SSM -Population Health 2 (2016) 468–475

Contents lists available at ScienceDirect

SSM -Population Health

journal homepage: www.elsevier.com/locate/ssmph

Article

Neighbourhood social and built environment factors and falls in community-dwelling canadian older adults: A validation study and exploration of structural confounding

Afshin Vafaei [a,*], William Pickett [a], Maria Victoria Zunzunegui [b], Beatriz E. Alvarado [a]

[a] Department of Public Health Sciences, Queen's University, Kingston, ON, Canada
[b] Département de médecine sociale et préventive, Université de Montréal, Montreal, QC, Canada

ARTICLE INFO

Article history:
Received 20 December 2015
Received in revised form
8 June 2016
Accepted 16 June 2016

Keywords:
Ecometric analysis
Falls
Social and built environment
Neighbourhoods
Older adults
Social Capital
Structural confounding
Validity

ABSTRACT

Older persons are vulnerable to the ill effects of their social and built environment due to age-related limitations in mobility and bio-psychological vulnerability. Falls are common in older adults and result from complex interactions between individual, social, and contextual determinants. We addressed two methodological issues of neighbourhood-health and social epidemiological studies in this analysis: (1) validity of measures of neighbourhood contexts, and (2) structural confounding resulting from social sorting mechanisms. Baseline data from International Mobility in Aging Study were used. Samples included community-dwelling Canadians older than 65 living in Kingston (Ontario) and St-Hyacinthe (Quebec). We performed factor analysis and ecometric analysis to assess the validity of measures of neighbourhood social capital, socioeconomic status, and the built environment and stratified tabular analyses to explore structural confounding. The scales all demonstrated good psychometric and ecometric properties. There was an evidence of the existence of structural confounding in this sample of Canadian older adults as some combinations of strata for the three neighbourhood measures had no population. This limits causal inference in studying relationships between neighbourhood factors and falls and should be taken into account in aetiological aging research.

1. Introduction

Social and environmental features of neighbourhoods may affect the health of residents beyond the contributions of individual-level risk factors (Macintyre & Ellaway, 2003). Older persons are often more vulnerable to the ill effects of their neighbourhoods due to their longer durations of exposure to potential environmental hazards, as well as age-related limitations in life space (Simon, Walsh, Regnier, & Krauss, 1992), and bio-psychological vulnerability (Glass & Balfour, 2003). In younger age groups, individuals are typically exposed to a diversity of contexts such as school, work, recreation/entertainment venues, and community. In contrast, older adults often experience the vast majority of environmental exposures from their residential neighbourhoods (Satariano, 2006; Scheidt & Windley, 2003). A recent systematic review of 33 related aging studies concluded that neighbourhood environmental factors were not strongly influential on older adults' health and functioning (Yen, Michael, & Perdue, 2009); however, very few studies included in the review directly measured neighbourhood features or contexts. Most included studies were cross-sectional with the inherent limitation of reverse causation. They also failed to simultaneously consider both physical and social aspects of neighbourhood safety; factors that may discourage seniors from leaving their homes which would have a direct impact upon physical activity and associated falls.

Social capital is an important feature of neighbourhood environments. Social capital typically is measured through assessment of levels of social cohesion and the quality of interpersonal relationships, and such factors have been shown to be determinants of health (Cagney & Wen, 2008; Kawachi & Berkman, 2014). Compared to persons from younger age groups, older people rely more on the capacity of social connections and community resources to remain productive and independent, and to maintain their health (Cannuscio, Block, & Kawachi, 2003). The positive health impacts of social capital among older people may be over and beyond individual factors, although direct evidence for such relationships is limited. Higher levels of social capital have been

* Correspondence to: Department of Public Health Sciences, Queen's University, Carruthers Hall 2nd Floor, 62 Fifth Field Company Lane, Kingston, ON, Canada K7L 3N6.
E-mail address: 5av14@queensu.ca (A. Vafaei).

http://dx.doi.org/10.1016/j.ssmph.2016.06.003

associated with better general health (Pollack & von dem Knesebeck, 2004), increased quality of life (Nilsson, Rana, & Kabir, 2006), and lower nutritional risks (Moore, Shiell, Haines, Riley, & Collier, 2005); however, findings are somewhat inconsistent (Cagney & Wen, 2008) with occasional intriguing and unexpected results. To illustrate, in a Chicago-based study of older adults who were hospitalised for serious diseases, high levels of social integration was unexpectedly a risk factor for diminished survival (Wen, Cagney, & Christakis, 2005).

Existing social theories explore the potential impacts of social capital on the health of older adults. Common models include social disorganisation theory (Browning, 2002) and collective efficacy models (Sampson, Raudenbush, & Earls, 1997). Although well developed and explored, these two models sometimes overlook the direct influence of physical environments on health, as well as the interaction of physical and social factors as etiological constructs. A modification of the specific ecological model proposed by Lawton (M. Lawton, 1980; M.P. Lawton, 1998) identifies the mechanisms by which '*neighbourhood*' impacts the health status of older adults through incorporation of both social and environmental factors. Originally, Lawton suggested that physical function and behaviours of an older adult are a function of balance between the demand of the environment (referred to as 'environmental press') and the person's ability to deal with that demand (called 'competence'). Small mismatches between these two factors will result in positive outcomes whereas large mismatches will result in negative outcomes and maladaptive behaviours (M.P. Lawton, 1998). For example, in a high risk crime environment, people who are psychologically and physically strong still go out and do their physical activity (a positive behaviour) whereas for people with lower levels of physical strength, the pressure of the environment may hinder positive behaviours (Glass & Balfour, 2003).

We adapted Lawton's model to explain the potential combined impact of social and physical factors as 'environmental press' for our outcome of interest, the occurrence of falls (Fig. 1). Features of social and built environments of a neighbourhood can act as the 'press' for the occurrence of falls, and interact with individual factors to produce different numbers of falls. When individual factors overcome environmental pressures, there will be a low potential for falls. For example, a healthy individual can maintain a good level of balance on a slippery sidewalk and will not fall. When the force of the environment is very high, even in the presence of good physical health falls remain a possibility (top right side of the figure). In contrast, very frail older adults still are prone to falling even in a favourable environment.

Every year, an estimated 30–40% of individuals in North America over the age of 65 fall at least once (Ambrose, Paul, & Hausdorff, 2013). The estimated annual prevalence of falls in community-dwelling Canadian seniors is between 20% and 30%, with a higher prevalence among seniors over 80 years (Canadian Community Health Survey – Healthy Aging (CCHS), 2010). About half of all falls occur outside the home in locations such as streets, parks, or shops (Lord, Sherrington, Menz, & Close, 2007). Falls among seniors result from a complex interaction between individual risk factors and contextual determinants. The role of individual and home level factors on the occurrence of falls is well-documented (Deandrea et al., 2010; Lord et al. 2007); however, conclusions from the few existing studies of the impact of neighbourhood built and social factors such as uneven sidewalks (Gallagher & Scott, 1997; Tinetti, Doucette, & Claus, 1995), social deprivation (Court-Brown, Aitken, Ralston, & McQueen, 2011; Syddall, Evandrou, Dennison, Cooper, & Sayer, 2012), the proportion of welfare recipients (Icks et al., 2009), and level of area wealth (West et al., 2004) are inconsistent.

Methodologically, there exist two issues that are salient to the study of neighbourhood factors on fall-related health outcomes. The first issue is that the reliability and validity of measures of neighbourhood contexts that conceptually might be related to the occurrence of falls have seldom been investigated. The second is the issue of *structural confounding*, that is, the confounding resulting from social sorting mechanisms (Oakes, 2006). When examining social factors at the neighbourhood level, some subjects within certain strata of social variables because of social sorting mechanisms could never be exposed to the aggregate level exposures of interest. For example, in a classic US example, with the objective of studying the effects of racial segregation on preterm birth (Messer, Oakes, & Mason, 2010) very few black women lived in neighbourhoods with low levels of deprivation. That is, the subgroup of black women only experienced one level of exposure (high deprivation). This is referred to as 'off-support' (Ahern, Hubbard, & Galea, 2009) or 'deterministic non-positivity' (Diez Roux, 2004; Oakes, 2004) and when this happens, additional data collection will be of little assistance. Analyses of 'off-support' data in the presence of structural confounding rely on model extrapolations which do not permit examination of the independent influence of social factors, and thus limit meaningful causal inference in etiological analyses (Cole & Hernan, 2008). Despite growing awareness of this methodological issue, it has been quantified only in a few studies (Messer et al., 2010; Vafaei, Pickett, & Alvarado, 2014) and to our knowledge no such study has

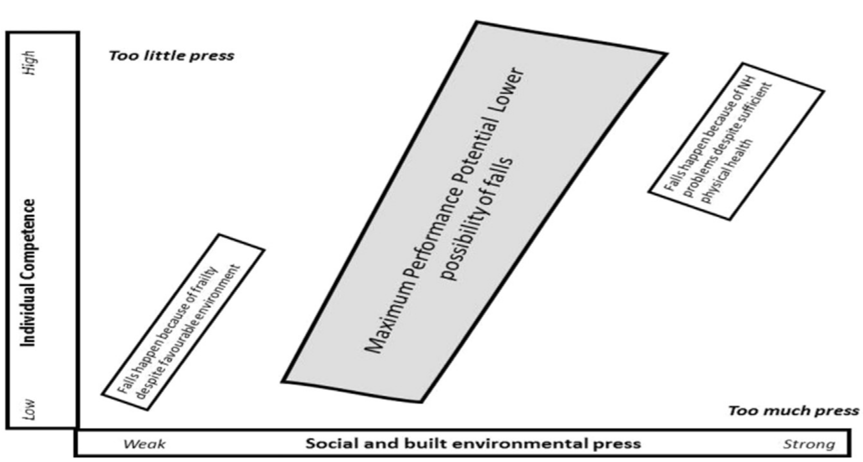

Fig. 1. Lawton's Ecological Model of Aging (adapted for the outcome of fall).

been conducted in social epidemiological studies of neighbourhood determinants of health in older adult populations. The objectives of our current study were therefore: (1) to develop a reliable and valid composite scale for measurement of neighbourhood-level social capital as perceived by older adults and to evaluate its psychometric and ecometric properties; (2) to examine the roles of neighbourhood-level socioeconomic status, social capital, and built environment factors as potential structural confounding variables in studies of the etiology of the occurrence of falls among older people.

2. Methods

2.1. Sampling strategies/data sources

The target population for this study was older adult Canadians living in the community. We obtained data from the baseline questionnaire of the IMIAS (International Mobility in Aging Study) project. IMIAS is a longitudinal study of 1995 non-institutionalized men and women aged between 65 and 74 years from four countries: Canada, Brazil, Colombia, and Albania. Baseline data were collected in 2012 with a first follow-up in 2014 and a final wave of data collection in 2016. Two Canadian cities (Kingston, Ontario; Saint-Hyacinthe, Quebec) were the Canadian research sites of IMIAS. The two chosen Canadian cities were different in terms of SES and built environmental contextual factors and thus provided sufficient variations for analysis of such factors and exploration of their relationships with the occurrence of falls. In concordance with the ethics requirements of Queen's University and the University of Montreal, we recruited the potential participants indirectly by sending invitation letters to them via their family physicians. Those interested in participation contacted the field coordinator to set up an in-home interview time. Approximately 30% of those invited to participate contacted the field coordinator, and of those 95% agreed to participate in the study and were enrolled. The final sample consisted of 799 participants (398 in Kingston; 401 in Saint-Hyacinthe) (Zunzunegui et al., 2015).

2.2. Definition of neighbourhoods

In this study, neighbourhoods were our chosen aggregate units of analysis and were defined by the administrative boundaries established by the city of Kingston (https://www.cityofkingston.ca/) and Ville de Saint-Hyacinthe Hyacinthe (http://www.ville.st-hyacinthe.qc.ca/). There are 45 neighbourhoods in Kingston and 9 neighbourhoods in Saint-Hyacinthe. Participants were assigned to neighbourhoods according to their residential postal codes using geocoding and geographic information system (GIS) technology.

2.3. Measures

2.3.1. Individual-level variables

Personal interviews, anthromorphic measurement, and physical functioning assessments were conducted by trained interviewers in participants' homes. Basic demographic variables of sex, age (in years), years of education, and sufficiency of income were measured by direct questions. Perceived income adequacy has been shown to be a valid indicator of financial capacity in older age, and can provide meaningful information about financial status (Litwin & Sapir, 2009; Zunzunegui et al., 2015). Past occurrence of falls was assessed by a self-reported question: Have you fallen during the past 12 months (yes or no)? Subsequent questions probed the locations of falls as well as the activities that led to their occurrence. Because this study was focused primarily on the specific effects of neighbourhood factors on the occurrence of falls in the neighbourhoods, those who fell at homes (n=93) or during sport activities (n=23) were excluded. For each neighbourhood, an ecological measure of the prevalence of falls was calculated by dividing the number of those who fell over the total number of participants from the neighbourhood (excluding those who fell at home or during sport).

2.3.2. Neighbourhood-level variables

2.3.2.1. Social capital. We followed a social cohesion-based perspective in measurement of social capital (Berkman, Kawachi, and Glymour (2014), page 29) which is the most widely adopted approach used in applied public health studies. As per precedents (Elgar, Trites, & Boyce, 2010; Harpham, Grant, & Rodriguez, 2004; Subramanian, Lochner & Kawachi, 2003; Takagi, Ikeda, & Kawachi, 2012 Vafaei, Pickett, & Alvarado, 2015), participants were asked about the potential availability of resources in their neighbourhood. They provided a rating for four statements using Likert-like responses, with three options: *'1-often'*; *2-sometimes*; and *3- never'*. There was also a 'do not know' option that was treated as 'missing' in data analyses. Statements focused on: (1) whether participants could ask their neighbours for a favour; (2) do neighbours watch out for each other; (3) do participants talk outside with others in the yard or on the street; and (4) if participants felt safe walking around their neighbourhood (Appendix Table 1).

2.3.2.2. Socioeconomic status (SES). Based on previous Canadian studies (Pampalon & Raymond, 2000; Vafaei et al., 2014), education, employment, and average income are valid indicators of neighbourhood SES. Using census-based measures, education at the neighbourhood level was defined according to the proportion of people older than 15 with at least a high school diploma. The employment ratio was the percentage of people (25+years) who were employed. We also obtained the average house income for each neighbourhood.

2.3.2.3. Built environments. Available measures included the amount of green space in each neighbourhood, and items indicating levels of street connectivity. The green space measure was the proportion of land areas covered by fields, parks, and wooden areas. This was measured directly via GIS for each neighbourhood (Huynh, Craig, Janssen, & Pickett, 2013). We also used GIS to measure three indicators of street connectivity (Mecredy, Janssen, & Pickett, 2012; Vafaei et al., 2014): (1) intersection density (number of intersections in each neighbourhood divided by total area); (2) average block length (total length of roads within the neighbourhood divided by number of real nodes); and (3) connected node ratio (number of real nodes divided by all types of nodes such as intersections, cul-de-sacs, and dead-ends).

2.4. Analysis

2.4.1. Descriptive

Distributions of basic individual demographic and neighbourhood characteristics across the two study sites were estimated and compared using *t*-test and χ^2 statistics.

2.4.2. Evaluation of psychometric and ecometric properties of scales

We performed exploratory factor analyses to assess the psychometric properties of composite scales describing neighbourhood social capital, SES, and built environments and hence their factorial validity. We employed two diagnostic measures of the Kaiser-Meyer-Olkin (for estimating of sampling adequacy) and the Bartlett's test of sphericity for the assessment of the robustness of the exploratory factor analysis. The reliability of the scales was assessed by calculating Cronbach alpha levels (Streiner, Norman, & Cairney, 2014). Since the response options for social capital questions were compiled in Likert-like formats, in the patten matrix polychoric correlation coefficients (instead of Pearson) were used as suggested by Wuench (Wuensch, 2012). Data for at least one item of social capital were missing for 121 (15.2%) of particpants. We therefore employed a multiple imputaion approach using SAS MI and MIANALYZE procedures (SAS Guide, 2014). Frequency distributions of answers to the four social capital items are presented in Appendix Table 1.

In contrast to the standard and objective measures of SES and built environment available to us, items measuring social capital were self-reported and subjective. Thus, we further evaluated the ecometric properties of social capital items using three-level models (Mujahid, Diez Roux, Morenoff, & Raghunathan, 2007; Raudenbush, 2003; Raudenbush & Sampson, 1999). Level 1 relates to item responses within individuals, Level 2 relates to persons resident in neighbourhoods, and level 3 represents the neighbourhoods themselves. This model estimates variance components corresponding to each level: within-individuals, within-neighbourhoods, and between-neighbourhoods. Using these estimates, we calculated intra-class (neighbourhood) correlation coefficients (ICC) that quantified the amount of variability in the social capital items attributable to between-neighbourhood differences. Higher levels of ICC indicate greater agreement in responses to items between respondents living in the same neighbourhood; i.e., larger differences between those from different neighbourhoods.

2.4.3. Structural confounding

Stratified tabulations (Messer et al., 2010; Vafaei et al., 2014) were the main analytic tool for exploring structural confounding. Total numbers of participants and numbers of falls occurring in neighbourhoods in each combined strata of community SES, built environment, and social capital were estimated. According to theories of structural confounding (Ahern et al., 2009; Diez Roux, 2004; Glass & Balfour, 2003; Messer et al., 2010; J.P. Oakes, 2006; J. M. Oakes, 2004), non-existence or low numbers of individuals in *extreme cells* is suggestive of strong social stratification and possible structural confounding. We defined extreme cells as combinations of 'low' social capital (lowest tertile) but 'good' built environment and SES (highest tertile), or a combination of 'poor' SES and 'poor' built environment but 'good' social capital. There is no established *low number* to represent the existence of structural confounding. A standard 'low number' varies based on the context of the study and sample size. For example, Messer et al. (2010) in their study of neighbourhoods of two counties in North Carolina with a sample size of 31,715 considered fewer than 30 in each cell as evidence for structural confounding. However, as per established precedents (Vafaei et al., 2014) we did not set any number to represent a 'low number' *a priori*.

All analyses were conducted using SAS v9.3 (SAS Institute Inc., Cary, North Carolina) and STATA v13. 1 (StataCorp, College Station, Texas).

3. Results

3.1. Description of the sample

Out of the original sample size of 799 individuals, the frequency of falls in all locations were 248 (31%). Consistent with literature (Lord et al., 2007), about half of the falls (n=132; 53%) occurred outside the home and during non-sport activities. There was no difference in age and sex distributions across the two cities; however, compared to Saint-Hyacinthe older adults living in Kingston were significantly better educated (76% with higher education vs. 39%) and more frequently reported having sufficient income (Table 1). At the neighbourhood level, despite equal proportions of employment, average income levels in Kingston neighbourhoods were much higher than Saint-Hyacinthe ($74,000 vs. $43,000). Older adults living in Kingston reported significantly higher levels of social capital. The most notable difference in built environmental characteristics was for green space: the proportion of green space was three times higher in Kingston vs. Saint-Hyacinthe neighbourhoods.

Table 1
Distribution of individual and neighbourhood level variables in the total sample and by research sites.

	Total (n=799)	Kingston (n=398)	Saint-Hyacinthe (n=401)	*P* value*
Individual-level variables				
Age (mean, SD)	68.8 (2.7)	69.1 (2.7)	68.6 (2.7)	0.011
Gender				
Male	375 (46.9)	184 (46.2)	191 (47.6)	0.69
Female	424 (53.1)	214 (53.8)	210 (52.4)	
Education				
> 12 years	461 (57.7)	304 (76.4)	157 (39.2)	< 0.0001
12 years	123 (15.4)	48 (12.1)	75 (18.7)	
Less than 12 years	215 (26.9)	46 (11.5)	169 (42.1)	
Sufficiency of income				
Sufficient	421 (52.7)	243 (61.0)	178 (44.4)	< 0.0001
To some extend	327 (40.9)	134 (33.7)	193 (48.1)	
Not sufficient	51 (6.4)	21 (5.3)	30 (7.5)	
Location of fall[a]				
No Fall	549 (69.1)	240 (60.8)	309 (77.3)	< 0.0001
Neighbourhood	132 (16.7)	87 (22.1)	45 (11.3)	
Home	93 (11.7)	51 (13.2)	39 (10.2)	
Sport	23 (2.9)	16 (4.1)	7 (1.8)	
Neighbourhood level Characteristics				
Number of neighbourhoods	54	45	9	–
Neighbourhood social capital (mean, SD)	2.11 (0.34)	2.25 (0.24)	1.65 (0.11)	< 0.0001
Socioeconomic status characteristics				
Average income $ (mean, SD)	68,044 (29,144)	74,112 (27,890)	43,098 (20,176)	0.003
Employed (mean proportion, SD)	0.95 (0.03)	0.95 (0.03)	0.95 (0.04)	0.22
High school diploma and higher (mean proportion, SD)	0.92 (0.09)	0.95 (0.04)	0.77 (0.11)	0.001
SES Composite Index	5.93 (2.17)	6.38 (2.11)	3.87 (0.83)	< 0.0001
Built environment characteristics				
Intersection density (mean, SD)	127,488 (377,811)	147,607 (419,301)	44,777 (46,807)	0.15
Average block length (mean, SD)	360 (297)	388 (325)	246 (58)	0.017
Connected nodes ratio (mean, SD)	0.81 (0.9)	0.79 (0.09)	0.87 (0.03)	< 0.0001
Green space (mean, SD)	0.14 (0.12)	0.16 (0.012)	0.05 (0.02)	< 0.0001
Built Environment composite index (mean, SD)	8.02 (0.94)	7.92 (0.95)	8.5 (0.76)	0.11

* From Chi square and t-test statistics where appropriate.
[a] Fall data for 5 participants were missing (4 in Kingston; 1 in Saint-Hyacinthe).

3.2. Findings from the factor analysis

Initial factorial validity tests via exploratory factor analysis indicated high and similar loadings for all included items of SES, built environment, and social capital (Table 2). The only exception was for the social capital item asking about neighbourhood 'safety', which showed a low loading of 0.11 and hence was excluded

Table 2
Factor analysis results.

Social capital		SES		Built environment	
Item	**Loading**	**Item**	**Loading**	**Item**	**Loading**
How often in your neighbourhood, neighbours		Average Household Income	0.71	Intersection density	0.89
…watch out for each other, such as calling for help if they see a problem?	0.78	Employment rate	0.76	Average block	0.96
…take care of each other, such as doing yard work or watching children?	0.76	Percentage with higher education	0.73	Connected node ratio	−0.68
…. talk outside in the yard or on the street?	0.62			Green space percentage	0.56
Do you feel it is unsafe to walk around your neighbourhood?	−0.11				
Cronbach's Alpha					
0.76[a]		0.77		0.80	
Eigenvalue					
1.59		1.44		2.49	
***P* value for Barlett's test of sphericity**					
< 0.0001		< 0.0001		< 0.0001	
Overall KMO measure of sampling adequacy					
0.68		0.70		0.51	

[a] Not including the safety item.

from further analysis. These scales were also reliable as shown by high internal consistency (Cronbach alpha for all > 0.75).

3.3. Ecometric properties of the social capital scale

The calculated ICC for the neighbourhood social capital items was 0.09 (95% CI: 3.7–20.9%). It suggests that 9% of the variability in the observed differences in answers to social capital items was solely due to between-neighbourhood differences.

3.4. Construction of composite scales of neighbourhood-level variables

Excluding the safety item because of its low loading, the composite scale for social capital was defined as the sum scores of the remaining three high-loading items, combined with equal weights (Table 2). These items represented the neighbourhoods *'cohesion'*, consistent with our theoretical framework (Berkman et al., 2014). Averages of individual scores were aggregated and neighbourhoods then were divided into low, medium, and high tertiles based upon the distribution of these scores (Table 3).

To construct a composite scale for neighbourhood SES, each of the 54 neighbourhoods was first ordered according to each of the three SES indicators. Then, the neighbourhoods were scored from one to three based on the tertiles of each indicator of SES (low=1, medium=2, high=3). An additive composite scale for the SES was constructed including the tertile-based scores of the three indicators with a possible range from 3 to 9. We employed similar methodologies for construction of the built environment composite scale. There are no meaningful cut-off points for composite scales of social capital, SES, and built environment and we categorized them into tertiles for analytic purposes.

3.5. Structural confounding assessment

We constructed a 3 by 3 table according to the tertiles of the three neighbourhood factors distributions (Table 4). Results suggest a possibility of social sorting mechanism for neighbourhood

Table 3
Tertiles of distributions of neighbourhood level variables.

	Range of Tertile 1 (low)	Range of Tertile 2 (medium)	Range of Tertile 3 (high)
Neighbourhood social capital	1.55–1.941	2–2.273	2.288–2.727
Socioeconomic status characteristics			
Average neighbourhood income $	28,344–53,807	53,951–74,983	75,073–130,227
Percentage employed (mean proportion, SD)	84–93.9	94.2–96.7	96.8–100
Percentage with high school diploma and higher	59–92	93–96.9	97–100
Built Environment characteristics			
Mean of neighbourhood intersection density	6278–24,836	25,727–53,966	63,272–2,532,220
Mean of neighbourhood average block length	310.2–2091	267.6–309.2	141.8–260.2
Mean of neighbourhood connected nodes ratio	0.565–0.788	0.794–0.855	0.857–1
Percentage of neighbourhood green space area	1.1–7.5	7.8–14.7	15.8–51.1

Table 4
Number of participants and injuries in each combination of social capital, SES, and built environment.

SES	High social capital Built environment			Medium social capital Built environment			Low social capital Built environment		
	Good sample size Number of falls	**Average sample size Number of falls**	**Bad sample size Number of falls**	**Good sample size Number of falls**	**Average sample size Number of falls**	**Bad sample size Number of falls**	**Good sample size Number of falls**	**Average sample size Number of falls**	**Bad sample size Number of falls**
High	0(0)	39(11)	26(5)	13(1)	14(2)	13(3)	0(0)	0(0)	0(0)
Medium	54(14)	43(13)	17(5)	34(8)	31(5)	57(10)	0(0)	126(10)	0(0)
Low	26(3)	45(12)	0(0)	52(5)	0(0)	13(2)	11(2)	172(21)	0(0)

levels of social capital, SES, and built environment in this sample of Canadian older adults. There were no population and fall cases in some combination of strata of our three neighbourhood measures and a number of *extreme cells* (defined above in methods) remained with no or very low numbers of observations.

4. Discussion

The first objective of this study was to validate the three neighbourhood level variables of SES, built environment, and social capital. We defined social capital according to the social cohesion perspective (Kawachi & Berkman, 2014) and constructed a composite scale based on the standard scale development methodologies (Streiner et al., 2014). First, in order to provide appropriate content validity (Harpham, 2008), the main aspects of social cohesion were measured by three direct questions. Our initial validation involved exploratory factor analysis and demonstrated that all items loaded onto a single underlying factor with relatively high loadings, which demonstrated a good factorial validity. The calculated Cronbach's alpha of 0.76 for the three-item scale demonstrated strong internal consistency (larger than 0.70) (Streiner et al., 2014) and being smaller than 0.90, was also an indication of no item redundancy (Boyle, 1991).

We took one further step for the validation of the social capital measure by assessing its ecometric properties (Raudenbush, 2003) to show how much variations in the responses to social capital items are attributable to between-neighbourhood differences. The main purpose was to assess how appropriate this composite scale is as a neighbourhood-level measure and for measurement of neighbourhood attributes. The calculated ICC of 9% was relatively low and suggests that most of these variations are due to within-neighbourhood (individual) differences; however, there is no established standard to guide what constitutes a *high* ICC for ecometric analyses and very few studies were available for comparison. A study conducted in a sample from southern Brazil (Hofelmann, Diez-Roux, Antunes, & Peres, 2013) reported ICC measures ranging in value from 0.27 to 0.82 for various neighbourhood measurement scales such as perception of physical and social disorder. One explanation for our low ICC might be that we only had three items whereas in that study each scale included 8 items. Another existing study reported results that were also variable. Using data on neighbourhood conditions collected from a telephone survey of 5988 residents at three US study sites, Mujahid et al. (2007) employed a similar methodology for assessing the ecometric properties of seven different neighbourhood condition scales. They reported ICC measures in a range from 0.05 for the 5 items measuring ‘activities with neighbours’ to 0.51 for the 6 for measurement items of ‘aesthetic quality’.

In concordance to other Canadian studies (Pampalon & Raymond, 2000; Vafaei et al., 2014), the two other neighbourhood-level variables of SES and built environment also showed high internal consistency, as demonstrated by Cronbach alpha measures of 0.77 and 0.80, as well as good psychometric properties. Conceptually, green space is not necessarily related to the other three street connectivity indicators, and one can argue against including all in a single scale; however, the relative high loading (0.56) of ‘green space’ onto a common factor supports our decision on constructing a single scale for built environment measures. To provide sufficient variations in the neighbourhood-level SES and built environmental factors that was needed for valid data analyses, we made use of data obtained from two Canadian cities that showed different ranges of such factors.

To address the second objective we chose to study potential structural confounding effects of three neighbourhood-level factors of SES, built environment, and social capital. These factors have been shown to be potential risk factors for the occurrence of falls in older adults (Cole & Hernan, 2008; Gallagher & Scott, 1997; Syddall et al., 2012; Tinetti et al., 1995; West et al., 2004). Cross-tabular analyses suggested the presence of structural confounding, and it appears that there is a social sorting mechanism in effect among this sample of community-dwelling Canadian older adults. Neighbourhoods with low levels of social capital also showed low levels of SES, suggestive of a clustering of multiple social disadvantages where economically poor communities also suffer from low levels of social capital. Polarisation and social division in large cities has been documented in various reports (Hulchanski, 2009; Simard, 2011) and we also showed the possibility of this issue in medium-sized Canadian cities.

Our measures of the built environment also showed a possible structural confounding effect but in a smaller magnitude compared to SES; there were few neighbourhoods with poor built environments that simultaneously had higher levels of SES and social capital.

Due to the existence of structural confounding, some empty cells were observed in our stratified table. Since these empty cells represent a deterministic non-positivity they cannot be filled by more data collection, as opposed to random non-positivity (Westreich & Cole, 2010). Our findings are consistent with those of a study conducted by Messer et al. (2010) in the socially stratified and racially segregated context of neighbourhoods of North Carolina where no white woman lived in the most deprived areas and no black woman lived in privileged neighbourhoods; however, this contrasts with our previous study of Canadian adolescents. Including the same three community level variables of SES, built environment, and social capital and utilising a similar methodology, there was no sign of structural confounding in a nationally representative sample of over 26,000 Canadian students aged 11–15 years (Vafaiei et al., 2014). The discrepancy between these child findings and the current study of older adults may relate to the fact that older adult communities are more directly influenced by social factors, therefore living in poor neighbourhoods also negatively impacts levels of social interactions. Using neighbourhoods defined by administrative boundaries versus the school as used in the adolescents study is another potential reason, since compared to an educational context, place of residence may impose a more direct social stratification. Finally, existence of structural confounding precludes causal inference in regression analyses due to scant data and should be taken into account in etiological aging research.

Strengths of our study included the fact that we followed the well documented ecological model of Lawton to conceptualise the issue of interest and chose the three specific neighbourhood-level variables based on this model. We also employed the most advanced analytic strategy of ecometric analysis for validation of the social capital items. Our study also fills a gap in the social epidemiology literature; quantitative exploration of structural confounding has been rarely performed and to our best knowledge never in older adults. Use of a study population that exclusively focused on older adults was therefore another strength of this study.

Our study also has some limitations. Our participants were not a representative sample of the Canadian population of older adults and the results are therefore not generalisable to that population. The Kingston sample was dominated by very highly educated individuals who might interpret social capital questions differently, therefore bias attributable to this selection issue is likely. The direction of this bias remains to be explored in future studies. It is also worth noting that in choosing aggregate level data we were limited to the predefined administrative boundaries provided by Statistics Canada for the SES variables, and municipal boundaries provided by City of Kingston and Ville de Saint-Hyacinthe for other variables. Despite significant differences in individual and neighbourhood levels of SES across the two study sites (Table 1), indicators of physical and mental health, mobility, grip strength as well as BMI, smoking status, and levels of most laboratory indicators showed similar distributions in Kingston and Saint-Hyacinthe (Appendix Table 2). This suggests that the two sample populations were sufficiently homogeneous to be appropriately combinable.

Same-source (Diez-Roux, 2007) or mono-method bias is also a potential threat to the validity of this study. This bias happens when self-reported data are used for both the outcome and the neighbourhood characteristics, and generates a spurious association because of the correlation between measurement errors in both exposure and outcome or because the outcome affects the perception of the neighbourhood attribute. This is not a major methodological concern in our circumstances. We aggregated our measure to neighbourhoods and there are some studies that conclude that aggregation of self-perceived measures to narrow area units reduces the possibility of this type of bias (de Jong et al., 2011). Also, this bias is more applicable to outcomes measured purely by individuals' subjective perception such as depression and level of physical activity. In older adults, a fall is an occurrence that is unlikely to be forgotten or over-reported because of other factors.

Finally, there is a possibility that, for various reasons, older adults move to low social capital or low SES environments and the observed sorting is a function of older adults' change of residence, and not a characteristic of residential areas per se. However, 80% of the participants reported that they had lived in their current residence for more than five years, and only seven percent had moved to their present neighbourhood in the prior year.

5. Conclusion

In conclusion, in this study of Canadian older adults we explored two major methodological issues of social epidemiological and neighbourhood research: the validity of composite neighbourhood level measures and the possibility of structural confounding. We showed that our neighbourhood-level composite measures are valid and also there is an evidence of existence of structural confounding in Canadian older adults. In etiological analyses that rely on such data from older adults, there is a need to take into account such limitations when making causal inferences. Further research is needed to examine the possibility of structural confounding in different settings and age groups, and with a variety of health outcomes.

Appendix

See appendix Table A1 and A2.

Table A2
Comparison of the health status of older adults across the two study sites.

	Kingston (n=398)	Saint-Hyacinthe (n=401)	*P* value*
Health status indicator			
Number of chronic diseases			
0–1	170 (43)	191 (48)	0.18
= > 2	226 (57)	210 (52)	
Depression			
Yes	41 (10)	44 (11)	0.77
No	355 (90)	356 (89)	
Difficulty climbing stairs of walking 400 m			
Yes	77 (19)	88 (22)	0.38
No	318 (81)	312 (78)	
BMI			
Underweight (< 18.5)	4 (1)	7 (2)	0.55
Normal (18.5–24.9)	121 (30.5)	109 (27)	
Overweight (25–29.9)	157 (39.5)	156 (39)	
Obese (> =30)	116 (29)	129 (32)	
Smoking			
Regular	19 (5)	26 (6.5)	0.11
Occasional	5 (1)	8 (2)	
Ex-smokers	197 (50)	222 (55.5)	
Never smoked	175 (44)	145 (36)	
Grip strength			
Mean (SD)	31.6 (11.9)	32.9 (11.2)	0.10
Laboratory indicators			
Total cholesterol levels			
Normal (< 200 mg/dl)	190 (58)	201 (58)	0.95
Borderline (200–239 mg/dl)	91 (28)	99 (29)	
High (> =200 mg/dl)	44 (14)	44 (13)	
Triglyceride levels			
Optimal (< 150 mg/dl)	262 (81)	249 (72.5)	0.01
Borderline (150–199 mg/dl)	32 (10)	56 (16.5)	
High (200–499 mg/dl)	28 (8)	39 (11)	
Very high (> =500 mg/dl)	3 (1)	0 (0)	
C-reactive protein			
Low (< 1)	110 (34)	93 (31)	0.13
Intermediate (1– < =3)	122 (38)	125 (41)	
High (3–10)	64 (19)	71 (23)	
Very high (> 10)	29 (9)	15 (5)	
Percentage HbA1c			
Mean (SD)	5.5 (0.73)	5.9 (0.68)	0.25

* From Chi square and t-test statistics where appropriate.

Table A1
Distributions of answers to social capital items.

	Often	Sometimes	Never	Do not know	No answer	Total missing	Percentage missing
How often in your neighbourhood, neighbours							
…watch out for each other, such as calling for help if they see a problem?	317	306	110	66	0	66	8.3%
…take care of each other, such as doing yard work or watching children?	259	258	191	90	1	91	11.4%
…. talk outside in the yard or on the street?	388	297	102	12	0	12	1.5%
Do you feel it is unsafe to walk around your neighbourhood?	22	65	700	12	0	12	1.5%

References

Ahern, J., Hubbard, A., & Galea, S. (2009). Estimating the effects of potential public health interventions on population disease burden: a step-by-step illustration of causal inference methods. *American Journal of Epidemiology*, *169*, 1140–1147.

Ambrose, A. F., Paul, G., & Hausdorff, J. M. (2013). Risk factors for falls among older adults: a review of the literature. *Maturitas*, *75*, 51–61.

Berkman, L. F., Kawachi, I., & Glymour, M. (2014). *Social epidemiology*. Oxford University Press, pp. 290–319.

Boyle, G. J. (1991). Does item homogeneity indicate internal consistency or item redundancy in psychometric scales? *Personality and Individual Differences*, *12*, 291–294.

Browning, C. R. (2002). The span of collective efficacy: extending social disorganization theory to partner violence.. *Journal of Marriage and Family*, *64*, 833–850.

Cagney, K. A., & Wen, M. (2008). Social capital and aging-related outcomes In: I. Kawachi, S. V. Subramanian, & D. Kim (Eds.), *Social capital and health* (First ed.). Springer, pp. 239–258.

Canadian community health survey – healthy aging (CCHS) (2010). Report no.: 5146. Statistics Canada, Ottawa.

Cannuscio, C., Block, J., & Kawachi, I. (2003). Social capital and successful aging: the role of senior housing. *Annals of Internal Medicine*, *139*, 395–399.

Cole, S. R., & Hernan, M. A. (2008). Constructing inverse probability weights for marginal structural models. *American Journal of Epidemiology*, *168*, 656–664.

Court-Brown, C. M., Aitken, S. A., Ralston, S. H., & McQueen, M. M. (2011). The relationship of fall-related fractures to social deprivation. *Osteoporosis International*, *22*, 1211–1218.

de Jong, K., Albin, M., Skärbäck, E., Grahn, P., Wadbro, J., Merlo, J., & Björk, J. (2011). Area-aggregated assessments of perceived environmental attributes may overcome single-source bias in studies of green environments and health: results from a cross-sectional survey in southern Sweden. *Environmental Health*, *10*, 4.

Deandrea, S., Lucenteforte, E., Bravi, F., Foschi, R., La Vecchia, C., & Negri, E. (2010). Risk factors for falls in community-dwelling older people: a systematic review and meta-analysis. *Epidemiology*, *21*, 658–668.

Diez Roux, A. V. (2004). Estimating neighborhood health effects: the challenges of causal inference in a complex world. *Social Science Medicine*, *58*, 1953–1960 [1982].

Diez-Roux, A. V. (2007). Neighborhoods and health: where are we and were do we go from here?: Environnement résidentiel et santé: état de la question et perspectives pour le futur. *Revue d'epidemiologie et Délelőtt Sante Publique*, *55* (1), 13–21.

Elgar, F. J., Trites, S. J., & Boyce, W. (2010). Social capital reduces socio-economic differences in child health: evidence from the canadian health behaviour in school-aged children study. *Canadian Journal of Public Health-Revue Canadienne De Sante Publique*, *101*, S23–S27.

Gallagher, E. M., & Scott, V. J. (1997). The STEPS Project: participatory action research to reduce falls in public places among seniors and persons with disabilities. *Canadian Journal of Public Health-Revue Canadienne De Sante Publique*, *88*, 129–133.

Glass, T. A., & Balfour, J. L. (2003). Neighborhoods, aging, and functional limitations In: I. Kawachi, & L. F. Berkman (Eds.), *Neighborhoods and health* (1st ed.). USA, New York: Oxford University Press, pp. 303–334.

Harpham, T. (2008). The measurement of community social capital through surveys In: I. Kawachi, S. V. Subramanian, & D. Kim (Eds.), *Social Capital and Health* (pp. 51–62). Springer.

Harpham, T., Grant, E., & Rodriguez, C. (2004). Mental health and social capital in Cali, Colombia. *Social Science Medicine*, *58*, 2267–2277 [1982].

Hofelmann, D. A., Diez-Roux, A. V., Antunes, J. L., & Peres, M. A. (2013). Perceived neighborhood problems: multilevel analysis to evaluate psychometric properties in a Southern adult Brazilian population. *BMC Public Health*, *13*, 1471–2458.

Hulchanski, J. D. (2009). *Neighbourhood trends in divided cities: income inequality, social polarization & spatial segregation. A selected bibliography*.

Huynh, Q., Craig, W., Janssen, I., & Pickett, W. (2013). Exposure to public natural space as a protective factor for emotional well-being among young people in Canada. *BMC Public Health*, *13*, 1471–2458.

Icks, A., Haastert, B., Wildner, M., Becker, C., Rapp, K., Dragano, N., … Rosenbauer, J. (2009). Hip fractures and area level socioeconomic conditions: a population-based study. *BMC Public Health*, *9*, 1471–2458.

Kawachi, I., & Berkman, L. F. (2014). Social capital, social cohesion, and health In: L. F. Berkman, I. Kawachi, & M. Glymour (Eds.), *Social epidemiology* (Second ed.). New York: Oxford University Press, pp. 290–319.

Lawton, M. (1980). Environment and aging In: V. Bengison (Ed.), *Brooks/cole series in social gerontology*. Monterey, California: Brooks/Cole.

Lawton, M. P. (1998). Environment and aging: theory revisited In: R. J. Scheidt, & P. G. Windley (Eds.), *Environment and aging theory: a focus on housing*. London: Greenwood Press.

Litwin, H., & Sapir, E. V. (2009). Perceived income adequacy among older adults in 12 countries: findings from the survey of health, ageing, and retirement in Europe. *The Gerontologist*, *49*(3), 397–406.

Lord, S. R., Sherrington, C., Menz, H. B., & Close, J. C. T. (2007). *Falls in older people: risk factors and strategies for prevention*. Cambridge University Press, pp. 2–25.

Macintyre, S., & Ellaway, A. (2003). Neighborhoods and health: an overview In: I. Kawachi, & L. F. Berkman (Eds.), *Neighborhoods and health* (1st ed.). USA, New York: Oxford University Press, pp. 20–42.

Mecredy, G., Janssen, I., & Pickett, W. (2012). Neighbourhood street connectivity and injury in youth: a national study of built environments in Canada. *Injury Prevention*, *18*, 81–87.

Messer, L. C., Oakes, J. M., & Mason, S. (2010). Effects of socioeconomic and racial residential segregation on preterm birth: a cautionary tale of structural confounding. *American Journal of Epidemiology*, *171*, 664–673.

Moore, S., Shiell, A., Haines, V., Riley, T., & Collier, C. (2005). Contextualizing and assessing the social capital of seniors in congregate housing residences: study design and methods. *BMC Public Health*, *5*, 38.

Mujahid, M. S., Diez Roux, A. V., Morenoff, J. D., & Raghunathan, T. (2007). Assessing the measurement properties of neighborhood scales: from psychometrics to ecometrics. *American Journal of Epidemiology*, *165*, 858–867.

Nilsson, J., Rana, A. K., & Kabir, Z. N. (2006). Social capital and quality of life in old age: results from a cross-sectional study in rural Bangladesh. *Journal of Aging and Health*, *18*, 419–434.

Oakes, J., J. P. (2006). Propensity score matching for social epidemiology In: K. J. Oakes J (Ed.), *Methods in social epidemiology* (First ed.). San Francisco, CA: Wiley, pp. 370–392.

Oakes, J. M. (2004). The (mis)estimation of neighborhood effects: causal inference for a practicable social epidemiology. *Social Science Medicine*, *58*, 1929–1952.

Pampalon, R., & Raymond, G. (2000). A deprivation index for health and welfare planning in Quebec. *Chronic Diseases in Canada*, *21*, 104–113.

Pollack, C. E., & von dem Knesebeck, O. (2004). Social capital and health among the aged: comparisons between the United States and Germany. *Health & Place*, *10*, 383–391.

Raudenbush, S. W. (2003). The quantitative assessment of neighborhood social environments In: I. Kawachi, & L. F. Berkman (Eds.), *Neighborhoods and health* (1st ed.). USA, New York: Oxford University Press, pp. 112–131.

Raudenbush, S. W., & Sampson, R. J. (1999). Ecometrics: toward a science of assessing ecological settings, with application to the systematic social observation of neighborhoods. *Sociological Methodology*, *29*, 1–41.

Sampson, R. J., Raudenbush, S. W., & Earls, F. (1997). Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science*, *277*, 918–924.

SAS Guide (2014). The MIANALYZE procedure.

Satariano, W. (2006). *Epidemiology of aging: an ecological approach*. Jones and Bartlett Publishers, pp. 39–84.

Scheidt, R. J., & Windley, P. G. (2003). *Physical environments and aging: critical contributions of m. powell lawton to theory and practice*. Haworth Press Incorporated, pp. 117–134.

Simard, J. A. (2011). Social social inequalities in health in Montréal progress to date. Direction de santé publique Agence de la santé et des services sociaux de Montréal. Montreal.

Simon, S. L., Walsh, D. A., Regnier, V. A., & Krauss, I. K. (1992). Spatial cognition and neighborhood use: the relationship in older adults. *Psychology and Aging*, *7*, 389–394.

Streiner, D. L., Norman, G. R., & Cairney, J. (2014). *Health measurement scales: a practical guide to their development and use*. Oxford University Press pp. 85–89.

Subramanian, S. V., Lochner, K. A., & Kawachi, I. (2003). Neighborhood differences in social capital: a compositional artifact or a contextual construct? *Health & Place*, *9*, 33–44.

Syddall, H. E., Evandrou, M., Dennison, E. M., Cooper, C., & Sayer, A. A. (2012). Social inequalities in osteoporosis and fracture among community dwelling older men and women: findings from the Hertfordshire Cohort Study. *Archives of osteoporosis*, *7*, 37–48.

Takagi, D., Ikeda, Ki, & Kawachi, I. (2012). Neighborhood social capital and crime victimization: Comparison of spatial regression analysis and hierarchical regression analysis. *Social Science Medicine*, *75*, 1895–1902.

Tinetti, M. E., Doucette, J. T., & Claus, E. B. (1995). The contribution of predisposing and situational risk factors to serious fall injuries. *Journal of the American Geriatrics Society*, *43*, 1207–1213.

Vafaei, A., Pickett, W., & Alvarado, B. E. (2014). Neighbourhood environment factors and the occurrence of injuries in Canadian adolescents: a validation study and exploration of structural confounding. *BMJ Opening*, *4*.

Vafaei, A., Pickett, W., & Alvarado, B.E. (2015). Relationships between community social capital and injury in Canadian adolescents: a multilevel analysis. *Injury Prevention*.

Wen, M., Cagney, K. A., & Christakis, N. A. (2005). Effect of specific aspects of community social environment on the mortality of individuals diagnosed with serious illness. *Social science medicine*, *61*, 1119–1134 [1982].

West, J., Hippisley-Cox, J., Coupland, C. A., Price, G. M., Groom, L. M., Kendrick, D., & Webber, E. (2004). Do rates of hospital admission for falls and hip fracture in elderly people vary by socio-economic status? *Public Health*, *118*, 576–581.

Westreich, D. & Cole, S. R. (2010). Invited commentary: positivity in practice. *American Journal of Epidemiology*.

Wuensch, K. (2012). *Factor analysis with data from dichotomous or likert-type items*.

Yen, I. H., Michael, Y. L., & Perdue, L. (2009). Neighborhood environment in studies of health of older adults: a systematic review. *American Journal of Preventive Medicine*, *37*, 455–463.

Zunzunegui, M. V., Alvarado, B. E., Guerra, R., Gómez, J. F., Ylli, A., Guralnik, J. M., & Group, I. R. (2015). The mobility gap between older men and women: the embodiment of gender. *Archives of Gerontology and Geriatrics*, *61*, 140–148.