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The influence of walkability on broader mobility for Canadian middle aged and older adults: An examination of Walk Score™ and the Mobility Over Varied Environments Scale (MOVES)

Jana A. Hirsch [a,b,*], Meghan Winters [b,c], Philippa J. Clarke [d,e], Nathalie Ste-Marie [f], Heather A. McKay [b,g,h]

[a] Department of Epidemiology and Biostatistics, University of South Carolina, USA
[b] Centre for Hip Health and Mobility, University of British Columbia, Canada
[c] Faculty of Health Sciences, Simon Fraser University, Canada
[d] Department of Epidemiology, University of Michigan, USA
[e] Institute for Social Research, University of Michigan, USA
[f] Simon Fraser University, Canada
[g] Department of Family Practice, University of British Columbia, Canada
[h] Department of Orthopaedics, University of British Columbia, Canada

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ABSTRACT

Neighborhood built environments may play an important role in shaping mobility and subsequent health outcomes. However, little work includes broader mobility considerations such as cognitive ability to be mobile, social connections with community, or transportation choices. We used a population-based sample of Canadian middle aged and older adults (aged 45 and older) from the Canadian Community Health Survey-Healthy Aging (CCHS-HA, 2008–2009) to create a holistic mobility measure: Mobility over Varied Environments Scale (MOVES). Data from CCHS-HA respondents from British Columbia with MOVES were linked with Street Smart Walk Score™ data by postal code ($n = 2046$). Mean MOVES was estimated across sociodemographic and health characteristics. Linear regression, adjusted for relevant covariates, was used to estimate the association between Street Smart Walk Score™ and the MOVES. The mean MOVES was 30.67 (95% confidence interval (CI) 30.36, 30.99), 5th percentile 23.27 (CI 22.16, 24.38) and 95th percentile was 36.93 (CI 35.98, 37.87). MOVES was higher for those who were younger, married, higher socioeconomic status, and had better health. In unadjusted models, for every 10 point increase in Street Smart Walk Score™, MOVES increased 4.84 points (CI 4.52, 5.15). However, results attenuated after adjustment for sociodemographic covariates: each 10 point increase in Street Smart Walk Score™ was associated with a 0.10 (CI 0.00, 0.20) point increase in MOVES. The modest but important link we observed between walkability and mobility highlights the implication of neighborhood design on the health of middle aged and older adults.

1. Introduction

In North America the population 65 years and older is expected to rise from 12.8% in 2008 to 20.8% in 2040 (Kinsella and Wan, 2009). This underscores the imperative to develop strategies facilitating later life health and mobility. Mobility has been defined as the ability to move oneself (either independently or using assistive devices or transportation) within environments that expand from one's home to the neighborhood and to regions beyond (Webber et al., 2010). By this definition mobility is multi-dimensional and fully immersed in social and community engagement, transportation, and cognition (Webber et al., 2010; World Health Organisation, 2014). Mobility is also intimately linked to health status and quality of life (Groessl et al., 2007; Metz, 2000; Yeom et al., 2008), thus, consequences of restricted physical functioning and social participation are dire. Specifically, impaired mobility precedes physical disability (Hirvensalo et al., 2000) and is associated with falling, loss of independence or social engagement (Rosso et al., 2013; Gardner, 2014), institutionalization, and death (Hirvensalo et al., 2000; Rubenstein et al., 2001; von Bonsdorff et al., 2006; Boyle et al., 2010; Cooper et al., 2010). Thus, focusing on predictors across

* Corresponding author at: Carolina Population Center, CB#8120, Chapel Hill, NC, USA.
E-mail address: hijana@live.unc.edu (J.A. Hirsch).

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multiple dimensions of mobility is critical to enhance health of older adults as they command a greater proportion of the population in decades to come.

Parallel trends in urbanization suggest by 2030 87% of North Americans will live in urban areas (World Health Organization, 2007). These concurrent processes set the stage to examine neighborhood environment features that influence health and mobility of older adults. Thus, environments where individuals live, work, and play form the context where health behaviors and outcomes are developed and manifest (Clarke and Nieuwenhuijsen, 2009). As physical function declines, older adults spend more time in their residential neighborhoods and become more responsive and sensitive to neighborhood environments. Specifically, aspects of the physical environment (e.g. streets and buildings), walkability (walking access to destinations, sometimes measured by Walk Score™ (Carr et al., 2010a; Carr et al., 2010b)), and access to transportation may play a key role in older adults' ability to maintain their physical (Rosso et al., 2011; Berke et al., 2007a; Fisher et al., 2004; Kerr et al., 2012; Michael et al., 2006; Van Cauwenberg et al., 2011), cognitive (Clarke et al., 2015; Lang et al., 2008; Sheffield and Peek, 2009; Wight et al., 2006), social (Rosso et al., 2013; Gardner, 2014), and transportation-related mobility (Marottoli et al., 2000; Kim and Ulfarsson, 1894). Thus, it is befitting that advocacy groups and policy makers focus on the role that neighborhoods might play to maintain independence and mobility of older adults (U.S. Environmental Protection Agency, 2009; Farber et al., 2011).

Emerging research documents the important role of neighborhood built environments on older adult mobility (Clarke and Nieuwenhuijsen, 2009; Kerr et al., 2012; Keysor et al., 2010; Clarke et al., 2008; Clarke et al., 2009; Clarke and Gallagher, 2013; Satariano et al., 2010). However, limited studies on the impact of environments on physical, mental health, and function include older adults (Rosso et al., 2011; Yen et al., 2009). Further, no previous work examined multiple dimensions of mobility. We recently developed a holistic score (Mobility Over Varied Environments Scale, MOVES) that combines various mobility domains (Hirsch et al., n.d.). Specifically, MOVES was designed to capture neighborhood built environment predictors across multiple dimensions of mobility. Thus, MOVES transcends measuring physical function to also assess cognitive ability to be mobile, social connections with community and transportation choices. Therefore, as a next step we aim to apply this index to more comprehensively examine the role that neighborhoods play in shaping older adult mobility.

Our specific objectives are twofold: 1. To comprehensively describe the mobility of older adults in British Columbia using the MOVES; 2. To examine the association between neighborhood walkability (measured by a composite, commercial measure, Walk Score™) and MOVES as a means to explore how neighborhood built environments might facilitate this type of holistic mobility. We hypothesize that individuals living in areas with higher walkability scores have higher mobility, due to increased proximity and access to destinations, social engagement opportunities, and alternative modes of transportation.

2. Methods

2.1. Sample

We drew our sample of middle-aged and older adults from the Canadian Community Health Survey- Healthy Aging (CCHS-HA). CCHS-HA is a cross-sectional survey ($n = 30{,}865$) that collected information related to health status, care utilization, and determinants for the population living in 10 Canadian provinces (Canadian territories were excluded). Details can be found elsewhere (Statistics Canada, 2008). Briefly, the Healthy Aging component of CCHS-HA was conducted from December 2008 through November 2009, surveyed people (≥45 years) using computer assisted personal interviewing (94% conducted in person), and achieved an overall response rate of 74.4%. Excluded from the survey's coverage were: persons living on reserves and other Aboriginal settlements, full-time members of the Canadian Forces, persons living in collective dwellings, and the institutionalized population. Our analysis included respondents if they lived in British Columbia (BC) Census Metropolitan Areas (CMAs; Vancouver, Abbotsford-Mission, Kelowna, and Victoria) and had complete information on exposure (walkability), outcome (mobility measured using MOVES), and covariates ($n = 2046$, representing 1,043,127 BC residents). Individuals who responded by proxy (2.2% of the CCHS-HA sample) were not included since several items for MOVES were not asked by proxy. These respondents represent 55% of the total BC respondents. This study did not require ethics review as it was deemed exempt under the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2), Article 2.4, by Simon Fraser University's Office of Research Ethics.

2.2. MOVES

Detailed methods describing how we designed and calculated the holistic measure of mobility, MOVES, can be found elsewhere (Hirsch et al., n.d.). Briefly, MOVES was grounded in the conceptual mobility frameworks of Webber et al. (Webber et al., 2010) and the World Health Organization's International Classification of Functioning, Disability, and Health (ICF) (World Health Organisation, 2014). These conceptual frameworks spanned four domains: physical (i.e. physical function and activity), cognitive (i.e. cognition and psychology), social (i.e. community engagement, participation, and sense of belonging), and transportation (i.e. use of various modes). To create MOVES we adopted an iterative process and engaged expert qualitative and quantitative researchers (expert panel) from diverse research fields to guide selection of measures deemed relevant to MOVES.

The two steps toward creation of MOVES were: 1) concept-based selection of CCHS-HA items for MOVES and 2) statistical refinement (using Cronbach's alpha and Principal Components Analysis), scoring, and compilation. Ultimately, MOVES was created for every individual with complete data on measures included in MOVES (92.5% of the CCHS-HA national sample; $n = 28{,}555$). Measures the expert panel selected to be incorporated into MOVES were activities of daily living, elements of the Health Utilities Index (both cognitive and physical), physical activity, fear of falling, transportation modes, sense of belonging in the local community, and frequency of participation in community activities. Measures within each domain were averaged so that each domain received equal weight, 10 points. A final score for MOVES was created by summing across the four domains for a possible score of 0 to 40.

2.3. Walkability

Walkability was measured using Street Smart Walk Score™ (www.walkscore.com, version: August 21, 2013). Street Smart Walk Score™ is a commercial measure of walkability that allocates points based on street-network distances to a range of amenities one would walk to (schools, shops, restaurants, parks, etc.). It then penalizes scores based on street characteristics (low intersection density and long block length representing lower walkability) to yield a score from 0 (“Very car-dependent”) to 100 (“Walker's paradise”). Walk Score™ has been validated within both the US (Carr et al., 2010a; Carr et al., 2010b; Duncan et al., 2011) and Canada (Manaugh and El-Geneidy, 2011). In previous studies it was associated with walking for transport and obesity (Brown et al., 2013; Hirsch et al., 2014; Hirsch et al., 2013).

We used the latitude and longitude of population-weighted centroid dissemination areas to purchase data for 4527 dissemination areas (census areas with populations of 400–700 people) within CMAs in BC. Postal codes were assigned to their respective dissemination areas and a Street Smart Walk Score™ was linked to participants' residential postal codes. We used Street Smart Walk Score™ as a continuous variable and standard cut-points that defined categories: 0 to 24 = “Very car-dependent,” 25 to 49 = Car-dependent,” 50 to 69 = “Somewhat walkable," 70 to 89 = "Very walkable," and 90 to 100 = "Walker's paradise."

2.4. Sociodemographic, living, and health covariates

We examined MOVES to i) ascertain its association with a range of mobility determinants, and ii) with a subset of covariates (selected a priori) developed linear models to assess associations between Street Smart Walk Score™ and MOVES. We included the following demographic variables in our analyses; respondent age (45–54; 55–64; 65–74; 75–84; 85 +), sex (male; female), marital status (married or common-law; widowed or separated or divorced; single, never married), education (less or secondary school graduation; some post-secondary; post-secondary graduation), retirement status (completely retired; partially retired or not retired), total household income from all sources (less than $19,999; $20,000 to $49,999; $50,000 to $99,999; $100,000 and over), and cultural/racial background (not white; white). We also assessed select characteristics about respondents' living arrangements including household size (alone; two people; three or more people) and home ownership (not owned by the respondent; owned by the respondent). Health was reported using self-perceived health (excellent; very good; good; fair; poor), having arthritis (excluding fibromyalgia), having chronic conditions, and depressive symptoms (felt depressed or lost interest in things for two weeks or more during the past year; did not feel either depressed nor lost interest in things) (Kessler et al., 2002).

2.5. Statistical analyses

Data matching and analyses took place within the Statistics Canada Research Data Centre at Simon Fraser University, Burnaby, British Columbia. To examine patterns using MOVES we estimated means across sociodemographic and health characteristics and compared them using analysis of variance (ANOVA). We assessed bivariate associations between Street Smart Walk Score™ and sociodemographic and health characteristics using Rao-Scott Chi-Square. Adjustment for confounding variables was determined a priori using first Directed Acyclic Graphs and DAGitty (Shrier and Platt, 2008; Textor et al., 2011) and then statistical tests of associations with both the exposure and outcomes. To estimate the association between Street Smart Walk Score™ and the MOVES we developed a linear regression models, which included MOVES and each subdomain as the dependent variables, Street Smart Walk Score™ as independent variables and age, sex, education, retirement status, and self-perceived health as relevant covariates. As no covariate significantly ($p < 0.1$) modified the association between Street Smart Walk Score™ and MOVES, we did not include interaction terms in the final models. We weighted demographic frequencies using the Statistics Canada proportional sampling scheme and applied Balanced Repeated Replication (BRR) with 500 bootstrap weight variables. All statistical analyses were conducted using SAS, version 9.4 (Cary, NC).

3. Results

3.1. Sample characteristics

Our CCHS-HA sample was comprised of 2046 respondents, representing 1,043,127 BC residents. Approximately 40% of the CCHS-HA sample used in these analyses were aged 45–54; slightly >27% were aged 65 or older, and more than half were either partially or not retired (Table 1). Approximately three-quarters of respondents were married, had post-secondary degrees, were white, owned their home, did not have arthritis, had at least one chronic condition and did not have depressive symptoms. Fewer than 20% lived alone and more than half reported very good or excellent self-perceived health.

3.2. Sample characteristics with Street Smart Walk Score™

More than half of the sample lived in neighborhoods defined as "Car dependent" (Street Smart Walk Score™ 0–49), about a quarter in "Somewhat walkable" neighborhoods (Street Smart Walk Score™ 50–69), and the remaining (about 25%) lived in either "Very walkable" or "Walker's paradise" neighborhoods (Table 2). Participants in neighborhoods defined as "Walker's paradise" tended to be older, less likely to be married, had lower household incomes, were non-white, lived alone, did not own their home, and had a wider distribution of perceptions about their health.

3.3. MOVES

Within the sample, mean MOVES was 30.7 (95% confidence interval (CI) 30.4, 31.0). The 5th percentile score was 23.3 (CI 22.2, 24.4) and the 95th percentile was 36.9 (CI 36.0, 37.9). MOVES was higher for younger participants (Fig. 1), those who were married or lived with more people, and who had higher socioeconomic status (still employed, higher education, higher income, owned their homes) (Table 1). Those with better self-perceived health, no arthritis, no chronic conditions, and no depressive symptoms also had higher MOVES. MOVES domains also differed by individual characteristics. In the physical, cognitive, and social domains, patterns were similar to overall MOVES. The transportation domain, however, had some different patterns; income was not as strong of a determinant of transportation mobility and transportation mobility did not vary across health conditions (arthritis, chronic disease, and depressive symptoms).

Living in more walkable areas was associated with increased mobility (Table 3). In unadjusted models, for every 10 point increase in Street Smart Walk Score™, MOVES increased 4.84 points (CI 4.52, 5.15). However, results attenuated substantially after adjusting for relevant sociodemographic covariates: 10 point increase in Street Smart Walk Score™ was associated with a 0.10 (CI 0.00, 0.20) point increase in MOVES. Several individual characteristics had strong associations with MOVES, for example, a decrease in MOVES of −0.97 (CI −1.63, −0.30) for those with secondary school graduation compared to those with post-secondary graduation and 6.25 (CI 5.06, 7.44) additional MOVES points for those in excellent health compared to those in poor health. Estimates for other covariates are in Supplemental Table S1. Results for the association between Street Smart Walk Score™ and each subdomain (Table 3) show that in unadjusted models neighborhood walkability was most strongly associated with the cognitive domain (mean difference for 10-unit increase in Street Smart Walk Score™ 1.42 (CI 1.32, 1.52)), while the weakest association was found with the transportation domain (mean difference for 10-unit increase in Street Smart Walk Score™ 1.00 (CI 0.94, 1.06)). However, after adjustment for covariates, the strongest association was found between neighborhood walkability and the transportation domain (representing increased transit modes); for a 10-unit increase in Street Smart Walk Score™, transportation increases 0.21 points (CI 0.14, 0.29). In fact, other domains, including physical and cognitive, showed lower scores at higher neighborhood walkability after adjustment and the social domain no longer had an association.

4. Discussion

We created and applied a mobility score (MOVES) to consider factors that influence the holistic mobility of older adults. Specifically, MOVES considers the contribution of physical mobility, cognitive ability, transportation use, and social or community interactions on the propensity for middle aged and older adults to move about their neighborhoods. We extend the limited literature and our understanding of the role different built environments play in shaping mobility. Across a population-based sample of middle-aged and older adults in British Columbia, those who lived in more walkable neighborhoods were more

Table 1
Sociodemographic, living, and health characteristics of CCHS-HA British Columbia Respondents (2008–2009) in Census Metropolitan Areas ($n = 2046$) and mean Mobility over Varied Environments Score (MOVES) across those characteristics.

Variable	Percent (95% CI)	Mean MOVES[a] (95% CI)	P-value[b]	Mean physical domain[a] (95% CI)	P-value[b]	Mean cognitive domain[a] (95% CI)	P-value[b]	Mean social domain[a] (95% CI)	P-value[b]	Mean transport domain[a] (95% CI)	P-value[b]
Age			<0.0001		<0.0001		<0.0001		0.0399		0.0005
45–54	40.5 (36.3, 44.8)	31.6 (31.0, 32.1)		8.8 (8.6, 9.0)		9.5 (9.3, 9.6)		7.1 (6.8, 7.3)		6.2 (5.8, 6.6)	
55–64	31.8 (28.3, 35.4)	31.5 (31.0, 32.0)		8.4 (8.2, 8.6)		9.5 (9.4, 9.6)		7.3 (7.1, 7.4)		6.3 (5.9, 6.7)	
65–74	17.1 (15.1, 19.1)	29.5 (29.1, 29.9)		7.9 (7.8, 8.0)		8.5 (8.3, 8.7)		7.4 (7.2, 7.5)		5.7 (5.5, 6.0)	
75–84	9.6 (8.2, 11.0)	26.7 (26.0, 27.4)		6.9 (6.6, 7.1)		7.5 (7.1, 7.8)		7.1 (6.9, 7.3)		5.3 (5.0, 5.6)	
85+	0.9 (0.4, 1.4)	25.8 (23.1, 28.6)		6.5 (5.7, 7.2)		6.4 (4.6, 8.3)		6.8 (6.2, 7.3)		6.2 (5.2, 7.1)	
Sex			0.0636		0.0002		0.0017		0.0613		0.183
Male	46.9 (42.9, 50.8)	31.0 (30.5, 31.5)		8.5 (8.4, 8.7)		9.3 (9.1, 9.4)		7.3 (7.1, 7.4)		5.9 (5.6, 6.2)	
Female	53.1 (49.2, 57.1)	30.4 (30.0, 30.8)		8.1 (8.0, 8.3)		9.0 (8.8, 9.1)		7.1 (6.9, 7.2)		6.2 (5.9, 6.5)	
Marital status			<0.0001		<0.0001		<0.0001		<0.0001		<0.0001
Married or common-law	77.6 (74.8, 80.5)	31.1 (30.7, 31.5)		8.4 (8.3, 8.5)		9.2 (9.1, 9.3)		7.3 (7.2, 7.5)		6.1 (5.9, 6.4)	
Widowed or separated or divorced	18.8 (16.1, 21.5)	29.3 (28.8, 29.8)		8.0 (7.8, 8.2)		8.6 (8.4, 8.9)		6.8 (6.6, 6.9)		5.9 (5.6, 6.2)	
Single, never married	3.6 (2.5, 4.6)	29.1 (28.3, 29.9)		8.1 (7.7, 8.5)		9.3 (8.9, 9.7)		6.0 (5.5, 6.5)		5.7 (5.0, 6.4)	
Highest level of education			<0.0001		<0.0001		<0.0001		<0.0001		<0.0001
Less or secondary school graduation	18.9 (16.0, 21.9)	29.2 (28.6, 29.8)		8.1 (7.8, 8.4)		8.7 (8.5, 9.0)		6.9 (6.7, 7.2)		5.5 (5.1, 5.8)	
Some post-secondary	6.9 (5.1, 8.7)	31.1 (30.2, 31.9)		8.4 (8.0, 8.8)		9.2 (9.0, 9.5)		7.4 (7.0, 7.7)		6.1 (5.5, 6.6)	
Post-secondary graduation	74.2 (70.9, 77.5)	31.0 (30.6, 31.4)		8.4 (8.2, 8.5)		9.2 (9.1, 9.3)		7.2 (7.1, 7.4)		6.2 (6.0, 6.5)	
Retirement status			<0.0001		<0.0001		<0.0001		0.3429		<0.0001
Completely retired	32.3 (29.2, 35.4)	28.7 (28.3, 29.1)		7.4 (7.3, 7.6)		8.4 (8.2, 8.5)		7.2 (7.1, 7.4)		5.6 (5.4, 5.8)	
Partially retired or not retired	67.7 (64.6, 70.8)	31.6 (31.2, 32.0)		8.7 (8.6, 8.9)		9.5 (9.3, 9.6)		7.1 (7.0, 7.3)		6.3 (6.0, 6.6)	
Total household income[c]			<0.0001		<0.0001		<0.0001		<0.0001		0.0467
Less than $19,999	7.4 (5.5, 9.2)	27.5 (26.2, 28.9)		7.1 (6.7, 7.5)		8.3 (7.9, 8.7)		6.3 (5.9, 6.7)		5.9 (5.2, 6.7)	
$20,000 to $49,999	21.4 (18.6, 24.2)	29.2 (28.7, 29.7)		7.9 (7.6, 8.1)		8.7 (8.5, 8.9)		7.0 (6.8, 7.2)		5.6 (5.4, 5.9)	
$50,000 to $99,999	39.0 (34.5, 43.4)	31.2 (30.6, 31.9)		8.5 (8.3, 8.7)		9.2 (9.0, 9.4)		7.2 (7.0, 7.5)		6.3 (5.8, 6.8)	
$100,000 and over	32.3 (28.1, 36.6)	31.7 (31.2, 32.2)		8.8 (8.6, 9.0)		9.4 (9.3, 9.6)		7.4 (7.1, 7.6)		6.1 (5.7, 6.5)	
Cultural/racial background[c]			0.598		0.6397		0.2708		0.3192		0.5596
Not white	27.2 (23.4, 30.9)	30.6 (29.8, 31.3)		8.3 (8.1, 8.5)		9.0 (8.7, 9.3)		7.1 (6.9, 7.3)		6.2 (5.8, 6.6)	
White	72.8 (69.1, 76.6)	30.8 (30.4, 31.1)		8.3 (8.2, 8.5)		9.2 (9.1, 9.3)		7.2 (7.1, 7.3)		6.1 (5.8, 6.3)	
Household size			<0.0001		<0.0001		<0.0001		<0.0001		<0.0001
Alone	19.2 (16.9, 21.5)	29.3 (28.9, 29.8)		8.0 (7.8, 8.1)		8.9 (8.7, 9.0)		6.7 (6.5, 6.9)		5.8 (5.6, 6.1)	
Two people	44.8 (40.9, 48.8)	30.9 (30.4, 31.3)		8.2 (8.1, 8.4)		9.1 (9.0, 9.3)		7.3 (7.2, 7.5)		6.2 (5.8, 6.5)	
Three or more people	35.9 (31.8, 40.1)	31.1 (30.5, 31.8)		8.6 (8.4, 8.8)		9.2 (9.0, 9.4)		7.2 (7.0, 7.5)		6.1 (5.7, 6.5)	
Home ownership[c]			0.0002		<0.0001		0.0005		0.0011		0.3502
Not owned by the respondent	15.2 (12.6, 17.7)	29.3 (28.5, 30.1)		7.6 (7.3, 7.9)		8.7 (8.4, 8.9)		6.7 (6.4, 7.0)		6.3 (5.8, 6.7)	
Owned by the respondent	84.8 (82.3, 87.4)	30.9 (30.6, 31.3)		8.4 (8.3, 8.6)		9.2 (9.1, 9.3)		7.3 (7.1, 7.4)		6.0 (5.8, 6.3)	
Self-perceived health			<0.0001		<0.0001		<0.0001		<0.0001		0.0002
Excellent	22.4 (19.2, 25.7)	32.2 (31.6, 32.8)		8.6 (8.4, 8.8)		9.6 (9.4, 9.7)		7.6 (7.5, 7.8)		6.4 (6.0, 6.8)	
Very good	33.4 (29.4, 37.4)	31.5 (31.0, 32.1)		8.7 (8.5, 8.8)		9.4 (9.3, 9.5)		7.2 (7.0, 7.4)		6.2 (5.8, 6.7)	
Good	29.8 (26.3, 33.3)	30.3 (29.8, 30.9)		8.3 (8.1, 8.5)		9.0 (8.8, 9.2)		7.1 (6.9, 7.3)		6.0 (5.7, 6.3)	
Fair	10.4 (8.3, 12.5)	28.0 (27.3, 28.8)		7.4 (7.1, 7.8)		8.3 (7.9, 8.6)		6.8 (6.4, 7.1)		5.6 (5.1, 6.0)	
Poor	4.1 (2.8, 5.3)	24.8 (23.4, 26.2)		6.4 (5.8, 7.0)		7.1 (6.4, 7.7)		6.5 (5.9, 7.0)		4.8 (4.0, 5.6)	
Has arthritis			<0.0001		<0.0001		<0.0001		0.0806		0.4572
Yes	22.5 (19.4, 25.6)	29.1 (28.3, 29.9)		7.7 (7.5, 7.9)		8.5 (8.2, 8.8)		7.0 (6.8, 7.2)		5.9 (5.5, 6.4)	
No	77.5 (74.4, 80.6)	31.1 (30.8, 31.5)		8.5 (8.4, 8.6)		9.3 (9.2, 9.4)		7.2 (7.1, 7.4)		6.1 (5.9, 6.4)	
Has a chronic condition[c]			<0.0001		<0.0001		<0.0001		<0.0001		<0.0001
Has two or more chronic conditions	53.5 (49.5, 57.5)	29.6 (29.2, 30.1)		7.9 (7.8, 8.1)		8.7 (8.5, 8.9)		7.1 (7.0, 7.3)		5.9 (5.6, 6.2)	
Has one chronic condition	20.3 (16.9, 23.7)	31.6 (30.9, 32.3)		8.7 (8.5, 8.9)		9.4 (9.3, 9.6)		7.2 (6.9, 7.5)		6.3 (5.7, 6.8)	
Has no chronic conditions	26.2 (22.6, 29.9)	32.0 (31.3, 32.6)		8.8 (8.6, 9.0)		9.7 (9.5, 9.8)		7.2 (7.0, 7.5)		6.2 (5.8, 6.6)	
Depressive symptoms[c]			0.0006		0.009		0.0002		0.002		0.6196
No	90.2 (87.4, 92.9)	30.9 (30.5, 31.2)		8.4 (8.2, 8.5)		9.2 (9.1, 9.3)		7.2 (7.1, 7.4)		6.1 (5.9, 6.3)	
Yes	9.8 (7.1, 12.6)	29.2 (28.4, 30.0)		7.9 (7.6, 8.2)		8.4 (8.0, 8.9)		6.6 (6.2, 7.0)		6.3 (5.7, 6.9)	

[a] MOVES ranges from 0 to 40; each subdomain ranges from 0 to 10.
[b] P-value from analysis of variance (ANOVA) across categories of each sociodemographic characteristic.
[c] Only a sub sample of the 2046 respondents had these variables: income reported for $n = 1695$; cultural/racial background reported for $n = 2003$; home ownership reported for $n = 2042$; chronic condition reported for $n = 2035$; depressive symptoms reported for $n = 2020$.

Table 2
Sociodemographic, living, and health characteristics of 2008–2009 CCHS-HA British Columbia Respondents (2008–2009) in Census Metropolitan Areas (n = 2046) across Street Smart Walk Score™ Categories.

Variable	Walker's paradise[a] Percent (95% CI)	Very walkable[a] Percent (95% CI)	Somewhat walkable[a] Percent (95% CI)	Car-dependent[a] Percent (95% CI)	P-value[b]
Overall percentage of total	7.6 (6.1, 9.2)	17.6 (14.6, 20.6)	23.4 (20.1, 26.7)	51.4 (47.4, 55.4)	
Age					0.0102
45–54	34.4 (23.2, 45.6)	41.0 (30.5, 51.5)	36.2 (27.8, 44.7)	43.2 (37.1, 49.3)	
55–64	32.2 (22.8, 41.5)	28.0 (20.8, 35.2)	39.7 (31.9, 47.5)	29.6 (24.4, 34.7)	
65–74	15.8 (10.4, 21.3)	16.5 (12.2, 20.8)	15.2 (11.5, 19.0)	18.4 (15.3, 21.4)	
75–84	14.7 (9.7, 19.8)	13.4 (9.5, 17.3)	7.4 (5.2, 9.6)	8.6 (6.5, 10.6)	
85+	2.8 (0.0, 6.6)	1.1 (0.0, 2.2)	1.5 (0.1, 3.0)	0.3 (0.1, 0.5)	
Sex					0.1727
Male	45.9 (35.5, 56.3)	53.3 (44.1, 62.4)	50.3 (42.3, 58.3)	43.3 (37.6, 48.9)	
Female	54.1 (43.7, 64.5)	46.7 (37.6, 55.9)	49.7 (41.7, 57.7)	56.7 (51.1, 62.4)	
Marital status					<0.0001
Married or common-law	60.4 (50.9, 69.8)	67.7 (58.8, 76.6)	77.1 (71.5, 82.7)	83.8 (80.5, 87.2)	
Widowed or separated or divorced	29.3 (20.9, 37.8)	27.2 (18.4, 36.1)	18.8 (13.9, 23.8)	14.3 (11.2, 17.4)	
Single, never married	10.3 (5.2, 15.4)	5.1 (2.7, 7.4)	4.1 (1.2, 6.9)	1.9 (0.8, 2.9)	
Highest level of education					0.2382
Less or secondary school graduation	13.5 (8.5, 18.4)	21.7 (13.0, 30.4)	23.3 (17.5, 29.1)	16.7 (12.7, 20.8)	
Some post-secondary	5.2 (2.3, 8.0)	5.7 (2.9, 8.6)	5.8 (2.1, 9.5)	8.0 (5.1, 10.9)	
Post-secondary graduation	81.3 (75.5, 87.2)	72.5 (63.7, 81.3)	70.8 (64.3, 77.4)	75.3 (70.6, 80.0)	
Retirement status					0.5412
Completely retired	38.1 (28.5, 47.7)	34.7 (27.4, 42.1)	31.6 (25.4, 37.8)	30.9 (26.6, 35.2)	
Partially retired or not retired	61.9 (52.3, 71.5)	65.3 (57.9, 72.6)	68.4 (62.2, 74.6)	69.1 (64.8, 73.4)	
Total household income[c]					0.0002
Less than $19,999	7.8 (4.3, 11.2)	11.1 (7.1, 15.2)	6.5 (4.2, 8.8)	6.4 (3.3, 9.6)	
$20,000 to $49,999	31.0 (22.3, 39.8)	28.5 (21.5, 35.6)	22.7 (16.4, 29.1)	17.1 (13.5, 20.6)	
$50,000 to $99,999	36.7 (26.5, 46.8)	41.0 (31.2, 50.7)	43.1 (33.7, 52.6)	36.7 (30.3, 43.2)	
$100,000 and over	24.5 (15.7, 33.4)	19.4 (11.4, 27.3)	27.7 (20.1, 35.2)	39.8 (33.2, 46.3)	
Cultural/racial background[c]					<0.0001
Not white	30.0 (20.1, 39.8)	42.1 (32.0, 52.2)	32.8 (24.2, 41.5)	19.0 (14.9, 23.1)	
White	70.0 (60.2, 79.9)	57.9 (47.8, 68.0)	67.2 (58.5, 75.8)	81.0 (76.9, 85.1)	
Household size					<0.0001
Alone	39.8 (30.5, 49.1)	21.8 (16.6, 27.0)	19.7 (14.6, 24.7)	15.1 (12.0, 18.2)	
Two people	47.1 (36.5, 57.6)	40.5 (31.7, 49.3)	41.3 (33.8, 48.8)	47.6 (41.8, 53.4)	
Three or more people	13.1 (6.9, 19.4)	37.7 (27.2, 48.2)	39.0 (30.5, 47.6)	37.3 (31.5, 43.2)	
Home ownership[c]					<0.0001
Not owned by the respondent	38.5 (29.0, 48.0)	21.3 (14.5, 28.1)	14.6 (8.9, 20.4)	9.9 (6.8, 13.0)	
Owned by the respondent	61.5 (52.0, 71.0)	78.7 (71.9, 85.5)	85.4 (79.6, 91.1)	90.1 (87.0, 93.2)	
Self-perceived health					0.0157
Excellent	22.9 (15.5, 30.2)	16.1 (11.2, 20.9)	19.3 (13.4, 25.2)	26.0 (20.8, 31.2)	
Very good	30.2 (19.1, 41.2)	25.6 (17.0, 34.1)	40.4 (32.1, 48.6)	33.3 (27.5, 39.2)	
Good	29.5 (20.5, 38.5)	40.4 (30.5, 50.3)	28.1 (21.2, 35.0)	26.9 (22.4, 31.4)	
Fair	12.3 (6.2, 18.4)	13.8 (9.0, 18.5)	9.5 (5.9, 13.1)	9.3 (6.0, 12.6)	
Poor	5.1 (2.2, 8.0)	4.2 (1.9, 6.5)	2.7 (0.9, 4.5)	4.5 (2.3, 6.6)	
Has arthritis					0.1966
Yes	21.3 (14.0, 28.6)	19.6 (14.5, 24.7)	19.4 (14.9, 23.9)	25.1 (19.9, 30.2)	
No	78.7 (71.4, 86.0)	80.4 (75.3, 85.5)	80.6 (76.1, 85.1)	74.9 (69.8, 80.1)	
Has a chronic condition[c]					0.0798
Has two or more chronic conditions	64.8 (54.1, 75.6)	60.0 (50.8, 69.2)	44.5 (36.9, 52.1)	53.7 (47.9, 59.5)	
Has one chronic condition	19.6 (8.8, 30.5)	16.7 (11.5, 21.9)	25.2 (17.4, 33.1)	19.3 (14.5, 24.2)	
Has no chronic conditions	15.6 (9.4, 21.8)	23.3 (14.7, 31.9)	30.3 (22.0, 38.6)	27.0 (21.9, 32.0)	
Depressive symptoms[c]					0.5259
No	92.6 (88.7, 96.6)	86.3 (76.9, 95.6)	91.0 (86.7, 95.3)	90.7 (86.9, 94.5)	
Yes	7.4 (3.4, 11.3)	13.7 (4.4, 23.1)	9.0 (4.7, 13.3)	9.3 (5.5, 13.1)	

[a] Street Smart Walk Score™ categories: car-dependent (combined vary car-dependent, 0 to 24, and car-dependent, 25 to 49); somewhat walkable, 50 to 69; very walkable, 70 to 89; Walker's paradise, 90 to 100.
[b] P-value from Rao-Scott Chi-square test across categories of Street Smart Walk Score™.
[c] Only a sub sample of the 2046 respondents had these variables: income reported for $n = 1695$; cultural/racial background reported for $n = 2003$; home ownership reported for $n = 2042$; chronic condition reported for $n = 2035$; depressive symptoms reported for $n = 2020$.

highly mobile. However, the influence of walkable built environments was less after accounting for relevant sociodemographic characteristics.

Our finding that greater walkability was associated with higher MOVES was consistent with previous work in older adults examining specific components of MOVES (Rosso et al., 2011; Yen et al., 2009). For example, in the physical domain, higher outdoor walking or physical activity (Berke et al., 2007a; Fisher et al., 2004; Michael et al., 2006; King et al., 2011; Owen et al., 2007; Patterson and Chapman, 2004), and lower mobility disability (Clarke et al., 2008; Clarke et al., 2009; Beard et al., 2009) were associated with pedestrian friendly neighborhoods with more destinations. This may result from those with higher mobility patterns during adulthood (e.g. more engagement, higher physical activity) maintaining activity levels as they age. Alternately, specific environment features may enable more physical activity even for those who have developed physical mobility restrictions. For example, shorter distance to destinations or more supportive pedestrian structures (e.g. sidewalks and crosswalks) may facilitate walking trips, especially among older adults. To this point, in a concept mapping project we conducted with intersectoral stakeholders, sidewalks and crosswalks emerged as prominent built environment aspects influencing older adult's outdoor walking (Hanson et al., 2013). In the cognitive domain, others have reported associations between cognitive decline (Clarke et al., 2015; Lang et al., 2008; Sheffield and Peek, 2009; Wight et al., 2006) or depression (Berke et al., 2007b) and the neighborhood

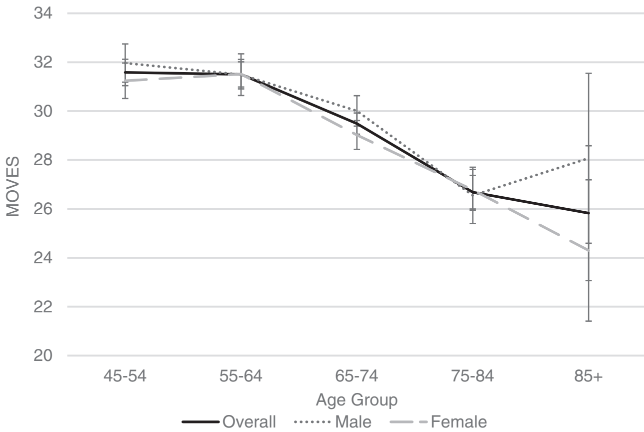

Fig. 1. Patterns of Mobility over Varied Environments Score (MOVES) by Age and Gender within CCHS-HA respondents from British Columbia (2008–2009). Solid line represents overall age trend, dashed light grey line represents females, and dotted dark grey line represents males.

environment. The opportunity for older adults to frequently engage in social activities and easier access to destinations for these social activities are potential explanations. Previous research in the social domain supports associations between walkable neighborhoods and social connections (Leyden, 2003; Richard et al., 2009; Sugiyama and Thompson, 2007; Mahmood et al., 2012). Finally, a substantial body of work in the planning sector explored the role walkability played in transportation options and mode choice (Kim and Ulfarsson, 1894; Frank et al., 2008; Saelens et al., 2003; Frank et al., 2007; Winters et al., 2010). Importantly, mode choice is one novel element directly assessed by MOVES. Earlier studies reported neighborhood, trip and personal and household characteristics shaped the type of transportation older adults choose (Kim and Ulfarsson, 1894). That is, older adults are more likely to use transit if they live within five blocks of a bus stop, and more likely to share a ride with others when making multiple stops or doing errands. Conversely, they are less likely to use transit to do their shopping or run errands (Kim and Ulfarsson, 1894). In summary, our work supports the growing evidence body identifying the important role neighborhood features play to facilitate all the domains of mobility assessed by MOVES.

We know that many individual factors influence mobility of older adults (Webber et al., 2010) – especially when mobility-disability ensues and in those most frail (Clarke et al., 2009). Thus, it was unsurprising that, after adjusting for sociodemographic characteristics, the association between Street Smart Walk Score™ and MOVES was attenuated. These individual factors may be especially important within our relatively homogenous study population that were mostly younger, married, white, and had high educations and incomes. Future research should test this relationship in a more diverse context. Despite this, our results suggest a role for neighborhood environment that persists even accounting for the many individual level factors. Importantly, although the size of the association for walkability was small in statistical models, positive neighborhood changes impact the entire residential population living in the area, across many years. Thus, policy changes that address built environments, such as "Age Friendly City" designations (World Health Organization, 2007), Complete Streets policies or other Smart Growth developments (U.S. Environmental Protection Agency, 2009; Smart Growth America, 2016), have potential for widespread impacts when considered at population levels rather than at the individual level. However, several potential factors may play roles in the reduction of the association after adjustment for confounders. First, individual sociodemographic characteristics may influence where our respondents choose to live, or can afford to live. If neighborhood environments are highly associated with a variable tightly linked with older adult mobility, the association in unadjusted models would be confounded by these influential variables. However, in this study we saw respondents in more walkable places had characteristics associated with lower mobility (older, non-married, non-white, non-homeowners, and wider distribution of perceived health), which we expect would bias unadjusted models downward. A second explanation may be that neighborhood walkability is strongly associated with some (e.g. transportation) but not all components of MOVES. For example, after controlling for potential covariates, we found small and nonsignificant associations with the social domain, and larger and significant associations with the transportation domain (which is understandable as dense, walkable places often have more transport options). These might have canceled each other out in models examining composite MOVES. Finally, our study included large metropolitan areas in BC, home to 55% of the population and representing 1,043,127 people. We did not include those who reside outside the CMAs, as walkability and its relevance may differs in rural contexts due to transportation patterns, cultural context, and relevant spatial scale (Frost et al., 2010; Feng et al., 2010). Despite this, almost three-quarters of respondents lived in "Somewhat walkable" or "Car-dependent" neighborhoods. This homogeneity has potential to reduce statistical variance of our exposure and, as a result, associations between Street Smart Walk Score™ and mobility that would be observed across the entire spectrum of walkability. It would be of future interest to discern the relationship between older adult residential choices, neighborhood environments, and mobility.

We highlight a number of study strengths. We used an objective, standardized measure of neighborhood walkability and a novel, holistic measure of mobility that more aptly captures ability to engage. A recent systematic review highlighted a need for standardized, objective measures of the built environment (Van Cauwenberg et al., 2011). In contrast to many of the studies reviewed, our work uses Street Smart Walk Score™ which has been validated (Carr et al., 2010a; Carr et al., 2010b; Duncan et al., 2011) and shown to be associated with walking (Brown et al., 2013; Hirsch et al., 2014; Hirsch et al., 2013; Tuckel and Milczarski, 2015). Another advantage of Street Smart Walk Score™ is that it is a composite index of access to destinations and street design.

Table 3
Associations between Street Smart Walk Score™, Mobility Over Varied Environments Score (MOVES), and MOVES domains in the 2008–2009 CCHS-HA British Columbia Respondents (2008–2009) in Census Metropolitan Areas ($n = 2046$).

	MOVES[a] Estimate (95% CI)	Physical domain[a] Estimate (95% CI)	Cognitive domain[a] Estimate (95% CI)	Social domain[a] Estimate (95% CI)	Transportation domain[a] Estimate (95% CI)
Unadjusted Association for Street Smart Walk Score™ (10-units)	4.84 (4.52, 5.15)***	1.30 (1.20, 1.39)***	1.42 (1.32, 1.52)***	1.12 (1.05, 1.20)***	1.00 (0.94, 1.06)***
Adjusted[b] Association for Street Smart Walk Score™ (10-units)	0.10 (0.00, 0.20)*	−0.05 (−0.08, −0.01)*	−0.04 (−0.08, 0.00)*	−0.02 (−0.07, 0.02)**	0.21 (0.14, 0.29)***

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.
[a] MOVES ranges from 0 to 40; each subdomain ranges from 0 to 10.
[b] Adjusted models include age, sex, education, retirement status, and self-perceived health.

This provided the opportunity to understand more comprehensively the role neighborhood walkability plays in older adult mobility. Another strength is generalizability of our results. CCHS-HA was designed to represent the Canadian population, or in our case, BC residents in metropolitan areas.

We also acknowledge limitations of our study. First, urban planners and other municipal staff often face decisions around specific design features, or in specific corridors. Thus, using composite walkability may present a challenge for municipalities trying to extract direct policy recommendations. Second, we were only able to use CCHS-HA participants who lived in CMAs, where we had Street Smart Walk Score™. Third, as per any cross-sectional study we are unable to draw causal inference. Finally, our results may have been influenced by residual confounding from unmeasured individual and neighborhood characteristics.

5. Conclusion

"Population ageing is unprecedented, without parallel in the history of humanity" (United Nations, 2002). This global reality demands comprehensive approaches to conceptualizing mobility. To address this need we used a holistic mobility measure to understand the potential for neighborhood built environments to facilitate mobility for older people.

Given that mobility is critical to promoting healthy behaviors and outcomes (Boyle et al., 2010; Cooper et al., 2010), social connectedness (Rosso et al., 2013; Marottoli et al., 2000), isolation (Gardner, 2014), and quality of life (Metz, 2000) our findings have relevance for researchers, policy makers, practitioners, and older adults. The modest but important link observed between our measure and neighborhood walkability has potential across iterations of residents to influence population-level mobility and health. Thus, we urge others to consider context as an important factors determining mobility.

Individual-level sociodemographic characteristics remain strong agents of mobility and need also be considered. We welcome future studies delving deeper into the way older adults engage with their neighborhood social and physical environments, and the potential interaction of individual mobility influences within diverse environments. We envision that our results may encourage crucial and much needed dialogue among urban planners, public health practitioners, gerontologists, community members, and other stakeholders regarding neighborhood supports for the mobility of people of all ages and abilities.

Supplementary data to this article can be found online at doi:10.1016/j.ypmed.2016.09.036.

Conflict of interest

The authors have no conflicts of interest to report.

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