivity, land use, population density *(2006)*	Walk for transportation *(2003)*
Wasfi et al. (2016)[45]	Cohort	All (excluding territories)	2 976	18–55	52	Walk Score *(2012)*	Walk for transportation *(1994, 1996, 1998, 2000, 2002, 2004, 2006)*
Winters et al. (2015)[47]	Cross-sectional	BC	1 309	65+	55	Walk Score *(2013)*	Walk for any purpose *(2008–2009)*

Abbreviations: AB, Alberta; All, all provinces and territories; BC, British Columbia; NR, not reported; ON, Ontario; QC, Quebec.

[a] Data collection date(s) are reported in brackets. If missing, date(s) were not reported or were unclear.

[b] Study included pedestrian counts.

walking data collected for the Canadian Community Health Survey,[44,47,53] Canadian Census[41] and National Population Health Survey.[45,53] Six studies included walking (e.g. trips by foot) reported in travel diaries.[40,46,48,49,58,59] Three studies measured walking using self-reports and accelerometers;[40,43,49] one study captured steps/day using pedometers;[60] and two studies audited pedestrian activity using automated counters.[51,52] Walking undertaken in the past seven days was most often assessed (n = 16), although walking in the previous day (n = 3), previous 14 days (n = 1) and previous three months (n = 3) were also captured.

With respect to the purpose of walking, 17 studies included transportation walking, 10 included walking for any purpose and 9 included recreational walking. While all 25 studies included in this review estimated associations between the built environment and walking, 4 studies also estimated associations between the built environment and other physical activities such as leisure time[44,49,53] and moderate-to-vigorous physical activity.[61]

Measurement of the built environment

The objectively measured built environment characteristics related to walking included walkability or overall built environment indices (n = 15), proximity or density of destinations (n = 8), land use (n = 7), pedestrian or street connectivity (n = 4), population density (n = 4), aesthetics (n = 2), personal safety (n = 2) and traffic safety (n = 1). Built environment characteristics were estimated using GIS primarily (n = 21); however, four studies also collected built environment data using in-person street audits.[40,41,54,60] Eight studies included Walk Score, while 10 studies used their own walkability indices.

Neighbourhoods or geographical areas or locations used to estimate built environment characteristics were typically delineated using census tract (n = 3), postal code (n = 5) or 400–1600 m buffers, pedsheds or polygons (n = 17) in which the participant's residential address was located. Line-based network buffers (n = 10) and circular network buffers (n = 6) were commonly used, while two studies used polygonal buffers[43,60] and one study created 805 × 805 m grids to delineate a neighbourhood.[40] Buffers were most often created around the centroid of the participant's geocoded postal code or census tract (n = 11) or the participant's geocoded complete household address (n = 3).

Adjustment for confounders

Among the 25 included studies, only 3 cross-sectional studies statistically adjusted for residential self-selection (i.e. a person's walking preferences, attitudes or behaviour that informs their decision to reside in a neighbourhood).[17,42,55] These studies captured residential self-selection via questionnaires where participants self-reported the importance of walking-related built characteristics in their decision to move to their current neighbourhoods. Length of exposure to the environment (i.e. tenure in neighbourhood) was adjusted for in six studies.[17,45,50,54-56] Demographic (e.g. age, gender, marital status, car ownership and number of dependents) and socioeconomic (e.g. income and education level) characteristics were adjusted for in all but three studies.[48,51,52] In addition, studies also adjusted for self-reported health and weight status (n = 13), smoking status and/or other physical activity behaviours (n = 6), weather or seasonality (n = 6) and other environmental characteristics (e.g. urbanicity) (n = 5).

Associations between the built environment and walking

Functional characteristics

Overview

Twenty studies[17,40-48,52-60,62] reported 144 comparisons between functional characteristics

and walking (Table 2). The most common functional characteristics examined included walkability (n = 15 studies; n = 116 comparisons), connectivity (n = 4 studies; n = 20 comparisons) and population density (n = 4 studies; n = 8 comparisons). Of the 144 estimated associations between functional characteristics and walking, 86 (59.7%) associations were null, 54 (37.5%) were positive and 4 (2.8%) were negative.

Walking for transportation

Walking for transportation was the most common walking outcome examined (n = 14 studies). Of the 69 associations estimated between functional characteristics and walking for transportation, 43 (62%) were positive, 26 (38%) were null and 0 were negative (Table 2). In terms of functional characteristics, walking for transportation was associated with overall walkability. Specifically, positive associations were found between functional characteristics and transportation walking participation (n = 25 comparisons), duration (n = 10 comparisons), volume (n = 4 comparisons), frequency (n = 3 comparisons) and achievement of sufficient physical activity (n = 1 comparison).

Walking for recreation

Seven studies estimated associations between functional characteristics and walking for recreation. Of the 32 associations estimated, 31 (97%) were null and 1 (3%) was negative (Table 2). These studies estimated associations between functional characteristics and recreation walking participation (n = 12 comparisons), frequency (n = 8 comparisons), duration (n = 4 comparisons), volume (n = 4 comparisons) and achievement of sufficient physical activity via walking (n = 4 comparisons). All studies that examined associations between functional characteristics and walking for recreation captured walking data using the IPAQ (n = 5 studies) or NPAQ (n = 2 studies).

Walking for any purpose

Eight studies estimated associations between functional characteristics and walking for any purpose (non-purpose specific). Of the 43 associations estimated, 29 (67%) were null, 11 (26%) were positive and 3 (7%) were negative (Table 2). Walkability was positively associated with achievement

TABLE 2
Summary of associations of functional characteristics and walking[a,b,c]

	Walking for transportation			Walking for recreation			Walking for any purpose			Total		
	−	Null	+	−	Null	+	−	Null	+	−	Null	+
Participation												
Overall walkability	0	5	25	0	12	0	0	0	0	0	17	25
Connectivity	0	0	0	0	0	0	0	0	3	0	0	3
Population density	0	0	0	0	0	0	0	0	1	0	0	1
Subtotal	0	5	25	0	12	0	0	0	4	0	17	29
Duration												
Overall walkability	0	8	10	0	4	0	0	0	0	0	12	10
Subtotal	0	8	10	0	4	0	0	0	0	0	12	10
Achieve sufficient physical activity												
Overall walkability	0	1	1	0	2	0	0	3	5	0	6	6
Connectivity	0	0	0	0	2	0	0	2	0	0	4	0
Population density	0	0	0	0	0	0	0	4	0	0	4	0
Subtotal	0	1	1	0	4	0	0	9	5	0	14	6
Frequency												
Overall walkability	0	4	3	1	7	0	0	6	0	1	17	3
Population density	0	2	0	0	0	0	0	0	0	0	2	0
Subtotal	0	6	3	1	7	0	0	6	0	1	19	3
Volume												
Overall walkability	0	0	4	0	0	0	3	10	2	3	10	6
Connectivity	0	5	0	0	4	0	0	4	0	0	13	0
Population density	0	1	0	0	0	0	0	0	0	0	1	0
Subtotal	0	6	4	0	4	0	3	14	2	3	24	6
Grand total	**0**	**26**	**43**	**1**	**31**	**0**	**3**	**29**	**11**	**4**	**86**	**54**

[a] Representative of 144 comparisons reported in 20 studies.

[b] Cell values are the counts of comparisons that report a statistically significant positive, null or statistically significant negative association.

[c] Statistically significant negative (-), null or statistically significant positive association (+).

of sufficient physical activity via walking (n = 5 comparisons) and walking volume (n = 2 comparisons), while pedestrian or street connectivity (n = 3 comparisons) and population density (n = 1 comparison) were positively associated with walking participation. Among the three associations reported between walkability and walking volume, all were in a negative direction.

Destination-related characteristics of the built environment

Overview

Eleven studies[40,46,49-52,54,58,61-63] reported 98 comparisons between destination-related features and walking (Table 3). The most common destination-related feature examined was land use (n = 38 comparisons). Thirty-one comparisons were reported between proximity to destinations and walking. Of the 98 estimated associations, 69 (70%) associations were null, 23 (24%) were positive and 6 (6%) were negative. All negative associations were found in studies that captured walking using self-reported questionnaires (n = 4 studies). Of the studies that explored an association between proximity to destinations and walking (n = 6), almost all studies focused on adults 44 years or older (n = 5).

Walking for transportation

Walking for transportation was the most common walking outcome examined (n = 6 studies). Of the 42 estimated associations, 12 (29%) were positive, 26 (62%) were null and 4 (10%) were negative (Table 3). In terms of destination-related characteristics, walking for transportation was associated with both land use and proximity to destinations. Specifically, positive associations were found between functional characteristics and transportation walking participation (n = 10 comparisons) and frequency (n = 2 comparison).

Walking for recreation

Five studies estimated associations between destination-related characteristics and walking for recreation. Of the 26 estimated associations, 3 (12%) were positive, 21 (81%) were null and 2 (8%) were negative (Table 3). Specifically, estimated associations were found between destination-related characteristics and recreational walking participation (n = 19 comparisons), volume (n = 4 comparisons), achievement of sufficient physical activity via walking (n = 2 comparisons) and frequency (n = 1 comparison). Positive associations were found between land use and recreational walking (n = 3 comparisons).

Walking for any purpose

Six studies estimated associations between destination-related characteristics and walking for any purpose. Of the 30 estimated associations, 8 (27%) were positive and 22 (73%) were null (Table 3). Proximity to destinations was positively associated with participation (n = 3 comparisons), achievement of sufficient physical activity via walking (n = 1 comparison), walking frequency (n = 1 comparison) and walking volume (n = 1 comparison), while land use was associated with walking participation (n = 2 comparisons).

TABLE 3
Summary of associations of destination-related characteristics and walking[a,b,c,d]

	Walking for transportation			Walking for recreation			Walking for any purpose			Total		
	−	Null	+	−	Null	+	−	Null	+	−	Null	+
Participation												
Land use	3	16	9	1	14	3	0	0	2	4	30	14
Proximity to destination	0	0	1	1	0	0	0	0	3	1	0	4
Subtotal	3	16	10	2	14	3	0	0	5	5	30	18
Achieve sufficient physical activity												
Land use	0	0	0	0	0	0	0	4	0	0	4	0
Proximity to destination	0	0	0	0	2	0	0	5	1	0	7	1
Subtotal	0	0	0	0	2	0	0	9	1	0	11	1
Frequency												
Land use	0	1	0	0	0	0	0	0	0	0	1	0
Proximity to destination	1	4	2	0	1	0	0	2	1	1	7	3
Subtotal	1	5	2	0	1	0	0	2	1	1	8	3
Volume												
Land use	0	3	0	0	2	0	0	5	1	0	10	1
Proximity to destination	0	2	0	0	2	0	0	6	0	0	10	0
Subtotal	0	5	0	0	4	0	0	11	1	0	20	1
Grand total	**4**	**26**	**12**	**2**	**21**	**3**	**0**	**22**	**8**	**6**	**69**	**23**

[a] Representative of 98 comparisons reported in 11 studies.

[b] Cell values are the counts of comparisons that report a statistically significant positive, null or statistically significant negative association.

[c] Statistically significant negative (-), null or statistically significant positive associations (+).

[d] Associations between destination-related characteristics of the built environment and duration of walking was not explored.

Safety characteristics of the built environment

Overview

Two studies[40,54] reported 16 comparisons between safety characteristics and walking (Table 4). The safety characteristics examined were personal safety (n = 10 comparisons) and traffic safety (n = 6 comparisons). Of the 16 estimated associations, 2 were positive and 14 were null.

Walking for transportation

Walking for transportation was the least common walking outcome examined (n = 4 comparisons) (Table 4). Of the 4 estimated associations, 1 was positive and 3 were null. Positive association was found between personal safety and volume of transportation walking.

Walking for recreation

Two studies[40,54] estimated associations between safety characteristics and walking for recreation. All 6 of the estimated associations were null (Table 4). Studies estimated associations between safety characteristics and recreational walking volume (n = 4 comparisons) and achievement of sufficient physical activity via recreational walking (n = 2 comparisons).

Walking for any purpose

Two studies[40,54] estimated associations between safety characteristics and walking for any purpose. Of the 6 estimated associations, 5 were null and 1 was positive (Table 4). Personal safety was positively associated with volume of walking for any purpose. Studies estimated associations between safety characteristics and volume of walking for any purpose (n = 4 comparisons) and achievement of sufficient physical activity via walking (n = 2 comparisons).

Aesthetic characteristics of the built environment

Overview

Two studies[40,56] reported 10 comparisons between aesthetic characteristics and walking (Table 5). Of the 10 estimated associations, 1 (10%) was positive and 9 (90%) were null.

Walking for transportation

One study[40] examined the association between aesthetic characteristics and walking for transport. Both associations estimated were null (Table 5).

TABLE 4
Summary of associations of safety-related characteristics and walking[a,b,c,d]

	Walking for transportation			Walking for recreation			Walking for any purpose			Total		
	–	Null	+	–	Null	+	–	Null	+	–	Null	+
Achieve sufficient physical activity												
Personal safety	0	0	0	0	2	0	0	2	0	0	4	0
Subtotal	0	0	0	0	2	0	0	2	0	0	4	0
Volume												
Personal safety	0	1	1	0	2	0	0	1	1	0	4	2
Traffic safety	0	2	0	0	2	0	0	2	0	0	6	0
Subtotal	0	3	1	0	4	0	0	3	1	0	10	2
Grand total	**0**	**3**	**1**	**0**	**6**	**0**	**0**	**5**	**1**	**0**	**14**	**2**

[a] Representative of 16 comparisons reported within 2 studies.

[b] Cell values are the counts of comparisons that report a statistically significant positive, null or statistically significant negative association.

[c] Statistically significant negative (–), null or statistically significant positive association (+).

[d] Associations between safety and participation, duration and frequency of walking were not explored.

Walking for recreation

One study[40] examined the association between aesthetic characteristics and walking for recreation. Of the 2 estimated associations, 1 was positive and 1 was null (Table 5).

Walking for any purpose

Two studies[40,56] estimated associations between aesthetic characteristics and walking for any purpose. All 6 estimated associations were null (Table 5). The association between aesthetic characteristics and walking for any purpose was estimated between achievement of sufficient physical activity via walking (n = 4 comparisons) and volume (n = 2 comparisons).

Discussion

This is the first review conducted into the relationship between objective measures of the built environment and physical activity (walking) in the Canadian context. The pattern in publication dates among the reviewed studies suggests that this relationship is an emerging research area in Canada. While findings to date are promising, gaps in evidence still exist—specifically with respect to rural areas and the territories (Northwest Territories, Nunavut and Yukon). Moreover, all but two studies had a cross-sectional study design, suggesting that the evidence pointing to an association between the

TABLE 5
Summary of associations of aesthetic characteristics and walking[a,b,c,d]

	Walking for transportation			Walking for recreation			Walking for any purpose			Total		
	–	Null	+	–	Null	+	–	Null	+	–	Null	+
Achieve sufficient physical activity												
Aesthetics	0	0	0	0	0	0	0	4	0	0	4	0
Subtotal	0	0	0	0	0	0	0	4	0	0	4	0
Volume												
Aesthetics	0	2	0	0	1	1	0	2	0	0	5	1
Subtotal	0	2	0	0	1	1	0	2	0	0	5	1
Grand total	**0**	**2**	**0**	**0**	**1**	**1**	**0**	**6**	**0**	**0**	**9**	**1**

[a] Representative of 10 comparisons reported in 2 studies.

[b] Cell values are the counts of comparisons that report a statistically significant positive, null or statistically significant negative association.

[c] Statistically significant negative (-), null or statistically significant positive association (+).

[d] Associations between aesthetics and participation, duration and frequency of walking were not explored.

built environment and physical activity is still preliminary and exploratory; thus, it is not possible to infer causation based on our review findings. Canadian studies to date have rarely adjusted for residential self-selection, which may lead to an overestimation of the association between the built environment and walking. As expected based on previous reviews,[14,21] most studies used self-reported measures of physical activity, measured the built environment using GIS instead of street audits or relied on publicly available walkability data (i.e. Walk Score). Nevertheless, as with other reviews,[14,16,19-21] our findings do suggest that the neighbourhood built environment is associated with walking, particularly walking for transportation among adults, and that some built characteristics may be more important for supporting certain types of walking.

Consistent with findings from other reviews,[14,16,20,21] there was a distinct association between overall neighbourhood walkability (e.g. Walk Score) and transportation walking. Specifically, we found that a higher level of neighbourhood walkability was positively associated with participation, duration, frequency and volume of transportation walking. These findings are important given that active transportation, which includes walking, is inversely associated with overweight/obesity,[64] as well as positively associated with decreased prevalence of adults with type 2 diabetes[65] and reduced cardiovascular risk.[66] The importance of land use and destinations for encouraging and supporting walking in adult population has been noted elsewhere.[14,16] Our review findings suggest that land use (e.g. having a mix of destinations) is important for encouraging participation across all walking domains. Proximity to destinations was associated with frequency of walking for transportation, as well as participation and frequency of walking for any purpose. Improving the walkability of neighbourhoods overall and increasing land use mix and proximity to destinations can potentially increase the physical activity levels of Canadian adults—in turn improving population health.

Unlike other reviews,[14,16,20] our findings suggest that the association between connectivity and population density with walking were non-significant, though very few comparisons were made between these built characteristics and walking. Of the few included studies that explored the association between connectivity[40,46,52,54] or population density[46,52,56,58] with walking, only one study found positive associations between population density and connectivity with walking for any purpose, measured by automatized pedestrian counters.[52] Future studies into these associations in the Canadian context could help determine if improving connectivity and increasing population density would enhance the ability of neighbourhoods to support physical activity. These studies could also provide a better understanding of how this association may differ in Canada compared to other countries.

Fewer studies included in our review captured walking for recreation, relative to walking for transport or walking for any purpose. The extent to which non-significant or negative associations between the built environment and walking for recreation were not published (i.e., publication bias) could not be determined from our review. Study findings estimating the association between the built environment and walking for recreation were mixed. Our study findings did, however, find less consistency in associations between the built environment and walking for recreation compared to associations between the built environment and walking for transportation.[14,16,20,21] It is possible that measures of the built environment included in the reviewed studies are tailored more towards walking for transportation. Manaugh et al.[59] found small but notable differences in the magnitude of estimated associations between non-work trips by foot and walkability that were related to trip purpose, the population subgroup examined and the definition of walkability used. Some evidence from our review suggested that built characteristics, including land use and aesthetics, were positively associated with participation and volume of walking for recreation. More research identifying which built characteristics are supportive of recreation versus transportation walking—and for whom—is needed.

Evidence from the Canadian studies did not find a significant association between safety and aesthetic characteristics of the built environment and walking, Moreover, safety and aesthetics were the least studied built characteristics within our review, which might be a consequence of our focus on objective measures of the built environment. Traffic and personal safety can be objectively measured (e.g. via crime and accident statistics and presence of incivilities). However, perceived safety likely informs people's decisions to walk, and these perceptions can be independent of, or unrepresentative, of the actual safety of a neighbourhood.[67] Further, studies that estimate safety from existing statistics may miss the micro-scale built characteristics (e.g. graffiti, drug paraphernalia, litter) associated with sense of safety that might be better captured via street audits—few of which existed in the studies we reviewed.[40,41,54,60]

With evidence suggesting that physical activity behaviours differ between countries, it was important to explore how the built environment is associated with walking in the Canadian context. Findings from this review are supported by other systematic reviews of evidence from the United States, Australia and Europe.[14,21] Cross-sectional study designs are frequently used and measures of walking are mostly self-reported.[14,16,20,21] A review by McCormack et al.[14] reported that there was wide variation in how the built environment is operationalized, but GIS tended to be the most commonly used technique among studies incorporating objective measures of the built environment, which was similar to our findings. Consistency in the measurement of the built environment and walking across studies would provide a better understanding of this association, and may make it possible to pool and synthesize findings using meta-analysis.

There are several limitations to this review that must be considered. Due to limited resources, a comprehensive systematic review (e.g. double-screening at all stages of the search process and validity assessment) was not feasible; nevertheless, steps were taken to ensure scientific rigour. Due to the broad range of built environment characteristics that were measured and defined across studies, we used an established theoretical framework[34] to classify characteristics into four categories (functional, safety, aesthetic, destination). It is possible that some built characteristics were associated with multiple categories from this theoretical framework. Due to the small number of Canadian studies included in the review, we were not able to stratify our findings based on smaller geographical scales (i.e. within and across provinces or cities). This more granular focus may be possible in the future as Canadian studies investigating

the relationship between the built environment and physical activity continue to accumulate. Moreover, our review only included studies that statistically tested an association between the built environment and walking. Despite providing important contributions to the field, several Canadian studies were excluded: either the nature and/or significance of the associations between the built environment and walking was not clearly described or they had a specific methodological focus.[68-71] The predominance of cross-sectional studies included in our review meant that we were not able to draw causal inferences. As suggested in previous reviews,[14,16,21,22] evidence from more rigorous study designs (i.e. natural and quasi-experiments) are needed. While our focus was the associations between the built environment and walking, the built environment could be an important correlate for other physical activities (e.g. cycling, leisure activity or moderate to vigorous activity).[14,20,21]

Conclusion

Within the Canadian context, current evidence suggests that the neighbourhood built environment is associated with walking and, in particular, walking for transportation. Improving neighbourhood walkability, land use and proximity to destinations may enable or support higher levels of transportation walking, and in turn contribute to better health outcomes among Canadian adults. Future research is needed on the relationship between the built environment and walking in non-urban locations as well as in the territories. Moreover, study designs that estimate the causal relationship between the built environment and walking and other physical activities are needed to better inform urban and transportation policy and planning decisions in Canada.

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Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Authors' contributions and statement

BF, DW and GM conceived the study. BF and DW undertook the database search and article selection and data extraction. All authors contributed to interpretation of the results. BF, GM and DW wrote the article. All authors read and approved the final manuscript.

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Original quantitative research

Exploring and visualizing the small-area-level socioeconomic factors, alcohol availability and built environment influences of alcohol expenditure for the City of Toronto: a spatial analysis approach

Andrew Leung, MSc (1); Jane Law, PhD (1,2); Martin Cooke, PhD (1,3,4); Scott Leatherdale, PhD (1)

This article has been peer reviewed.

Abstract

Introduction: Many Canadians continue to drink alcohol in excess of the recommended low-risk guidelines. In this study, we visualized the geographic variation of licensed premises alcohol expenditures in Toronto and examined the effects of area-level socioeconomic characteristics, alcohol availability and built environment influences on alcohol expenditures at the Dissemination Area (DA) level.

Methods: Dissemination Area average total household expenditures on alcohol from licensed premises, from the 2010 Survey of Household Spending, was the main outcome variable. Moran's I and Local Moran's I were used to quantify geographic variation and determine hot spots and cold spots of expenditure. We used DA-level socioeconomic characteristics from the 2006 Census of Canada, and the density of licensed premises and other built environment characteristics from the 2008 DMTI Spatial and 2010 CanMap datasets to predict alcohol expenditures in multivariate spatial regression models.

Results: The results indicated that the most significant area-level predictors of alcohol expenditure were the percentage of individuals in management or finance occupations and the percentage with postsecondary education (one-unit increases associated with 78.6% and 35.0% increases in expenditures respectively). Presence of subway lines in the immediate and neighbouring areas was also significant (one-unit increases resulted in 5% and 28% increases respectively). Alcohol outlet density was also positively associated with alcohol expenditures.

Conclusion: The associations identified between licensed premises alcohol expenditures and small-area-level characteristics highlight the potential importance of small-area-level factors in understanding alcohol use. Understanding the small-area-level characteristics of expenditures and geographic variation of alcohol expenditures may provide avenues for alcohol use reduction initiatives and policies.

Highlights

- Alcohol use exceeding low-risk drinking guidelines remains a public health problem. Small-area-level associations with alcohol expenditures have not been examined, leaving potentially significant factors affecting alcohol use unidentified.
- Understanding the geographical variation of alcohol expenditures in the city of Toronto can help provide target areas for interventions. Spatial regression models can control for geographical variation when looking for associations with small-area-level characteristics.
- This study quantified the level of geographical variation in the licensed premises alcohol expenditures and helped visualize the areas of high expenditures using maps.
- Significant positive associations were found for small-area-level socioeconomic and built environment factors.

Keywords: *small-area studies, dissemination areas, spatial analysis, spatial regressions, alcohol expenditure, alcohol use, low-risk drinking guidelines, geographic variation, GIS*

Introduction

Harmful alcohol use is recognized as one of the main modifiable behavioural risks for noncommunicable disease. Despite the negative consequences, many Canadians continue to drink in excess of the recommended low-risk guidelines, and thus may be at risk for experiencing alcohol-related harms. In Canada, alcohol use was estimated to be responsible for 8953 deaths and 172 255 potential years of life lost in 2005.[1] In 2011, the indirect and direct costs of alcohol use were estimated to be $5.3 billion for the province of Ontario.[2-4] These economic and social costs of alcohol use are projected to rise with increasing levels of consumption.[2]

Author references:
1. School of Public Health and Health Systems, University of Waterloo, Waterloo, Ontario, Canada
2. School of Planning, University of Waterloo, Waterloo, Ontario, Canada
3. School of Pharmacy, University of Waterloo, Waterloo, Ontario, Canada
4. Department of Sociology and Legal Studies, University of Waterloo, Waterloo, Ontario, Canada

Correspondence: Andrew Leung, School of Public Health and Health Systems, University of Waterloo, Waterloo, ON N2L 3G1; Tel: 647-825-2667; Email: as2leung@uwaterloo.ca

Various individual-level factors have also been related to alcohol consumption, including ethnicity, occupation, income, housing and education.[5-8] There is evidence that the physical and demographic aspects of neighbourhoods can also potentially influence alcohol use.[9,10] These neighbourhood-level factors include area-level socioeconomic factors, characteristics of the built environment and local alcohol availability.[11-16]

A number of area-level socioeconomic measures have been found to be associated with alcohol use, although the directions of the effects found are not always consistent. Cerdá and colleagues[17] found that models including a measure of deprivation provided better estimates of alcohol use compared to models that omitted measures of deprivation. Studies by Galea et al.[18] and Pollack et al.[19] found that areas with the lowest levels of neighbourhood deprivation had the highest prevalence of alcohol use. Area-level income and education inequality have also been found to be positively associated with alcohol use.[18,20]

In general, the built environment can be defined as the aspects of a physical area that are not characteristics of the people who live there but rather capture the physical resources available in the particular location.[21] Elements of the built environment that might affect alcohol consumption include the presence of public transportation[21,22] and alcohol availability, reflected by the presence of alcohol retailers, restaurants and bars.[23] Prior work has also suggested that the physical condition of buildings in a neighbourhood is a significant factor. Bernstein et al.[9] identified that rates of heavy drinking were 150% higher among individuals in neighbourhoods characterized by high levels of dilapidation, an effect that was significant in multilevel models that also included individual income and education.

A significant portion of research relating neighbourhood factors to alcohol use has used survey measures that capture alcohol consumption. Although we have self-reported alcohol consumption data collected from self-report surveys, those data potentially suffer from the typical problems of self-reported measures. Alcohol *expenditure* data, while conceptually close to consumption, have been examined less frequently and provide an alternative way of capturing alcohol use.[5,24] Expenditure data can also be obtained from self-report surveys, such as the data used in the present analysis. These data are therefore subject to the same limitations, but similar research might be done using alcohol sales data that are reported by liquor authorities as well as retailers.

The goal of our study was to examine the association between geographic and environmental influences on licensed premises alcohol expenditures for the City of Toronto. We used expenditure data on alcohol purchased in licensed premises as the main outcome variable and examined the effects of area-level socioeconomic factors, alcohol availability and built environment influences. We employed small-area-level analysis and multivariate spatial regression models to examine the associations between these area-level factors and reported alcohol expenditures, and we used geographic information systems (GIS) techniques to visualize "hot" and "cold" spots of alcohol expenditure for the City of Toronto.

Methods

Unit of analysis

The unit of analysis for the study was the Dissemination Area (DA), which is the smallest Statistics Canada geographic unit that covers all of Canada, with each DA containing 400 to 700 persons.[25] Socioeconomic and built environment variables are more homogenous within DAs than within larger geographic areas, and using a small spatial scale allows for identification of spatial patterns that might have been masked at larger geographic scales. Figure 1 shows the 3685 Dissemination Areas that make up the City of Toronto from the 2006 Census of Canada.[26]

Data sources

We used data from four different sources. Licensed premises alcohol expenditures were taken from the 2010 Survey of Household Spending.[27] The 2008 DMTI Spatial Enhanced Points of Interest dataset[28] provided licensed premises outlet locations, and 2010 CanMap Route Logistics data[29] provided built environment data (subway lines, highways and land-use). The 2006 Census of Canada data[26] provided DA-level socioeconomic characteristics. These characteristics were collected by the census "2B long form," which was distributed to 20% of the population in 2006. In this study, we used the 2006 census because of changes to the 2011 census and to the National Household Survey (NHS), which replaced the long form in 2011. In particular, because the NHS was made voluntary, Statistics Canada did not release the socioeconomic characteristics of some DAs due to nonresponse.[30] In order to conduct the analysis at the Dissemination Area level, this study used the 2006 data.

Measures

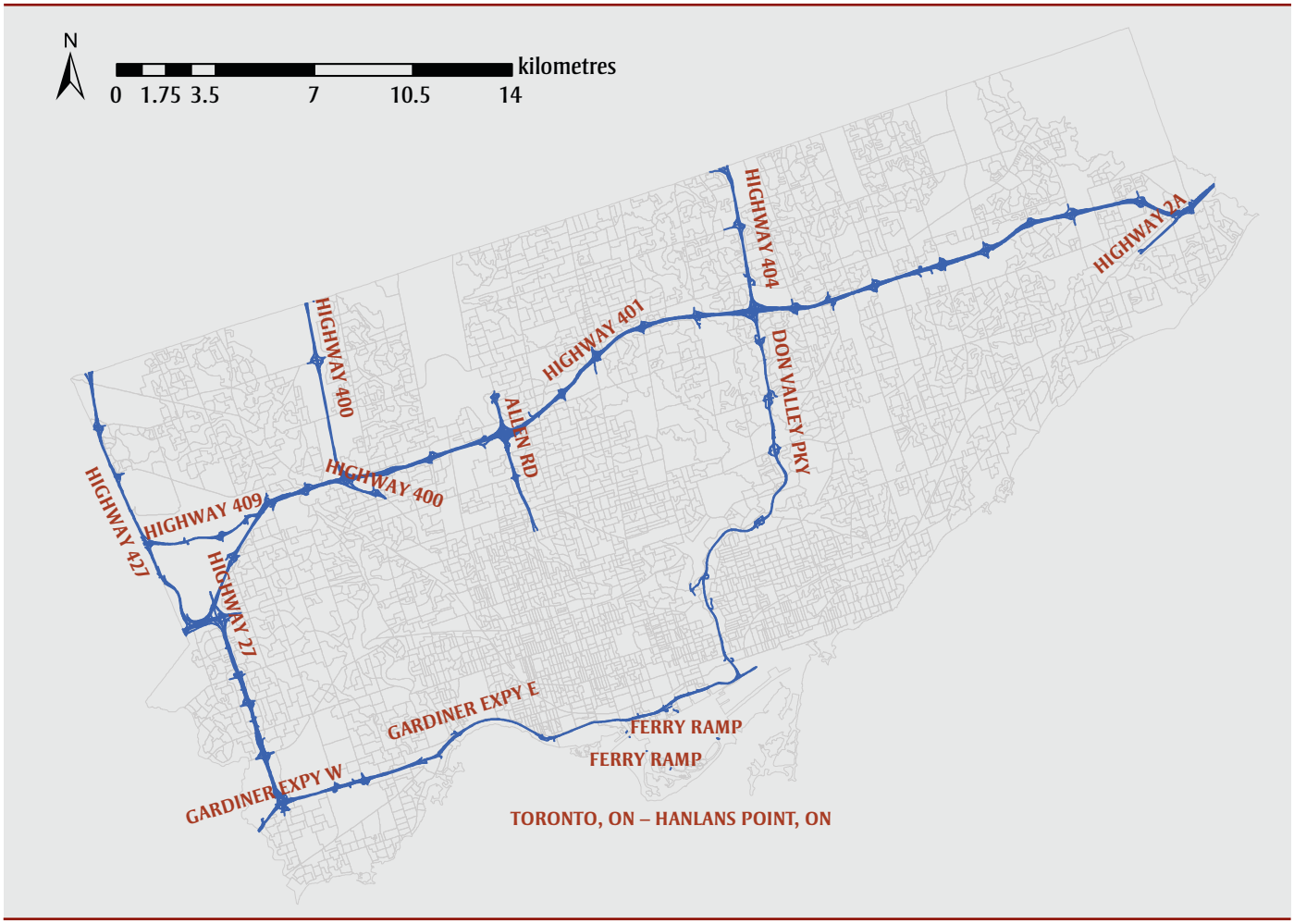
The main outcome variable was the DA average total household alcohol expenditure per year from licensed premises in 2010. These data were collected using diary and short-period recall questions.[27] We applied a log transformation to correct for skewness.

Consistent with previous alcohol use and expenditure studies,[5-8,31] we examined a number of relevant socioeconomic variables as predictors of licensed premises expenditure, including neighbourhood ethnic composition, visible minority concentration, occupation, income, neighbourhood deprivation, housing and education. These were taken from the 2006 census data.

We measured area ethnic composition using the percentage of the DA population reporting Black, Chinese, South Asian and Filipino ethnicities. The concentration of nonvisible minorities was measured using the percentage of the DA population identifying as "not a member of a visible minority." We defined occupation as the percentage of employed DA population reporting working in management, business, finance and administration. This variable was created by combining several groups of occupations according to the 2001 National Occupational Classification for Statistics (NOCS) definition.[32]

We used two measures of area income: median household after-tax income and the average income from government transfer payments. Education was defined as the proportion of the DA population that reported having completed one of the following qualifications: registered apprenticeship, trades certificate or diploma, college, CEGEP, other non-university certificate or diploma and university certificate, degree or diploma.

FIGURE 1
Dissemination Area map of Toronto, Canada, with major highways



Data source: Statistics Canada. 2006 Census of Population [Internet]. Ottawa (ON): Statistics Canada; 2006. Available from: http://www12.statcan.gc.ca/census-recensement/2006/index-eng.cfm

Three measures captured the nature of housing in each DA. These were the proportion of dwelling types that were apartment buildings with fewer than five floors, the proportion of single detached houses and the proportion of row (attached) houses. We included the presence of subway lines in a neighbourhood as the number of subway intercepts (access points) within the DA. Spatially "lagged" subway intercepts indicated the presence of subway lines in an adjacent DA.

Alcohol outlet data were retrieved from the 2008 DMTI Enhanced Points of Interest dataset.[28]

We measured local alcohol availability by the densities of two types of restaurant in each DA. "Primary drinking restaurants" were those whose main business was serving alcohol, while "restaurants" were those with a dual focus on serving both food and alcohol. The densities of these two types of business were calculated by dividing the number of restaurants by the area of the DA in square kilometres. Spatially "lagged" versions of these variables captured the effect of outlet density in neighbouring DAs.[33]

Analyses: global spatial autocorrelation, local cluster analysis procedure and multivariate spatial regression

We first calculated Global Moran's I statistic to quantify the average level of spatial autocorrelation and to test the null hypothesis that the alcohol expenditure levels in DAs were fully independent of expenditure in adjacent DAs.[34] We then calculated Local Moran's I measures to identify clusters of hot spots and cold spots, where hot spots were clusters of adjacent DAs with similarly high levels of licensed premises expenditures and cold spots were clusters with low levels of licensed premises expenditures. Clustering techniques were carried out using GeoDa v1.6.7.[35] High resolution maps were created in ArcGIS 10.3 (Environmental Systems Research Institute, Inc., Redlands, CA, USA).

Consistent with the approach used by Pridemore and Grubesic,[36] Grubesic et al.[24] and Zhu, Gorman and Horel,[37] we used multivariate spatial regressions to estimate the effects of the area-level factors on area-level alcohol expenditure. In the presence of positive spatial autocorrelation, ordinary least squares (OLS) regression can result in biased and inefficient parameter estimates.[37] Spatial regression models have been developed to address this problematic effect and have been widely employed in spatial econometrics.[38]

Spatial regression models include at least one additional variable, known as a *spatial autoregressive term*, to control for geographical variation. We estimated four main spatial regression models: a spatial lag regression model (also known as *spatial autoregressive model* or SAR), a spatial error regression model (SEM), a spatial Durbin model (SDM) and a spatial Durbin error model (SDEM).[14,34,38-42] In the spatial lag model, values of the dependent variable (y) for a unit (i) are assumed to be directly influenced by the values of y in neighbouring units.[14,43] In order to account for this effect, a spatially lagged dependent variable (pWy) is included as an explanatory variable (Figure 2). Alternatively, the SEM incorporates geographical variation by adding a spatial autoregressive error term as a dependent variable (Figure 2). The SDM and SDEM are extensions of the spatial lag and spatial error models respectively, as these models are the same as their counterparts, except for an additional spatial autoregressive term for independent variables (Figure 2).

Our procedure began with descriptive statistics and correlation analysis to describe the distribution of the dataset and to identify issues of multicollinearity. Preliminary bivariate OLS regressions suggested positive spatial autocorrelation, therefore we calculated bivariate regressions using an SEM. We then included statistically significant explanatory variables in a multivariate SEM. The number of insignificant explanatory variables was reduced with backwards stepwise regression ($\alpha = 0.10$). We tested four different spatial regression models, with the best-fitting model determined by the highest log-likelihood value. All regression models were estimated using the software package R version 3.2.3.[44]

Results

Descriptive statistics

In 2010, the average annual household alcohol expenditure in licensed premises was $337.51 (range: $47.54 to $2963.02). Table 1 provides descriptive statistics for licensed premises expenditure and the area-level explanatory variables.

Spatial autocorrelation

For licensed premises alcohol expenditure, the Global Moran's I value was 0.634 and highly significant *($p = .001$)* (Figure 3), indicating a high degree of positive spatial autocorrelation. A total of three hot spots and three cold spots were identified for alcohol expenditures, using Local Moran's I (Figure 4).

Spatial regression results

For the licensed premises expenditure, the SDEM model had the largest log-likelihood, indicating the best fit. The model coefficients and significance of coefficients are provided in Table 2.

Socioeconomic and demographic variables

The percentage of people reporting Filipino ethnicity was the only significant ethnicity variable in the final model. A one-unit increase in the percentage of Filipino ethnicity was associated with a decrease in alcohol expenditures of 0.28%. The percentage that was nonvisible minority was positive and significant, with a one-unit increase associated with an increase in alcohol expenditures of 0.44%.

The percentage of employed residents working in management and administration was significantly associated with alcohol expenditures, with a one-unit increase leading to a predicted increase in expenditures of 78.57%. Median after-tax income was also found to have a positive association, as a one-dollar increase was found to increase predicted expenditures by 0.0006%. Conversely, the percentage of income from transfer payments was negatively associated with alcohol expenditures, as a one percentage point increase was associated with a decrease in expenditures by 1.74%. Postsecondary education had a significantly positive effect on expenditures, with a one-unit increase in the proportion of a DA with postsecondary qualifications associated with an increase in predicted expenditures of 35.00%.

FIGURE 2
Spatial regression models for calculating average total alcohol expenditures levels for licensed premises in Toronto, Canada, Dissemination Areas, 2010

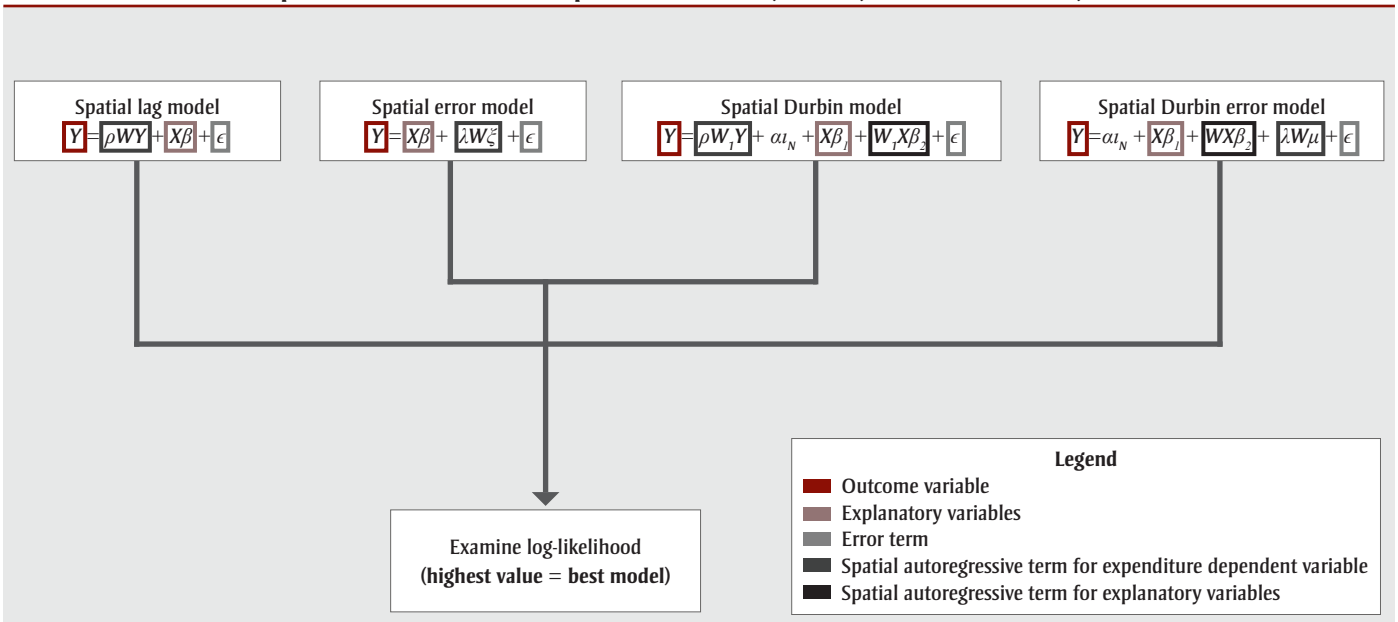


TABLE 1
Table of descriptive statistics for all outcome and explanatory variables, Dissemination Areas in Toronto, Canada, 2010

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Expenditures in LP	3512	47.54	2963.02	337.51	291.01
Log transformed LP	3512	3.86	7.99	5.56	0.70
% nonvisible minority	3512	0.00	100.00	59.72	26.62
% ethnicity Filipino	3512	0.00	60.86	3.11	5.38
% employed in management	3512	0.07	0.93	0.53	0.15
Median household income—after tax	3512	11776.00	335039.00	56303.79	25201.81
% income from transfer payments	3512	0.00	56.30	11.17	7.37
% apartments < 5 floors	3512	0.00	100.00	19.04	23.95
% apartments—duplex	3512	0.00	61.39	6.60	7.92
% row houses	3512	0.00	100.00	5.62	14.00
% single detached	3512	0.00	100.00	39.87	34.50
% postsecondary education	3512	0.00	0.94	0.48	0.16
Subway intercept	3512	0.00	1.00	0.06	0.23
Lagged subway intercept	3512	0.00	1.00	0.07	0.16
Primary drinking restaurant density by DA	3512	0.00	116.78	1.10	6.46
Lagged primary drinking restaurant density by DA	3512	0.00	38.79	1.13	3.43
Eating restaurant density by DA	3512	0.00	826.78	21.54	59.30
Lagged eating restaurant density by DA	3512	0.00	493.35	21.53	41.11

Abbreviations: DA, Dissemination Area; LP, licensed premises.

Notes: A lagged variable considers the effect of a variable of interest (i.e., alcohol expenditures) in neighbouring areas to a specific DA. For example, for a DA called DA1, if DA2 and DA3 are considered neighbours, their average total alcohol expenditure values can be averaged and included as a spatially-lagged independent variable. What constitutes a neighbour is dependent on the contiguity definition (i.e., rook criterion: sharing a common edge or queen criterion: sharing a common edge or a common vertex), and the resulting neighbourhood structure is stored as a spatial weight matrix.

Lagged restaurant density: The effect of restaurant densities in areas immediately adjacent to a DA.

Lagged subway intercept: The effect of the presence of subways in areas immediately adjacent to a DA.

The percentage of apartments with fewer than five floors, the percentage of single-detached houses and the percentage of row houses were all positively associated with alcohol expenditure. The associated expenditure increases from a one-unit increase were 0.13%, 0.23% and 0.48% respectively.

Built environment variables

Both the presence of subways and geographically lagged subway presence (the presence of subways in neighbouring areas) were positively associated with alcohol expenditures. A one-unit increase in subway intercepts was found to increase expenditures by 5.01%. Having subways in adjacent areas (lagged subways) resulted in an increase to expenditures by 28.28%. The density of primary drinking restaurants and lagged primary drinking restaurants were also both positively associated with alcohol expenditures, as one-unit increases resulted in 0.06% and 0.73% increases in expenditure respectively. Finally, both restaurant density and lagged restaurant density were positively associated with alcohol expenditure. A one-unit increase in restaurant density led to an increase in expenditures by 0.03%. As for lagged restaurant density, a one-unit increase was associated with an increase in expenditures by 0.10%.

Discussion

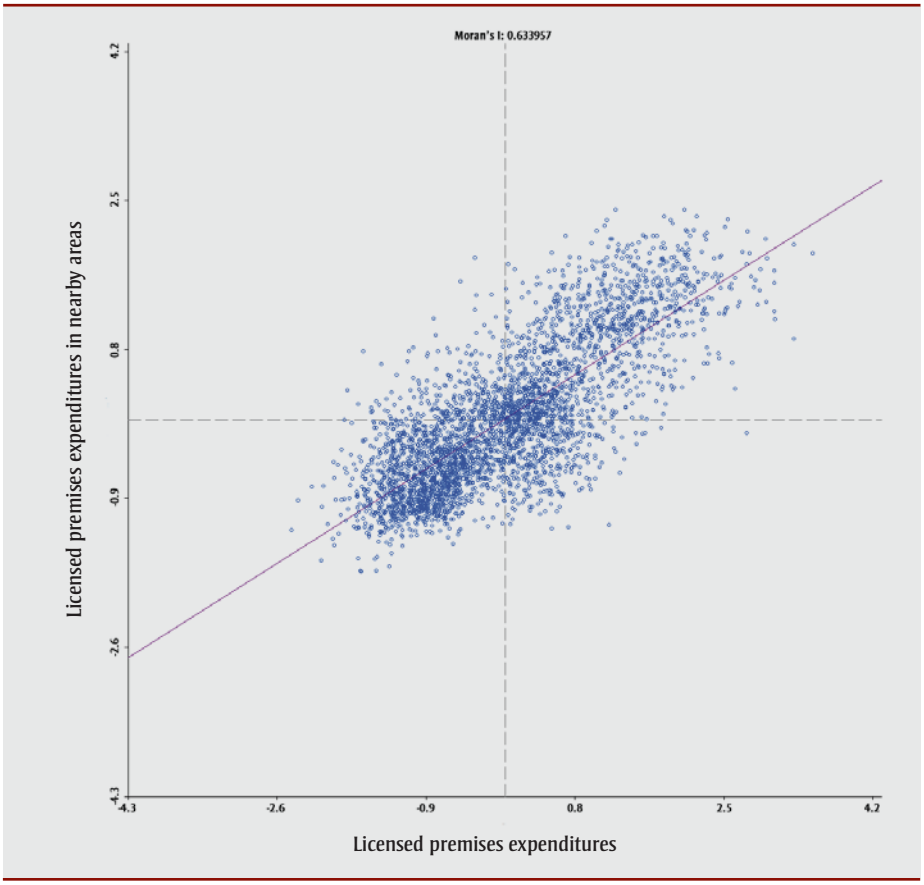
Our study found that significant associations existed between area-level socioeconomic variables and licensed alcohol expenditures. Most notably, the proportions of residents in management occupations and with postsecondary degrees were highly positively associated with alcohol expenditures. For public health promotion, this suggests that campaigns such as The Centre for Addiction and Mental Health's (CAMH) "Rethink Your Drinking" might be tailored to target these sociodemographic groups or the establishments that they frequent. It is possible that many drinking establishments in Toronto target clientele from management and administrative occupations, as they may have more disposable income.

This study also found a positive association between the presence of subways and area-level alcohol expenditure. Previous studies have acknowledged the possibility that increased access by public transportation to areas with high alcohol outlet densities could lead to greater alcohol consumption.[19] The findings in this study lend their support to this notion, as having a subway line in the same DA led to an average increase of 5.00% in alcohol expenditures. Furthermore, having subway lines in neighbouring areas was also related to higher alcohol expenditures. For policy makers, this could serve as an additional consideration in recommending alcohol outlet densities.

The density of primary drinking restaurants and other restaurants increased expenditures slightly. The direction of association for this finding agrees with previous work by Gruenewald, Ponicki and Holder[16] who found that, independent of alcoholic beverage pricing and while controlling for sales and availability, physical availability in the form of alcohol outlets increased the sales of alcoholic beverages.

Several systematic reviews of international alcohol outlet density literature have found considerable evidence of a significant positive association between alcohol outlet density and consumption. Livingston et al.[45] examined literature from North America, the UK and Nordic countries, including cross-sectional studies, natural experiments and time-series experiments. The majority of these studies found significant positive associations between alcohol outlet density and alcohol consumption. In another review, Campbell et al.[46] also reported that studies generally found outlet density to be associated with increased alcohol consumption, and showed that alcohol bans and changes to

FIGURE 3
Global Moran's I statistic scatterplot for licensed premises alcohol expenditures, Toronto, Canada, 2010



Note: The Global Moran's I statistic plots the licensed premises expenditure values (x-axis) against expenditure values in nearby areas (y-axis). The resulting correlation value is the Moran's I value. Monte Carlo testing using 999 permutations was used to produce a p-value that determined whether the points plotted form a significant cluster. The Moran's I values were significant at the .001 significance level.

licensing arrangements for alcohol can be effective strategies. Popova et al.[47] conducted a systematic review with a focus on both the density of outlets and the hours of sale and their relation to consumption and property damage. Similarly, a majority of the studies reported a positive association between alcohol outlet density and higher overall alcohol consumption.

Several studies have examined the effect of alcohol outlet density and retail arrangements on alcohol consumption in Canada. Xie et al., examining Canadian data from 1968 to 1986, found a significant association between reductions in the density of off-premises sales outlets and reduction in alcohol consumption.[46] Trolldal conducted a time-series analysis of the relationship between alcohol sales and availability in four Canadian provinces; however, he did not find a significant positive association.[45] Trolldal also examined the impact of allowing wine sales in grocery stores in Quebec and alcohol retail privatization in Alberta. He found the change in Quebec led to a 10% increase in sales of wine and a smaller increase in total alcohol sales.[46] In Alberta, privatization was found to have resulted in a permanent increase in the sale of spirits only.

It may be that some of the variability in the results of the outlet density–consumption relationship is due to that relationship being a nonlinear one. Livingston et al.[48] distinguish between two different effects of increasing alcohol outlet density on alcohol-related harms: a *proximity* effect and an *amenity* effect. The proximity effect hypothesizes that the effect of outlet density on consumption is reduced at higher density levels, and that outlet density eventually reaches a saturation point. As a result, the corresponding levels of alcohol-related harms from consumption will also plateau. Conversely, the amenity effect postulates that as alcohol outlet density increases, alcohol-related harms increase at an accelerating rate, as more drinkers are brought into closer proximity with each other.

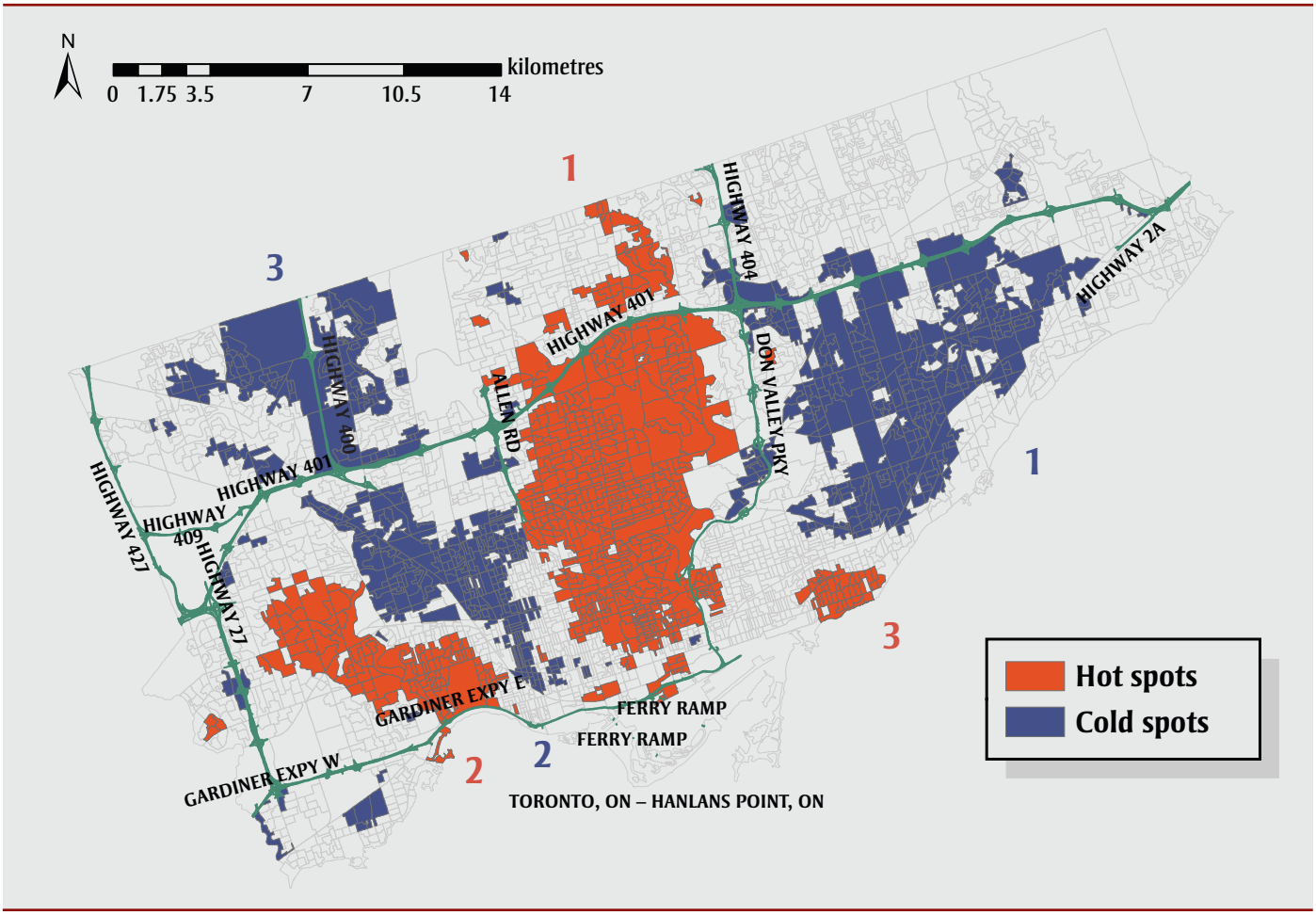
Future research is needed to improve our understanding of these possible relationships. However, the present study does provide evidence of the clustering of both alcohol sales and consumption, which we think can help inform decisions regarding the number and distribution of alcohol sales licenses. In the future, critical values for outlet density could be determined, in order to mitigate alcohol-related harms.[46,48,49]

Strengths and limitations

This study, using a novel approach, was able to replicate the impact of alcohol availability and income on expenditure observed using more traditional methods. To our knowledge, this was the first study to quantify and visualize the spatial structure of alcohol expenditure and examine associations between expenditures and area-level characteristics in the City of Toronto. It demonstrates the application of spatial methods and use of alcohol expenditure data in the Canadian context.

One of the limitations of this study is the use of DA characteristics in 2006 to predict 2010 licensed premises expenditures. These were the only data available at the time of the study; however, it is hoped that future studies will be able to use area data that are closer in time to the expenditure data. For small-area studies, another primary problem is the issue of the "modifiable area unit problem" (MAUP), in which analyses at different spatial scales result in differing associations between explanatory variables and the outcome variable.[13] For this study, the Dissemination Area was chosen as the unit of analysis to balance data availability, limiting MAUP and finding local patterns that have applicability to policy efforts. Another possible limitation is the risk of the ecological fallacy, in which associations observed at a group level are used to make causal inferences at an individual level[50,51] leading to erroneous conclusions.[52,53] It is, therefore, important to remember that the findings here are only applicable for understanding alcohol expenditure in Toronto at the DA level. Furthermore, it should also be kept in mind that our results are based on cross-sectional data

FIGURE 4
Hot spot and cold spot map for licensed premises alcohol expenditures by Dissemination Area in Toronto, Canada, 2010



Data source: Licensed premises alcohol expenditures are from Statistics Canada. Survey of Household Spending (SHS): detailed information for 2013 [Internet]. Ottawa (ON): Statistics Canada; 2013 [modified 2017 Dec 12; cited 2015 Aug 7]. Available from: http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3508

Notes: This map shows the hot spots (areas with high levels of alcohol expenditure clustered together) in red and the cold spots (areas with low levels of alcohol expenditure clustered together) in blue. The major highways have also been overlaid to provide a sense of location for the clusters. The correspondingly coloured numbers indicate the locations of the 3 hot spots and 3 cold spots.

and causal inferences should not be made. Future studies could make use of spatial multilevel models to allow findings to be generalizable to the individual level. Time-series analyses could also be done to address the cross-sectional nature of our study.

Finally, the use of sociodemographic characteristics of residents of a DA to predict alcohol expenditures in the same DA assumes that purchases are made in the area of residence. It is likely that household expenditures often include purchases made in other areas, and this is particularly true because of the small size of this geographic classification and the fact that people travel for work. To fully account for this would require data on the location of expenditures and household characteristics, which are presently unavailable. However, some purchasing activity in other DAs can be statistically accounted for by the spatial Durbin error model, as the spatially lagged alcohol outlet density variables capture the effects of alcohol outlet density in adjacent DAs on the average expenditures in a local DA. The positive associations found indicate that purchases at outlets outside of a local DA have a significant impact on the average expenditures within that DA. The significant spatial error term (Lambda) in the models might also be the result of purchases in adjacent DAs increasing expenditure levels within the DA of residence. In the absence of more in-depth data, one way to overcome this disconnect between place of residence and place of retail behaviour is to employ "gravity models," such as the kernel density estimation method, to better account for retail behaviour in external DAs affecting the expenditures in a local DA.[54]

Conclusion

The results of this study suggest that both area-level socioeconomic factors and built environment variables may be related to levels of alcohol expenditure. The results corroborated the findings of previous individual-level studies of socioeconomic correlates of alcohol use, and also found associations between small-area-level alcohol expenditure and socioeconomic characteristics for the first time. We also identified significant built environment associations with alcohol expenditures, which underscore the importance of examining contextual factors as significant influences of health behaviours. Moreover, this study adds considerably to the current

TABLE 2
Spatial Durbin error model regression results for licensed premises expenditures in Toronto, Canada, Dissemination Areas, 2010: coefficients and significance

Socioeconomic variables	
Percentage nonvisible minority	0.004***
Percentage of Filipino ethnicity	−0.003*
Percentage employed in management occupations	0.580***
Median household income, after tax	0.00001***
Percentage of income from transfer payments	−0.018***
Percentage of apartments < 5 floors	0.001***
Percentage of single detached houses	0.002***
Percentage of row houses	0.005***
Percentage postsecondary education	0.300***
Built environment variables	
Subway intercepts	0.049
Lagged subway intercepts	0.249***
Primary drinking restaurant density by DA (km^2)	0.001
Lagged primary drinking restaurant density by DA (km^2)	0.007*
Restaurant density by DA (km^2)	0.0003*
Lagged restaurant density by DA (km^2)	0.001**
Constant	4.506***
Spatial autoregressive error term	
Lambda	0.639***

Data source: Statistics Canada. Survey of Household Spending (SHS): detailed information for 2013 [Internet]. Ottawa (ON): Statistics Canada; 2013 [modified 2017 Dec 12; cited 2015 Aug 7]. Available from: http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3508.

Abbreviation: DA, Dissemination Area.

Notes: A lagged variable considers the effect of a variable of interest (i.e., alcohol expenditures) in neighbouring areas to a specific DA. For example, for a DA called DA1, if DA2 and DA3 are considered neighbours, their average total alcohol expenditure values can be averaged and included as a spatially-lagged independent variable. What constitutes a neighbour is dependent on the contiguity definition (i.e., rook criterion: sharing a common edge or queen criterion: sharing a common edge or a common vertex), and the resulting neighbourhood structure is stored as a spatial weight matrix.

Lagged restaurant density: The effect of restaurant densities in areas immediately adjacent to a DA.

Lagged subway intercept: The effect of the presence of subways in areas immediately adjacent to a DA.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

understanding of alcohol expenditures by recognizing geographic influences. The findings in this study demonstrate the utility of a spatial analysis approach for understanding alcohol use, and furthermore, highlight how the spatial methods used may help municipalities more effectively formulate alcohol-use reduction strategies to assist in reducing alcohol-related harms. Future research will benefit from this spatial understanding of licensed premised alcohol expenditures and can explore other avenues, such as examining additional built environment variables and applying models that explicitly address area-level effects.

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Conflicts of interest

The authors state that they have no competing interests in this work.

Authors' contributions and statement

AL, JL, MC, and SL all proposed and planned the analysis. AL conducted the analysis and wrote the first draft. AL, JL, MC, and SL commented and edited subsequent drafts.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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Original quantitative research

Validation of the Children's Intrinsic Needs Satisfaction Scale among Canadian youth: psychometric properties, criterion-related validity and multitrait multimethod confirmatory factor analysis

Heather Orpana, PhD (1,2); Caryn Pearson, MA (1); Raelyne L. Dopko, PhD (1); Lucie Kocum, PhD (3)

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Abstract

Introduction: Based on self-determination theory, the Children's Intrinsic Needs Satisfaction Scale (CINSS) measures autonomy, competence and relatedness at school, home and with peers. The factor structure and criterion-related validity of the CINSS in the Canadian youth population are tested using data from the Canadian Student Tobacco, Alcohol and Drugs Survey (CSTADS).

Methods: Data from the 2014/2015 CSTADS were analyzed for evidence of convergent and discriminant validity and for method variance. A multitrait multimethod (MTMM) confirmatory factor analysis (CFA) was conducted to account for the conceptual structure of the measure. Criterion-related validity was demonstrated through correlations between related constructs, prosocial behaviours and behavioural problems, and the CINSS subscale scores. Mean differences on CINSS subscale scores between those who reported and did not report being bullied or bullying others were also examined.

Results: Correlation analyses demonstrated that, in general, correlations were higher between concept/context item pairs and lowest between items measuring different concepts and contexts. Cronbach's alpha for concept and context subscales were high: $\alpha = 0.77$ for autonomy, $\alpha = 0.85$ for competence and $\alpha = 0.79$ for relatedness. A MTMM CFA demonstrated that the model fit the data well, with no modifications. Criterion-related validity was demonstrated through correlations between CINSS subscales and related concepts or mean differences on CINSS subscales between groups.

Conclusion: The CINSS demonstrates good internal consistency, factorial validity and criterion-related validity in this sample of Canadian students. The measurement of positive mental health among Canadian youth is central to surveillance efforts which will help inform mental health promotion activities across Canada.

Keywords: *positive mental health, self-determination theory, youth, well-being, factor analysis, Children's Intrinsic Needs Satisfaction Scale*

Highlights

- The factor structure of the Children's Intrinsic Needs Satisfaction Scale (CINSS) was confirmed using multitrait multimethod confirmatory factor analysis.
- The CINSS tool showed good internal reliability as well as criterion-related validity through correlations between subscales and related constructs.
- The CINSS tool is a promising measure of positive mental health among Canadian youth.

Introduction

The mental health and well-being of children and youth is a public health priority in Canada[1] and in many countries around the world.[2,3] The Public Health Agency of Canada (PHAC) defines positive mental health as "the capacity of each and all of us to feel, think, and act in ways that enhance our ability to enjoy life and deal with the challenges we face."[4] Similarly, well-being is defined as "good mental states, including all of the various evaluations, positive and negative, that people make of their lives, and the affective reactions of people to their experiences."[5] However, the data on the mental health and well-being of children and youth in Canada, especially at the population level, are limited. Furthermore, mental health promotion approaches acknowledge a need to focus on strengths and resources to promote positive mental health for all children and youth, rather than on deficits and stress.[6] Strengths-based approaches focus on "what is going right," as a foundation for promoting the well-being and health of the population.

Author references:

1. Public Health Agency of Canada, Ottawa, Ontario, Canada
2. School of Epidemiology and Public Health, University of Ottawa, Ottawa, Ontario, Canada
3. Department of Psychology, St. Mary's University, Halifax, Nova Scotia, Canada

Correspondence: Heather Orpana, Centre for Surveillance and Applied Research, Public Health Agency of Canada, 785 Carling Ave, Ottawa, ON K1A 0K9; Tel: 613-878-5011; Email: heather.orpana@canada.ca

Surveillance efforts in the area of mental health have traditionally focused on what is going wrong, using measures of disorder, distress and problematic behaviour. For example, the Strengths and Difficulties Questionnaire (SDQ), developed as a short behavioural screening questionnaire for use in clinical settings, program evaluation and surveillance, includes only one subscale that deals with the positive attributes of the child or youth.[7] The Child Behaviour Checklist, one of the most widely used measures in child mental health, also focusses on problematic behaviours, including anxious, depressed, withdrawn and aggressive behaviours.[8] For public health to focus on strengths-based approaches and positive mental health, foundational measurement and surveillance efforts of these constructs are required.

To measure positive mental health among Canadians, PHAC developed the Positive Mental Health Surveillance Indicator Framework (PMHSIF), which includes three positive mental health outcomes: emotional, psychological and social well-being.[9] Positive mental health outcomes are measured by self-rated mental health, happiness, life satisfaction and psychological well-being in adults,[10] and a sense of community belonging for social well-being. However, measures that are appropriate for adults are often not appropriate for children or youth due to developmental and other differences.

Few measures of positive mental health for youth and children have been implemented on large-scale Canadian surveys. These include the Strengths and Difficulties Questionnaire on the Canadian Health Measures Survey (CHMS), the Health Utilities Index's single item on emotion (CHMS) and the Children's Intrinsic Needs Satisfaction Scale (CINSS). The CINSS was implemented for the SHAPES Mental Fitness survey component,[11] as well as the 2014/2015 Canadian Student Tobacco, Alcohol and Drugs Survey (CSTADS).[12] After comparing these measures, the CINSS was chosen as a strong candidate measure of positive mental health among children and youth because it covered two of the three positive mental health outcomes included in the PMHSIF.

The CINSS is based in self-determination theory (SDT), a theory of motivation and personality that proposes the basic psychological human needs of autonomy, competence and relatedness.[13-16] Autonomy is the experience of choice for one's activities; competence is a feeling of mastery and self-efficacy; and relatedness is a feeling of closeness with significant others. These concepts map onto the constructs of psychological well-being (autonomy and competence) and social well-being (relatedness) in the PMHSIF. These three concepts are also hypothesized to contribute to emotional well-being. Situations or environments that support individual autonomy, competence and relatedness are predicted to lead to greater subjective well-being and happiness.[13] On the other hand, situations that do not support these basic needs may lead to decreased well-being.

Although autonomy, competence and relatedness in the context of well-being have been widely studied in adult populations, children and youth remain an inadequately studied population. In order to measure the core concepts of self-determination theory among children and youth, Véronneau et al. (2005) developed the CINSS.[17] The scale's 18 questions cover the three concepts (competence, relatedness, autonomy) each across three contexts (with home, school and peers). While this measure has been implemented on the School Health Planning and Evaluation System and the CSTADS,[11,12] there is limited information about its reliability and validity, and we were unable to identify any published reports of its factor structure.

The purpose of this paper is to test the factor structure and construct validity of the CINSS in the Canadian youth population using data from the CSTADS. Convergent validity is demonstrated by high correlations among measures of the same trait by the same method, and discriminant validity is demonstrated by relatively lower correlations between different traits and different methods. We anticipate that CINSS subscales will be positively associated with prosocial behaviour and negatively associated with behavioural problems, bullying and being bullied.

Methods

Data from the 2014/2015 CSTADS—obtained through a sharing agreement with Health Canada and PHAC—were analyzed. The CSTADS is a school-based survey conducted every second year, with funding from Health Canada. The target population for the 2014/2015 cycle was students in Grades 6 to 12 (Secondary 5 in Quebec) who were attending public, private and Catholic schools in the 10 provinces in Canada. The three territories were excluded. During this cycle, schools on military bases and on First Nations reserves and schools for youth with visual or hearing impairments or special needs were also excluded. While New Brunswick was included in the sample, estimates could not be calculated for this province due to a very low participation rate. A stratified single-stage cluster design, based on the smoking rate for the health region as well as type of school, was used, with schools randomly selected within strata. The final sample included 336 schools from 128 school boards, with a school-level response rate of 47%; 42 094 students responded, representing a 66% student-level response rate. The paper and pencil survey, which took less than 30 minutes to complete, was administered in classrooms, in English and French, between October 2014 and May 2015.

Ethics approval was granted by the Health Canada and the PHAC's Research Ethics Board, the Office of Research Ethics at the University of Waterloo, the provincial institutional ethics review boards and the ethics boards of participating school boards. Consent procedures varied by school board and included active permission or active information/passive permission by home and guardians. Participation in the survey was at the students' discretion.

Measures

The CINSS consists of 18 questions,[17] which respondents answer using a four-point Likert scale ranging from 1 ("Really false for me") to 4 ("Really true for me"). There were six questions per concept (autonomy, competence and relatedness) and six questions per context (with peers, at home and at school), for a total of two questions per context/concept pair. Subscale scores were created by summing responses to each of the six questions for the autonomy, competence and relatedness subscales. Sample questions and their corresponding concepts and contexts include: "My teachers like me and care about me" (relatedness/school); "I feel free to express myself at home" (autonomy/home); and "I feel my friends think I am good at things" (competence/with

peers). If a respondent was missing data on an item, the value for that subscale was not computed.

For measures of criterion-related validity, correlations between the CINSS total score and subscale scores were examined for the following modules: bullying, prosocial behaviours and behavioural problems.

Bullying

Bullying and being bullied were based on questions about frequency over the past 30 days. Students were asked "1) In the last 30 days, how often have you been bullied by other students?" and "2) In the last 30 days, how often have you bullied other students?"

Students were grouped according to whether they reported 1) being bullied (responses b through e) or not bullied (response a), and whether they 2) reported bullying others (responses b through e) or not bullying others (response a):

a. I have not been bullied by/have not bullied other students in the last 30 days;

b. Less than once a week;

c. About once a week;

d. 2 or 3 times a week;

e. Daily or almost daily.

Prosocial behaviours

The prosocial behaviour scale of the Health Behaviours in School Aged Children Brief Symptom Checklist [18] was measured using the following five positive statements:

a. I often do favours for people without being asked;

b. I often lend things to people without being asked;

c. I often help people without being asked;

d. I often compliment people without being asked;

e. I often share things with people without being asked.

Behavioural problems

The behavioural problems scale of the Health Behaviours in School Aged Children Brief Symptom Checklist [18] was measured using the seven following negative statements:

a. I cut classes or skip school;

b. I make other people do what I want;

c. I disobey my parents;

d. I talk back to my teachers;

e. I get into fights;

f. I often say mean things to people to get what I want;

g. I take things that are not mine from home, school, or elsewhere.

Responses to the prosocial behaviours and behavioural problems scale statements were chosen from a six-point Likert scale that ranged from 1 ("definitely not like me") to 6 ("definitely like me"). The responses were summed for all questions answered, then divided by the number of questions answered for all respondents who answered three or more questions.

Demographic variables

Demographic variables included sex and grade. Ethnicity was based on the question "How would you describe yourself?" Response categories included: White, Black, West Asian/Arab, South Asian, East/Southeast Asian, Latin American/Hispanic, Aboriginal and "Other." School socioeconomic status was determined by using median household income from the 2011 Census of the households in the school's forward sortation area (first three digits of the postal code). Urban/rural status was also determined using the school's postal code and the Statistical Area Classification system variable from the Postal Code Conversion File + version 6a1.

Analysis

Descriptive statistics and correlation analyses were conducted in SAS EG (SAS Institute Inc., Cary, NC, USA). Descriptive analyses were stratified by sex.

Multitrait multimethod (MTMM) confirmatory factor analysis (CFA) was conducted to test the structural validity of the CINSS. The MTMM approach to CFA makes it possible to measure several traits using a number of methods.[19] In this case, we used MTMM CFA to test the factor structure of three "traits" (autonomy, competence and relatedness) as measured in three "method" contexts (home, school and with friends). This method is required to take into account the conceptual structure of the measure, which includes both traits and contexts, whereas a standard CFA would only take into account either the traits or the contexts, but not both simultaneously. Our analytic plan involved testing two models, as described by Marsh and Grayson:[20] correlated traits correlated methods (CTCM) and correlated traits correlated uniqueness (CTCU). The CTCM estimates factors for traits and methods, as well as correlations among traits and among methods, separately (i.e. does not estimate correlations between traits and methods). An advantage of this model is that it closely resembles what MTMM strives to achieve, theoretically; however, it rarely converges in practice because the model is usually underidentified.[21] The CTCU, which provides an estimate of trait factors and intercorrelations among the method item residuals, is normally tested as a backup.

To assess model fit, we used Hu and Bentler's [22] criteria for adequate fit: a value of 0.95 or greater for the comparative fit index (CFI) and Tucker-Lewis index (TLI); a value of less than 0.08 for the standardized root mean square residual (SRMR); and a value of less than 0.06 for root mean square error of approximation (RMSEA). All analyses were weighted to account for the sampling design of the CSTADS and bootstrapping was used to obtain standard errors for descriptive statistics.[12]

Results

Study participants included youth in Grades 6 through 12, with about 15% of the sample in each of these grades (Table 1). The sample comprised 51.4% males and 48.6% females. All provinces were represented proportionally except for New Brunswick, which comprised less than 1% of the sample. The median household income of the neighbourhood in which a school was located was $66 509, and 79.8% of schools were located in urban settings. While most students identified as White (66.5%), considerable diversity is apparent, with 10.8% of students identifying as South Asian/Indian, 8.7% as East Asian/Chinese, 5.3% as Black, 4.2% as Aboriginal, 3.2% as Asian/Arab, 2.6% as Latin American/Hispanic and 7.3% as "Other."

Table 2 shows descriptive statistics for CINSS items reported separately/split by sex and for males and females combined. All items had relatively high mean responses

TABLE 1
Description of sample composition (*N* = 42 094)

Characteristics		%	95% CI
Sex	Male	51.41	51.40–51.42
	Female	48.59	48.58–48.60
Grade	6	12.77	12.67–12.87
	7	13.83	13.71–13.95
	8	14.03	13.90–14.15
	9	14.97	14.90–15.05
	10	14.99	14.92–15.07
	11	15.14	15.05–15.23
	12	14.26	14.17–14.35
Self-reported ethnicity	White	66.53	64.95–68.11
	Black	5.30	5.01–5.59
	Asian/Arab	3.24	3.01–3.46
	South Asian/Indian	10.79	9.49–12.09
	East Asian/Chinese	8.73	8.32–9.14
	Aboriginal	4.22	3.93–4.51
	Latin American	2.60	2.31–2.89
	Other	7.31	7.07–7.54
Location of school	Urban	79.82	77.55–82.09
	Rural	20.18	17.91–22.45
Median household income of school neighbourhood ($)		66 509	65 731.57–67 285.61
Province	Newfoundland & Labrador	1.35	1.34–1.36
	Prince Edward Island	0.45	0.44–0.45
	Nova Scotia	2.59	2.57–2.62
	New Brunswick	2.22 [E]	1.36–3.08
	Quebec	18.63	18.46–18.79
	Ontario	44.02	43.63–44.40
	Manitoba	3.90	3.86–3.93
	Saskatchewan	3.12	3.09–3.15
	Alberta	11.18	11.08–11.28
	British Columbia	12.55	12.44–12.66

Abbreviations: CI, confidence interval; CV, coefficient of variation.

[E] CV > 16.6, interpret with caution.

on the four-point scale. Item and subscale means were similar for males and females. There were low levels of missing data, ranging from 3% to 5% per item. Cronbach's alpha for the three domain subscales were as follows: autonomy $\alpha = 0.77$; competence, $\alpha = 0.85$; and relatedness $\alpha = 0.79$. The appropriate level of alpha depends on the intended use of the measure, with an alpha of at least 0.70 being adequate for most research and 0.80 for most applied purposes.[23]

Table 2 shows mean scores by concept and context for both sexes combined and for females and males separately. There were no statistically significant differences in subscale scores for females and males, with the exception of relatedness, where mean scores were 3.41 (95% CI: 3.40–3.41) and 3.34 (95% CI: 3.34–3.35), respectively.

Table 3 shows the correlation matrix for CINSS items. Convergent validity was demonstrated by higher correlations for same trait, same context items. In general, correlations were highest between trait/context pairs (e.g. relatedness with friends, $r = 0.63$) and between trait items (e.g. competence) and context items (e.g. at school). However, item pairs for autonomy at home ($r = 0.34$) and at school ($r = 0.35$) were lower than expected. Discriminant validity was demonstrated through lower correlations between different trait, different context items (e.g. having a choice over when to do chores (autonomy at home) and likes to be with friend (relatedness with peers, $r = 0.21$).

As tests of criterion-related validity, we also examined the relative strength of the relationships between the CINSS subscales with prosocial behaviour and problematic behaviour measures (Table 4). Relatedness was most highly correlated with problematic behaviour ($r = -0.33$), as was competence ($r = -0.31$) (Table 4). Scores on all subscales were significantly lower among those reporting being bullied in the past 30 days compared to those who did not report this, and among those reporting bullying others in the past 30 days compared to those who did not report this. Those who reported being bullied, or bullying others, had scores approximately one-quarter point lower than those who were not bullied or did not bully others.

The CTCM model was tested in MPlus[24] using robust maximum likelihood estimation. As anticipated, the model did not converge. The CTCU model, however, fit the data well: the Chi-square test value for the model was 75 545.40 ($df = 153$; $p < 0.001$). The CFI exceeded Bentler and Hu's criterion at 0.97; TLI of 0.94 was slightly lower than the 0.95 cutoff. RMSEA was 0.026 (95% CI: 0.025–0.027; $p < 0.001$) and SRMR was 0.028. All factor loadings were significant, with standardized values ranging from .49 to .74. Statistically significant intercorrelations between item residuals ranged from $r = .04$ to $r = .45$. Correlations were highest among item residuals measured for home and peer contexts and lowest for the school context, where five item residual correlations were not significant. No modifications were needed to obtain an adequate fit according to the criteria set by Hu and Bentler.[22] High correlations among the trait factors ($r_{aut\text{-}rel} = .91$; $r_{aut\text{-}comp} = .90$; $r_{rel\text{-}comp} = .95$) suggested that a second order factor might better represent the factor structure of the data. When relatedness,

TABLE 2
Means, standard deviations and percent missing data by item, Children's Intrinsic Needs Satisfaction Scale, 2014/15 (*N* = 42 094)

Item		Both sexes			Females			Males		
		Mean	SE	% missing	Mean	SE	% missing	Mean	SE	% missing
Relatedness										
Cared about by teachers	R1	3.21	.004	3	3.25	.004	3	3.18	.005	4
Spends time with parents	R2	3.30	.003	4	3.34	.003	3	3.27	.004	5
Cared about by parents	R3	3.74	.003	4	3.74	.004	3	3.73	.003	5
Likes to be with teachers	R4	2.84	.004	4	2.86	.005	3	2.81	.006	5
Cared about by friends	R5	3.47	.003	4	3.53	.004	3	3.41	.003	5
Likes to be with friends	R6	3.65	.002	4	3.68	.003	4	3.62	.003	5
Overall relatedness	–	3.37	.002	8	3.41	.003	8	3.34	.003	9
Autonomy										
Expresses her/himself at home	A1	3.39	.003	4	3.39	.005	3	3.38	.003	5
Expresses her/himself with friends	A2	3.45	.004	4	3.49	.005	3	3.42	.004	5
Choice school work	A3	3.20	.004	4	3.23	.006	3	3.16	.004	5
Choice friend activities	A4	3.39	.003	4	3.40	.005	3	3.38	.003	5
Expresses her/himself at school	A5	2.99	.004	4	2.96	.006	3	3.02	.004	5
Choice chores	A6	2.94	.004	4	2.95	.005	3	2.94	.005	5
Overall autonomy	–	3.23	.003	7	3.24	.005	7	3.22	.003	8
Competence										
Well at school	C1	3.29	.003	3	3.30	.004	4	3.28	.004	4
Teachers think he/she is good	C2	3.21	.004	4	3.20	.004	3	3.21	.005	5
Well at home	C3	3.35	.003	4	3.33	.004	3	3.37	.003	4
Parents think he/she is good	C4	3.47	.003	4	3.46	.004	3	3.48	.004	5
Well with friends	C5	3.40	.003	4	3.41	.004	3	3.38	.004	5
Friends think he/she is good	C6	3.37	.003	4	3.38	.004	3	3.36	.004	5
Overall competence	–	3.35	.002	7	3.36	.003	6	3.35	.003	8

Abbreviation: SE, standard error.

autonomy and competence factors were loaded onto a second-order factor of basic psychological need satisfaction, the factor variance was significant ($Z = 6.49, p < .001$). Factor loadings for items and first order factors are presented in Table 5.

Discussion

These analyses of the 2014/2015 CSTADS support the factorial and criterion-related validity of the CINSS scale. In this sample of youth in Grades 6 to 12, mean levels of autonomy, competence and relatedness were relatively high, with item means ranging from 2.84 to 3.74 on a four-point scale and subscale mean scores of 3.23 for autonomy, 3.35 for competence, to 3.37 for relatedness. There were no substantive differences between females and males, although the difference in the relatedness scales between females and males was small but statistically significant. The level of missing data was relatively consistent between items, ranging from 2% to 5% depending on the item and sex. We observed similar levels of internal consistency as Véronneau et al. in their initial study in Montréal,[17] with Cronbach's alphas in the high 0.70s to mid 0.80s for the subscales.

The pattern of correlations largely supported the MTMM measurement structure of the CINSS, although the autonomy subscale had lower item-pair correlations than anticipated. Autonomy is measured in each context by two questions: the first is about expressing oneself; the second is about choosing when to do schoolwork, homework or activities with friends. It may be that expression and choice of activities are both conceptually related to autonomy, but reflect different aspects. It may be worthwhile to explore these items further in order to determine if they should be reflected in lower order factors under autonomy. The CFA confirmed that the CTCU model is a good fit to the data, with no modifications needed to the proposed factor structure to obtain acceptable fit.

The CINSS demonstrated good criterion-related validity, with a moderate positive correlation between the relatedness subscale and prosocial behaviours and a moderate negative correlation with behavioural problems. Correlations between autonomy and prosocial and problematic behaviours were lower. Children reporting being bullied or bullying others in the past 30 days had lower scores on all three

TABLE 3
Correlation matrix of items of the Children's Intrinsic Needs Satisfaction Scale, 2014/15 (*N* = 39 734–40 650)

	R1	R2	R3	R4	R5	R6	A1	A2	A3	A4	A5	A6	C1	C2	C3	C4	C5	C6
Relatedness																		
R1 Cared about by teachers	–	.36	.35	.63	.40	.32	.35	.30	.32	.35	.44	.26	.52	.66	.39	.43	.36	.42
R2 Spends time with parents	.36	–	.54	.39	.33	.30	.52	.31	.28	.31	.34	.33	.36	.40	.54	.53	.33	.36
R3 Cared about by parents	.35	.54	–	.26	.40	.37	.51	.34	.32	.36	.30	.30	.36	.38	.50	.61	.36	.38
R4 Likes to be with teachers	.63	.39	.26	–	.32	.27	.30	.27	.33	.34	.46	.29	.43	.57	.37	.39	.35	.39
R5 Cared about by friends	.40	.33	.40	.33	–	.63	.36	.58	.28	.55	.50	.26	.37	.40	.41	.42	.64	.67
R6 Likes to be with friends	.32	.30	.37	.27	.63	–	.30	.55	.24	.49	.40	.21	.32	.32	.33	.34	.57	.57
Autonomy																		
A1 Expresses her/himself at home	.35	.52	.51	.30	.36	.30	–	.39	.31	.37	.41	.34	.37	.40	.53	.51	.36	.38
A2 Expresses her/himself with friends	.30	.31	.34	.27	.58	.55	.39	–	.28	.49	.51	.22	.31	.33	.40	.32	.56	.52
A3 Choice school work	.32	.28	.32	.33	.28	.24	.31	.28	–	.35	.35	.45	.34	.36	.35	.38	.31	.32
A4 Choice friend activities	.35	.31	.36	.34	.55	.49	.37	.49	.35	–	.45	.31	.36	.38	.39	.39	.59	.54
A5 Expresses her/himself at school	.44	.34	.30	.46	.50	.40	.41	.51	.35	.45	–	.31	.42	.46	.41	.38	.49	.56
A6 Choice chores	.26	.33	.30	.29	.26	.21	.34	.22	.45	.31	.31	–	.24	.28	.38	.35	.27	.30
Competence																		
C1 Well at school	.52	.36	.36	.43	.37	.32	.37	.31	.34	.36	.42	.24	–	.62	.47	.49	.38	.46
C2 Teachers think he/she is good	.66	.40	.38	.57	.40	.32	.40	.33	.36	.38	.46	.28	.62	–	.46	.52	.39	.50
C3 Well at home	.39	.54	.50	.37	.41	.33	.53	.40	.35	.39	.41	.38	.47	.46	–	.58	.44	.47
C4 Parents think he/she is good	.43	.53	.61	.39	.42	.34	.51	.32	.38	.39	.38	.35	.49	.52	.58	–	.40	.49
C5 Well with friends	.36	.33	.36	.35	.64	.57	.36	.56	.31	.59	.49	.27	.38	.39	.44	.40	–	.62
C6 Friends think he/she is good	.42	.36	.38	.39	.67	.57	.38	.52	.32	.54	.56	.30	.46	.50	.47	.49	.62	–

subscales, with the lowest of these being on the competence subscale for both variables. This relationship between perceptions of competence and bullying or being bullied should be explored further, and enhancing competence may be an avenue for addressing bullying in schools. Competence is the experience of "oneself as effective in one's interactions with the social and physical environments,"[25,p. 27] and future research could explore whether bullying behaviours stem from a need to assert control when this is low in other domains. A Hong Kong study found no association between bullying and being bullied and teacher support for competence or autonomy, but did find an association with teacher support for relatedness.[26] However, this study measured teacher support for autonomy, competence and relatedness, while the CINSS measures these concepts in three contexts: at home, at school and with peers.

Strengths and limitations

This study is the first of its kind to validate the CINSS in a large, representative school-based sample of youth in Canada. Other studies have examined the CINSS in

TABLE 4
Subscale means by being bullied or bullying in the past 30 days, and correlations between subscale scores and prosocial behaviours and problematic behaviours

	Not bullied	95% CI	Bullied	95% CI	Did not bully others	95% CI	Bullied others	95% CI	Prosocial (*r*)	Problematic behaviour (*r*)
Autonomy	3.32	3.31–3.32	2.98	2.97–2.99	3.27	3.27–3.28	3.01	3.00–3.03	0.20	–0.22
Competence	3.43	3.42–3.43	3.15	3.14–3.16	3.40	3.39–3.40	3.11	3.10–3.12	0.24	–0.31
Relatedness	3.44	3.43–3.44	3.21	3.20–3.22	3.42	3.41–3.42	3.15	3.14–3.16	0.27	–0.33

Abbreviation: CI, confidence interval.

TABLE 5
Standardized factor loadings for the correlated traits–correlated uniqueness model

Factors	Standardized loadings
Relatedness	0.98
R1 Cared about by teachers	0.63
R2 Spends time parents	0.55
R3 Cared about by parents	0.55
R4 Likes to be with teachers	0.58
R5 Cared about by friends	0.64
R6 Likes to be with friends	0.53
Autonomy	0.93
A1 Expresses her/himself at home	0.59
A2 Expresses her/himself with friends	0.59
A3 Choice school work	0.58
A4 Choice friend activities	0.61
A5 Expresses her/himself at school	0.74
A6 Choice chores	0.49
Competence	0.97
C1 Well at school	0.66
C2 Teachers think he/she is good	0.69
C3 Well at home	0.66
C4 Parents think he/she is good	0.68
C5 Well with friends	0.62
C6 Friends think he/she is good	0.72

Note: Loadings appearing next to factors are the first-order factor loadings on the second-order basic psychological need satisfaction.

more specific contexts and with smaller samples: among school-aged children in New Brunswick and PEI;[27] an examination of intrinsic needs satisfaction and depression;[28] and an examination of the impact of a school-based intervention.[29] While we did not have additional measures that closely aligned with the concepts of autonomy, competence and relatedness on the CSTAD survey, which focusses primarily on tobacco, alcohol and drugs, there were related concepts that we were able to include in tests of criterion-related validity such as prosocial behaviours and problematic behaviours. It would be useful to examine how the CINSS subscales are associated with other closely related concepts, such as self-esteem, mastery and perceived control in the future. This survey was administered at a single point in time, and thus we were not able to examine its stability over time. Similarly, the data we analyzed only included children and youth in Grades 6 to 12. Further evaluation of this measure is required for younger children. While the concepts measured by the CINSS align well with our three-factor concept of positive mental health, this instrument was not developed as a measure of positive mental health. Given the high level of attention to promoting positive mental health among children in research and practice, it may be useful to develop an instrument measuring the concept of positive mental health.

Conclusion

Based on self-determination theory, the CINSS measures competence, autonomy and relatedness in three contexts: at home, at school and with peers. The CINSS scale is a promising measure of positive mental health in children and youth for national surveillance purposes. The CINSS subscales align well with the concepts of psychological well-being (competence, autonomy) and social well-being (relatedness) reported in the PMHSIF. The availability of validated scales of positive mental health for children and youth is an essential foundation for research that can inform policies and programs that aim to improve the well-being of this population group. Future research should examine levels of competence, autonomy and relatedness in different groups of students, and whether the CINSS is sensitive to change for use in intervention research.

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Conflicts of interest

There are no conflicts of interest to report.

Authors' contributions and statement

HO and CP conceived the project and developed the research study. LK provided advice on methods. CP and HO conducted analysis. HO, CP, RD and LK interpreted the results. All authors drafted the manuscript, reviewed and revised the manuscript.

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