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Associations of social cohesion and quality of life with objective and perceived built environments: a latent profile analysis among seniors

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ABSTRACT

Background Healthy aging requires support from local built and social environments. Using latent profile analysis, this study captured the multidimensionality of the built environment and examined relations between objective and perceived built environment profiles, neighborhood social cohesion and quality of life among seniors.

Methods In total, 693 participants aged 66–97 were sampled from two US locales in 2005–2008 as part of the Senior Neighborhood Quality of Life Study (SNQLS). Perceived social cohesion and quality of life were assessed using validated surveys. Six objective (geographic information system (GIS)-based) and seven perceived built environment latent profiles generated in previous SNQLS publications were used for analyses. Mixed-effects models estimated social cohesion and quality of life separately as a function of the built environment profiles.

Results More walkable and destination-rich perceived built environment profiles were associated with higher social cohesion and quality of life. Objective built environment profiles were not associated with social cohesion and only positively associated with quality of life in only one locale (Baltimore/DC).

Conclusions Latent profile analysis offered a comprehensive approach to assessing the built environment. Seniors who perceived their neighborhoods to be highly walkable and recreationally dense experienced higher neighborhood social cohesion and quality of life, which may set the stage for healthier aging.

Keywords environment, older people

Successful aging encompasses the absence of disease and disability, maintenance of physical and mental functioning, and sustained engagement in social and productive activities,[1] resulting in increased quality of life for seniors[2–5] and reduced healthcare costs for society at large.[6–8] Successful aging and improved quality of life for seniors requires support from both built environments and social environments.[9] Moreover, individuals who experience a higher quality of life are more likely to be active and to choose to live in more activity-friendly neighborhoods, which in turn determines the available neighborhood assets that are related to their quality of life.[10]

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Elements and characteristics of the social environment, such as social cohesion, are important enablers of successful aging.[9] Social cohesion has been defined as 'the extent of connectedness and solidarity among groups in society.'[11] In a socially cohesive community, there is high connectedness, social support and resources for individuals.[11] Neighborhood social cohesion has been associated with seniors' cognitive function,[12] psychological distress,[13] hypertension,[14] stroke,[15] self-reported health[16] and various health behaviors.[17] Neighborhood influences may be particularly important for older adults who, after occupational retirement, often spend much of their time within their neighborhoods.[13]

There is also considerable evidence for associations between built environment assets, such as access to green space and neighborhood walkability, and seniors' physical activity levels, weight status, mental health and general wellbeing.[18–22] Despite the importance of the social as well as built environments for successful aging, there is limited research on the interplay between both, and how they may be associated with each other. Furthermore, assets of the built environment are typically measured subjectively by self-report or derived objectively using geographic information system (GIS); objective and perceived (subjective) measures of the built environment are often not considered together. Some studies that have simultaneously examined both have found a mismatch.[19] For example, a systematic review of the neighborhood physical environment and active travel in older adults found that perceived built environment features generated stronger evidence of positive associations than did objectively measured features.[23] Understanding these discrepancies could assist in developing intervention strategies aimed at changing individuals' perceptions of the built environment to achieve better health.

The majority of the built environment literature typically focuses on only one or a few built environment assets, without considering the diversity and multidimensionality of the built environment; different features of the built environment may not be independent and could correlate in complex ways.[18–21] In studying the built environment, one of the remaining challenges thus concerns how to capture complex and coexisting patterns of the built environment. Latent profile analysis is a multivariate analysis method that is useful for identifying common patterns among numerous variables and classifying individuals into subgroups based on their response patterns. Based on inputs of potential indicators, latent profile analysis yields a discrete set of model-derived clusters of observations with distinctive patterns (profiles) of indicator (built environment feature) scores in each model and allows for statistical comparison of models of differing complexity. Furthermore, latent profile analysis maximizes between-profile variance and minimizes within-profile variance across the set of indicators.[21]

Based on these considerations, the goals of this paper were to examine the cross-sectional relations between objectively measured and perceived built environment profiles, generated using a latent profile analysis approach and social cohesion and quality of life in seniors from two US regions. We hypothesized that individuals with more activity-supportive built environment profiles (both GIS-derived and perceived) would experience higher levels of social cohesion and quality of life. To test our hypothesis, we used data gathered from the Senior Neighborhood Quality of Life Study (SNQLS), an observational study that was originally designed to evaluate relations of the built environment with physical activity and body weight in older adults living in neighborhoods differing in walkability and income levels.[24]

Methods

As part of SNQLS, 719 seniors were sampled from Seattle-King County, WA and Baltimore, MD-Washington, DC regions in 2005–2008 with the goals of maximizing variability in neighborhood walkability and income at the Census block group level. Participants were free-living (i.e. not living in institutional settings that provide full-time care, such as nursing homes) older adults aged 66–97 years (52.2% women, 30% racial/ethnic minority). Inclusion criteria included ages 66 and older, and able to complete surveys in English and walk at least 10 feet continuously. Details on the sampling and recruitment of the original study can be found in King *et al*.[24] All research activities involving human subjects were approved by the Institutional Review Boards of Stanford University, San Diego State University and University of California San Diego.

Participants' sociodemographic information, quality of life and neighborhood social cohesion were assessed using self-reported surveys. Quality of life was measured by the following four questions: (i) in general, would you say your health is excellent, very good, good, fair or poor? (ii) All things considered, how satisfied are you with your life as a whole? (very satisfied, moderately satisfied, no feels either way, moderately dissatisfied or very dissatisfied); (iii) During the past 4 weeks, how much did pain interfere with your normal work, including both work outside the home and housework? (not at all, a little bit, moderately, quite a bit or extremely); and (iv) How often do you feel isolated from others? (hardly ever, some of the time, or often).[25] An average total Z-score was then generated to summarize the measure.

Neighborhood social cohesion was measured by five Likert-type survey questions, as follows: (i) people around my

neighborhood are willing to help their neighbors; (ii) this is a close-knit neighborhood; (iii) people in this neighborhood can be trusted; (iv) people in this neighborhood generally do not get along with each other; and (v) people in this neighborhood do not share the same values.[26] The questions were rated on a five-point scale (strongly disagree, somewhat disagree, neutral, somewhat agree, strongly agree), and the average of these responses was the summary measure.

In terms of built environment assessments, previous research on SNQLS data[19,21] identified the three objective and four perceived built environment profiles that are used in the present study. The objective (GIS-based) profiles were derived based on 1-km street network buffers around participants' home addresses. The profile elements included net residential density, land-use mix, retail floor area ratio, intersection density, public transit density and public park and private recreation facility density. Descriptions of these profile elements can be found in Todd *et al*.[21] Profiles were selected based on model fit criteria (i.e. sample size-adjusted Bayesian Information Criterion or BIC and model log-likelihood values), within-profile sample sizes (i.e. profiles with $>5\%$ of the sample were considered viable) and interpretable neighborhood profiles, in terms of built environment characteristics and elements.[27] Three profiles each were generated for both Seattle/King County and Baltimore/DC. The first profile, L-L-L, pertained to neighborhoods with low walkability (i.e. low residential density, land use mix and intersection density), low transit access and low recreation access (i.e. limited access to parks and recreational facilities). The second profile, M-M-M, referred to neighborhoods with moderate walkability, moderate transit access and moderate recreation access. Lastly, the third profile, H-H-H, referred to neighborhoods with high walkability, high transit access and high recreation access.[21]

Perceived built environment features were derived from the Neighborhood Environment Walkability Scale (NEWS),[28] which consists of eight subscales—residential density, land-use mix diversity, land-use mix access, street connectivity, walking and cycling facilities, aesthetics, pedestrian/traffic safety and crime safety. These scales have been validated and shown acceptable reliability in previous research.[28–30] Other perceived built environment items that were measured separately in addition to the NEWS included distances to the nearest point of interest (i.e. bus or train stop, park, recreation center or gym or fitness facility), and time to walk to these places (measured on a five-point scale from 31 min or more to 1–5 min); the scales were computed as the mean of responses. Similar to the GIS-based profile generation, perceived built environment profiles were generated and selected based on model fit criteria, sample sizes per profile and interpretable neighborhood profiles.[27] Three profiles were generated for both the Seattle/King County and the Baltimore/DC regions. The first profile, LWTR, pertained to neighborhoods with low walkability (i.e. the lowest scores for residential density, land use mix diversity and access, intersection density and access to walking and cycling facilities), low access to public transit and low recreation access (i.e. limited access to parks and recreational facilities). The second profile, MWMR, included neighborhoods with moderate walkability (i.e. low scores for residential density and street connectivity, high score for walking and cycling facilities, high scores for pedestrian and traffic safety and moderate scores for all other environmental variables, including transit access) and moderate access to recreational facilities and parks. The third profile, HWRD, referred to neighborhoods with high walkability and recreational density. Additionally, a fourth profile, LWRS, was generated for the Baltimore/DC region. This profile represented neighborhoods with low walkability that were also recreationally sparse but had access to transit. Further information regarding the generation of these profiles can be found in Adams *et al*.[19]

Multilevel mixed linear models were used to estimate social cohesion and quality of life separately as a function of the individual objective and perceived built environment latent profiles. Analyses were limited to only those participants with both social cohesion and quality of life scores and built environment profiles. In order to account for clustering, individual participants were nested within neighborhoods defined by Census block group in a two-level data structure, with Census block group incomes treated as a random effect. Demographic variables were included as covariates in the models. Basic descriptive statistics were calculated for all primary indicators and outcome variables as well as other covariates. Stata 15.0 (Stata Corp, College Station, Texas) was used for all data analyses.

Results

A total of 693 participants had the above data of interest and were included in the analyses. They were ages 66–97 years (45.9% Seattle/King County, 54.1% Baltimore/DC) with 52.2% women and 30% reporting being part of a racial/ethnic minority group. Detailed participant characteristics and proportion of participants living in each of the neighborhood profiles can be found in Table 1.

Associations between built environment profiles and social cohesion

The objectively derived built environment profiles were not significantly associated with social cohesion (Table 2).

Table 1 Participant characteristics

	Seattle/King County region (n = 318, 45.9%)		*Baltimore/DC region (n = 375, 54.1%)*	
Participant characteristics (Categorical)	*n*	*%*	*n*	*%*
Gender				
Male	164	51.6	167	44.5
Female	154	48.4	208	55.5
Race/ethnicity				
Non-Hispanic white/Caucasian	268	84.3	217	57.9
Racial/ethnic minority	50	15.7	158	42.1
Education level				
High school or less	60	18.9	94	25.1
Some college or vocational training	105	33.0	96	25.6
Completed college or university	95	29.9	79	21.1
Completed graduate degrees	58	18.2	106	28.3
Type of residence				
Single family house	236	74.2	244	65.1
Apartment/condominium/townhouse or other	82	25.8	131	34.9
Valid driver's license holder				
Yes	296	93.1	346	92.3
No	22	6.9	29	7.2
Comfortable driving distance from home				
10 miles or less	52	16.4	73	19.5
more than 10 miles	266	83.7	301	80.5
Marital status				
Married or living with a partner	190	59.8	208	55.5
Widowed	79	24.8	92	24.5
Divorced/separated or single	49	15.4	75	20.0
Employment Status				
Employed	64	20.1	98	26.1
Unemployed/retired and not currently working	249	78.3	272	72.5
Disabled or on temporary medical leave	5	1.6	5	1.3
Annual household income				
<$30 000	106	35.9	104	29.8
$30 000–$49 000	83	28.1	81	23.2
$50 000–$79 000	67	22.7	100	28.7
>$80 000	39	13.2	64	18.3
GIS-based latent profile membership				
Low walkability/transit/recreation (L-L-L)	188	59.9	247	67.9
Mean walkability/transit/recreation (M-M-M)	120	38.2	83	22.8
High walkability/transit/recreation (H-H-H)	6	1.9	34	9.3
Perceived latent profile membership				
Low walkability, transit and recreation (LWTR)	65	20.5	70	18.8
Low walkability/recreationally sparse (LWRS)			106	28.5
Moderately walkability/moderately recreational (MWMR)	102	32.2		
Moderately walkability/recreationally dense (MWRD)			139	37.4
High walkability/recreationally dense (HWRD)	150	47.3	57	15.3
Participant characteristics (Continuous)	Mean	SD	Mean	SD
Age (years)	74.8	6.6	73.6	5.8
BMI (kg/m^2)	26.3	4.8	26.9	4.8
Duration at current address (years)	25.0	16.6	25.0	14.4
Number of people living in the same household	1.8	0.8	1.8	0.7
Quality of life Z-score	0.0	0.7	0.0	0.7
Average social cohesion score	3.7	0.7	3.7	0.8

Alternatively, as illustrated in Table 2 and Fig. 1 (electronic version only), the perceived built environment profiles were found to have positive relations with social cohesion. In general, the better the perceived profiles (more walkable and more recreationally dense neighborhoods), the higher the social cohesion experienced by participants in both Seattle/King County and Baltimore/DC regions. Specifically, participants in Seattle/King County with MWMR profiles experienced higher social cohesion (marginal mean = 3.87 on a 1–5 scale) than participants with LWTR profiles (marginal mean = 3.55; $\beta = 0.32$, SE = 0.13, $P = 0.01$). In the Baltimore/DC region, participants with MWMR profiles experienced higher social cohesion (marginal mean = 3.70 in a 1–5 scale) than participants with LWTR (marginal mean = 3.39; $\beta = 0.31$, SE = 0.12, $P = 0.01$), as did those with HWRD profiles (marginal mean = 3.99; $\beta = 0.60$, SE = 0.19, $P = 0.001$). As shown in Table 2, there were additional significant covariates in the model. In the Baltimore/DC region, for example, years

Table 2 Latent profiles and social cohesion

Variables	*GIS-based latent profiles*						*Perceived latent profiles*					
	Seattle/King County			*Baltimore/DC*			*Seattle/King County*			*Baltimore/DC*		
	β	*SE*	*95% CI*	*β*	*SE*	*95% CI*	*β*	*SE*	*95% CI*	*β*	*SE*	*95% CI*
Latent profile membership												
L-L-L/LWTR												
LWRS	N/A			N/A			N/A			−0.00	0.12	−0.25, 0.24
M-M-M/MWMR	0.09	0.10	−0.12, 0.30	−0.11	0.12	−0.36, 0.15	0.32*	0.13	0.06, 0.59	0.31*	0.12	0.06, 0.56
H-H-H/HWRD	−0.07	0.31	−0.71, 0.56	−0.01	0.21	−0.45, 0.42	0.17	0.11	−0.07, 0.40	0.60**	0.19	0.23, 0.99
Gender												
Male												
Female	0.02	0.09	−0.16, 0.21	−0.03	0.09	−0.22, 0.15	0.05	0.09	−0.13, 0.24	0.01	0.09	−0.17, 0.18
Race/ethnicity												
Non-Hispanic white												
Racial/ethnic minority	−0.27*	0.12	−0.52, −0.02	0.07	0.09	−0.12, 0.26	−0.26*	0.12	−0.50, −0.03	0.09	0.09	−0.09, 0.27
Education level												
High school or less												
Some college/vocational training	0.18	0.12	−0.07, 0.42	0.12	0.11	−0.11, 0.35	0.16	0.12	−0.08, 0.40	0.15	0.11	−0.07, 0.37
Completed college or university	0.33*	0.13	0.07, 0.60	0.03	0.13	−0.23, 0.29	0.28*	0.13	0.03, 0.54	−0.04	0.12	−0.29, 0.21
Completed graduate degrees	0.41*	0.14	0.12, 0.71	0.18	0.13	−0.08, 0.44	0.36*	0.14	0.07 - 0.65	0.15	0.12	−0.09, 0.40
Type of residence												
Single family house												
Apartment/condominium/ townhouse or other	0.00	0.13	−0.27, 0.28	−0.13	0.11	−0.36, 0.09	−0.08	0.13	−0.34, 0.18	−0.19	0.11	−0.41, 0.04
Valid driver's license holder												
Yes												
No	0.33	0.21	−0.11, 0.77	−0.36*	0.18	−0.71, −0.00	0.29	0.20	−0.13, 0.71	−0.28	0.17	−0.62, 0.06
Comfortable driving distance from home												
10 miles or less												
more than 10 miles	−0.03	0.14	−0.31, 0.26	0.33*	0.12	0.08, 0.59	−0.05	0.14	−0.34, 0.23	0.24*	0.12	0.00, 0.49
Marital status												
Married or living with a partner												
Widowed	−0.20	0.14	−0.48, 0.08	−0.03	0.12	−0.28, 0.22	−0.18	0.13	−0.46, 0.09	−0.05	0.12	−0.28, 0.19
Divorced/separated or single	−0.26	0.15	−0.56, 0.04	−0.04	0.13	−0.30, 0.24	−0.24	0.14	−0.53, 0.06	−0.02	0.12	−0.28, 0.23
Employment Status												
Employed												
Unemployed/retired/not working	−0.07	0.10	−0.28, 0.14	−0.01	0.09	−0.19, 0.17	−0.09	0.10	−0.29, 0.12	0.00	0.08	−0.17, 0.17
Annual household income												
<$30 000												
$30 000–$49 000	0.10	0.11	−0.13, 0.33	0.13	0.11	−0.10, 0.36	0.12	0.11	−0.10, 0.35	0.15	0.11	−0.07, 0.37
$50 000-$79 000	0.10	0.13	−0.17, 0.38	0.09	0.12	−0.16, 0.34	0.14	0.13	−0.13, 0.41	0.06	0.12	−0.18, 0.30
>$80 000	−0.05	0.15	−0.37, 0.26	−0.01	0.15	−0.32, 0.28	−0.06	0.15	−0.37, 0.25	−0.05	0.14	−0.34, 0.24
Age (years)	0.00	0.01	−0.01, 0.02	0.00	0.01	−0.02, 0.02	0.01	0.01	−0.01, 0.02	0.00	0.01	−0.01, 0.02
BMI (kg/m^2)	−0.01	0.01	−0.03, 0.01	−0.01	0.01	−0.02, 0.01	−0.01	0.01	−0.03, 0.01	−0.01	0.01	−0.02, 0.01
Duration at current address (years)	0.00	0.00	−0.00, 0.01	0.00	0.00	−0.00, 0.01	0.00	0.00	−0.00, 0.01	0.01*	0.00	0.00, 0.01
Number of people living in household	−0.05	0.07	−0.19, 0.09	−0.02	0.07	−0.16, 0.11	−0.05	0.07	−0.19, 0.09	−0.00	0.06	−0.13, 0.13

*$P<0.05$; **$P<0.01$.

at the current address had a positive relationship with social cohesion. Alternatively, participants with higher education levels experienced higher social cohesion in Seattle/King County, while this relationship was not observed in the Baltimore/DC region.

Associations between built environment profiles and quality of life

The examination of GIS-based built environment profiles and quality of life (Table 3) revealed no associations in the Seattle/King County region. In the Baltimore/DC region, participants living in M-M-M neighborhoods experienced a higher quality of life (marginal mean = 0.13 in a − 3.20 to 1.02 standardized scale) compared to those living in L-L-L neighborhoods (marginal mean = −0.89; $\beta = 0.22$, SE = 0.10, $P = 0.03$), as shown in Fig. 2 (electronic version only). Additional significant covariates are shown in Table 3.

The relations between perceived built environment profile and quality of life are illustrated in Table 3 and Fig. 3 (electronic version only). In Seattle/King County, participants living in MWMR neighborhoods experienced a higher quality of life (marginal mean = 0.14 in a −3.20 to 1.02 standardized

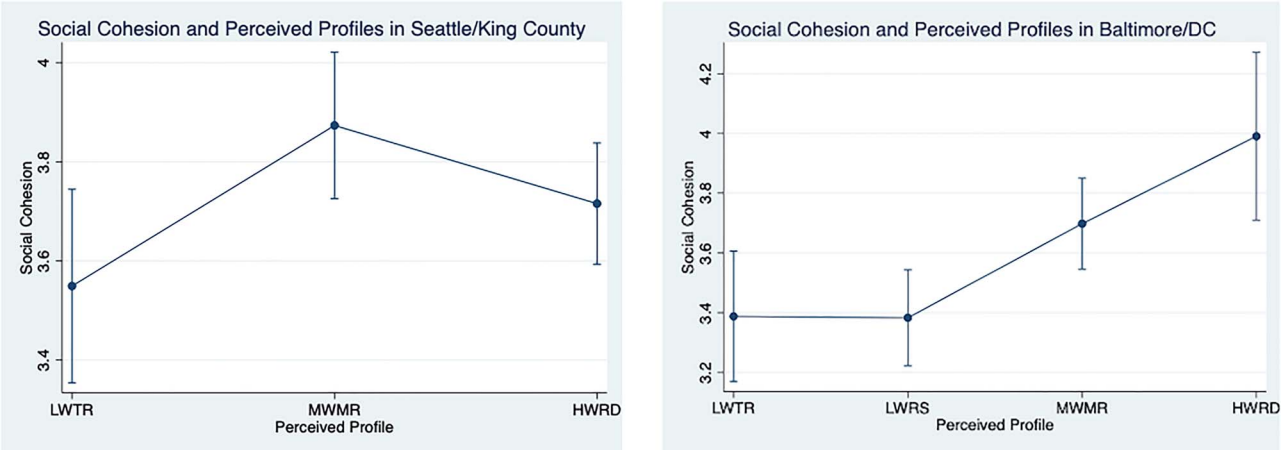

Fig. 1 Social cohesion and perceived BE profiles, Seattle/King County and Baltimore/DC.

scale) compared to those living in LWTR neighborhoods (marginal mean = −0.09; $\beta = 0.23$, SE = 0.12, $P = 0.04$), whereas in Baltimore/DC, participants who lived in HWRD neighborhoods experienced a higher quality of life (marginal mean = 0.34) compared to those who lived in LWTR neighborhoods (marginal mean = −0.08; $\beta = 0.42$, SE = 0.15, $P = 0.005$). Additional significant covariates are shown in Table 3.

Discussion

Main finding of this study

In our analysis of older participants sampled from Seattle/King County, WA and Baltimore, MD-Washington, DC, objective built environment profiles were not associated with neighborhood social cohesion and were only associated with quality of life in Baltimore/DC, but not in Seattle/King County. Alternatively, perceived built environment profiles that were seen as more walkable and destination-rich were associated with higher social cohesion and higher quality of life.

What is already known on this topic

In the previous research, elements of more walkable, destination-rich, activity-friendly built environments have been related to physical activity[20,31,32], and have been shown to have additional co-benefits.[33,34] Sallis *et al*.[34] extensively reviewed the literature and summarized the evidence on the co-benefits of activity-friendly environments. The authors defined five physical activity settings (e.g. parks/open space/trails, schools). For each setting, evidence-based activity-friendly features were identified, along with six potential outcomes/co-benefits consisting of physical health, mental health, social benefits, safety/injury prevention, environmental sustainability and economics. It was concluded that the multidimensionality of the built environment and the combination of multiple environmental features produced stronger impacts on physical activity and other co-benefits than any single feature.[33,34]

What this study adds

To the best of our knowledge, this was the first investigation using latent profile analysis to examine and compare both objective (GIS-based) and perceived built environment profiles to neighborhood social cohesion and quality of life. Prior studies have often focused on a few built environment features without considering the complexity of the built environment. A latent profile analysis can offer a more comprehensive approach. Using latent profile analysis and building on previous work from SNQLS, the present investigation captured the multidimensionality of the built environment, including walkability, transit and recreational resources.

Clear differences were observed between the models generated for Seattle/King County and Baltimore/DC. Specifically, we observed regional differences in the associations between social cohesion and quality of life and demographic or individual-level variables, including race/ethnicity, education, income, employment status and driving capability. Despite the differences found in these individual-level variables, the models consistently showed perceived built environment profiles to be related to the quality of life and social cohesion. Alternatively, there was little evidence of an effect of objectively measured built environments on quality of life and social cohesion. This investigation thus indicates perceptions of existing built environment resources likely play an essential role in understanding older adults' assessments of neighborhood social cohesion and of their quality of life. Previous research using the same SNQLS dataset demonstrated the relevance of built environment perceptions for other

Table 3 Latent profiles and quality of life

Variables	*GIS-based latent profiles*						*Perceived latent profiles*					
	Seattle/King County			*Baltimore/DC*			*Seattle/King County*			*Baltimore/DC*		
	β	*SE*	*95% CI*	*β*	*SE*	*95% CI*	*β*	*SE*	*95% CI*	*β*	*SE*	*95% CI*
Latent profile membership												
L-L-L/LWTR												
LWRS	N/A			N/A			N/A			−0.10	0.11	−0.33, 0.14
M-M-M/MWMR	0.01	0.09	−0.18, 0.20	0.22*	0.10	0.01, 0.42	0.24*	0.12	0.00, 0.47	0.12	0.11	−0.10, 0.36
H-H-H/HWRD	0.51	0.28	−0.05, 1.09	0.24	0.15	−0.06, 0.54	0.03	0.10	−0.18, 0.25	0.42*	0.15	0.14, 0.77
Gender												
Male												
Female	0.08	0.08	−0.09, 0.24	−0.06	0.09	−0.25, 0.13	0.05	0.08	−0.11, 0.22	−0.02	0.09	−0.22, 0.15
Race/ethnicity												
Non-Hispanic white												
Racial/ethnic minority	0.03	0.11	−0.20, 0.25	0.07	0.08	−0.10, 0.24	−0.04	0.10	−0.26, 0.17	0.13	0.08	−0.04, 0.30
Education level												
High school or less												
Some college/vocational training	0.03	0.10	−0.18, 0.25	0.04	0.11	−0.20, 0.27	0.09	0.10	−0.13, 0.30	0.05	0.11	−0.17, 0.28
Completed college or university	0.04	0.11	−0.19, 0.27	0.08	0.13	−0.18, 0.34	0.10	0.11	−0.13, 0.33	0.03	0.13	−0.23, 0.28
Completed graduate degrees	−0.09	0.13	−0.35, 0.17	0.08	0.13	−0.18, 0.34	−0.10	0.13	−0.36, 0.17	0.08	0.12	−0.17, 0.33
Type of residence												
Single family house												
Apartment/condominium/ townhouse or other	0.04	0.12	−0.21, 0.29	−0.11	0.11	−0.33, 0.10	−0.01	0.12	−0.24, 0.23	−0.21*	0.11	−0.44, 0.00
Valid driver's license holder												
Yes												
No	0.32	0.19	−0.07, 0.71	−0.18	0.18	−0.54, 0.18	0.28	0.18	−0.09, 0.66	−0.22	0.17	−0.58, 0.13
Comfortable driving distance from home												
10 miles or less												
more than 10 miles	0.09	0.12	−0.16, 0.35	0.38**	0.12	0.13, 0.63	0.10	0.12	−0.15, 0.36	0.36*	0.12	0.11, 0.60
Marital status												
Married or living with a partner												
Widowed	−0.04	0.12	−0.28, 0.21	0.12	0.12	−0.14, 0.37	−0.07	0.12	−0.32, 0.17	0.07	0.12	−0.16, 0.33
Divorced/separated or single	−0.08	0.13	−0.34, 0.19	−0.08	0.13	−0.34, 0.19	−0.11	0.13	−0.37, 0.16	−0.10	0.13	−0.36, 0.16
Employment status												
Employed												
Unemployed/retired/not working	−0.28**	0.09	−0.47, −0.10	−0.13	0.09	−0.31, 0.06	−0.32**	0.09	−0.51, −0.14	−0.14	0.09	−0.32, 0.04
Annual household income												
<$30 000												
$30 000–$49 000	0.06	0.10	−0.14, 0.26	−0.25*	0.11	−0.48, −0.02	0.05	0.10	−0.15, 0.26	−0.27*	0.11	−0.49, −0.03
$50 000–$79 000	0.26*	0.12	0.02, 0.50	−0.01	0.12	−0.26, 0.24	0.24*	0.12	−0.00, 0.48	−0.07	0.12	−0.31, 0.17
>$80 000	0.27	0.14	−0.01, 0.55	−0.03	0.15	−0.33, 0.27	0.19	0.14	−0.09, 0.47	−0.09	0.15	−0.39, 0.21
Age (years)	−0.01	0.01	−0.02, 0.01	−0.01	0.01	−0.02, 0.01	−0.00	0.01	−0.02, 0.01	−0.01	0.01	−0.02, 0.01
BMI (kg/m^2)	−0.04**	0.01	−0.06, −0.02	−0.02*	0.01	−0.04, −0.00	−0.04**	0.01	−0.05, −0.02	−0.02*	0.01	−0.04, 0.00
Duration at current address (years)	0.00	0.00	−0.00, 0.01	−0.00	0.00	−0.01, 0.01	0.00	0.00	−0.00, 0.01	−0.00	0.00	−0.01, 0.01
Number of people living in household	0.05	0.06	−0.08, 0.17	0.01	0.07	−0.12, 0.15	0.05	0.06	−0.08, 0.17	0.01	0.06	−0.12, 0.14

*$P<0.05$; *$P<0.01$.

outcomes.[35,36] Hong *et al*., for example, showed that parks and tree-lined streets, elements of green space, may be less advantageous to those who perceived their neighborhoods as unsafe for pedestrians.[36]

Future research could focus on examining the discrepancies between people's perceptions of their environment and objective measures of the environment, and on determining what are the drivers of these discrepancies. Moreover, it will be important for future research to focus on understanding and evaluating the relative effectiveness of interventions aimed at changing perceptions of the built environment, compared to interventions that modify concrete aspects of the built environment, on outcomes including quality of life and social cohesion.

Limitations and strengths of this study

This study had several limitations as well as strengths. Strengths included the use of latent profile analysis to examine objectively measured and perceived built environment profiles of the same cohort, and the use of validated self-report measures of neighborhood social cohesion and quality of life. Limitations included the cross-sectional nature of the study, which prevents causal inference. Longitudinal research is indicated, which would allow investigation of mediational

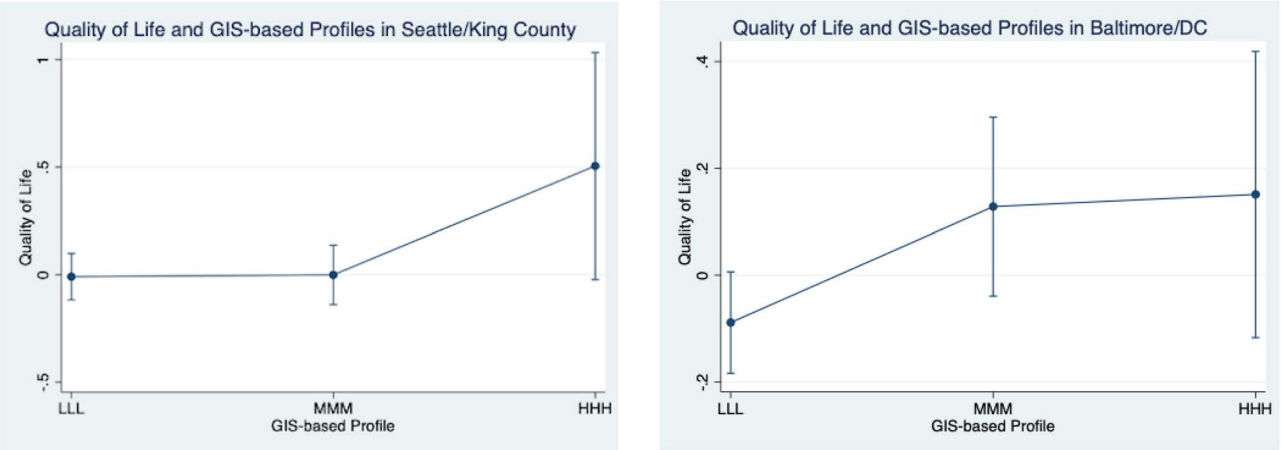

Fig. 2 Quality of life and GIS-based BE profiles, Seattle/King County and Baltimore/DC Regions (electronic version only).

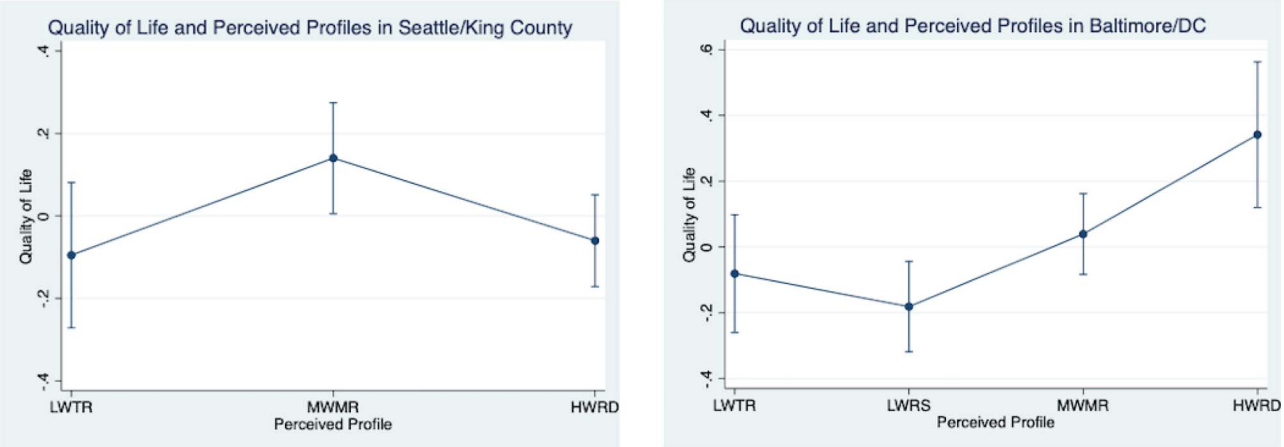

Fig. 3 Quality of life and perceived BE profiles, Seattle/King County and Baltimore/DC (electronic version only).

and moderator effects of the variables being studied. In addition, the sample lacked substantial diversity, with 30% racial/ethnic minorities (as opposed to 40% across the US population),[37] and the sample was relatively highly educated, which limits the generalizability of study results. Given that we documented differential results by region, results of this investigation may not generalize to other locales. Moreover, some of the identified built environment profiles had small sample sizes. For example, only 1.9% and 9.3% of the participants in Baltimore/DC, but not in Seattle/King County, respectively, were categorized under the H-H-H objective profile, which may have hindered our ability to find statistical significance despite positive association trends. Finally, there are likely other unmeasured environmental variables, such as air pollution and noise, as well as other unmeasured individual-level variables, such as personal social networks and perceived stress, that could have impacts on the relationships between the built environment and social cohesion and quality of life.

Conclusion

Healthy aging can increase seniors' quality of life and reduce society's healthcare costs, but it requires support from both built and social environments.[9] In the present study, no association was found between objective built environment profiles and social cohesion. Alternatively, more walkable and destination-rich perceived built environment profiles were associated with higher social cohesion and quality of life. These variables have been related to physical activity among older and younger age groups in prior studies.[18,23,31,32,34,38] It thus appears that perceiving the neighborhood environment as activity-supportive could have additional co-benefits regarding social cohesion and quality of life for older adults, in addition to other age groups. Nevertheless, the cross-sectional nature of this study impedes our ability to draw causal inferences, and thus future longitudinal studies are warranted. Latent profile analysis offers an arguably more comprehensive approach to assessing the built environments

than more commonly used analytic approaches that examine one or two built environment assets at a time. The finding that seniors who perceived their environments as highly walkable and recreationally dense experienced higher neighborhood social cohesion and quality of life may set the stage for future longitudinal and interventional research and eventually contribute to healthy aging.

Supplementary data

Supplementary data are available at the *Journal of Public Health* online.

Conflicts of interests

None.

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Authors' contributions

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Interpretation of results: JH, BC, AK, AM.
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References

1 Rowe JW, Kahn RL. Successful aging. *Gerontologist* 1997;**37**(**4**):433–40.

2 Choi M, Lee M, Lee MJ *et al.* Physical activity, quality of life and successful ageing among community-dwelling older adults. *Int Nurs Rev* 2017;**64**(**3**):396–404.

3 Li CI, Lin CH, Lin WY *et al.* Successful aging defined by health-related quality of life and its determinants in community-dwelling elders. *BMC Public Health* 2014;**14**(**1**):1013.

4 Montross LP, Depp C, Daly J *et al.* Correlates of self-rated successful aging among community-dwelling older adults. *Am J Geriatr Psychiatry* 2006;**14**(**1**):43–51.

5 Reichstadt J, Sengupta G, Depp CA *et al.* Older adults' perspectives on successful aging: qualitative interviews. *Am J Geriatr Psychiatry* 2010;**18**(**7**):567–75.

6 Daskalopoulou C, Stubbs B, Kralj C *et al.* Physical activity and healthy ageing: a systematic review and meta-analysis of longitudinal cohort studies. *Ageing Res Rev* 2017;**38**:6–17.

7 Friedman SM, Mulhausen P, Cleveland ML *et al.* Healthy aging: American Geriatrics Society white paper executive summary. *J Am Geriatr Soc* 2019;**67**(**1**):17–20.

8 Jeste DV, Blazer DG II, Buckwalter KC *et al.* Age-friendly communities initiative: public health approach to promoting successful aging. *Am J Geriatr Psychiatry* 2016;**24**(**12**):1158–70.

9 Hernandez DC, Johnston CA. Individual and environmental barriers to successful aging: the importance of considering environmental supports. *Behav Med Rev* 2017;**11**(**1**):21–3.

10 Engel L, Chudyk AM, Ashe MC *et al.* Older adults' quality of life - exploring the role of the built environment and social cohesion in community-dwelling seniors on low income. *Soc Sci Med* 2016;**164**:1–11.

11 Kawachi I, Berkman L. Social cohesion, social capital, and health. In: Berkman L, Kawachi I (eds). *Social Epidemiology*. Oxford: Oxford University Press, 2000, 174–90.

12 Zhang W, Liu S, Sun F, Dong X. Neighborhood social cohesion and cognitive function in U.S. Chinese older adults-findings from the PINE study. *Aging Ment Health* 2019;**23**(**9**):1113–21.

13 Choi YJ, Matz-Costa C. Perceived neighborhood safety, social cohesion, and psychological health of older adults. *Gerontologist* 2018;**58**(**1**):196–206.

14 Lagisetty PA, Wen M, Choi H *et al.* Neighborhood social cohesion and prevalence of hypertension and diabetes in a south Asian population. *J Immigr Minor Health* 2016;**18**(**6**):1309–16.

15 Kim ES, Park N, Peterson C. Perceived neighborhood social cohesion and stroke. *Soc Sci Med* 2013;**97**:49–55.

16 Dong X, Bergren SM. The associations and correlations between self-reported health and neighborhood cohesion and disorder in a community-dwelling U.S. Chinese population. *Gerontologist* 2017;**57**(**4**):679–95.

17 Kim ES, Kawachi I. Perceived neighborhood social cohesion and preventive healthcare use. *Am J Prev Med* 2017;**53**(**2**):e35–40.

18 Adams MA, Ding D, Sallis JF *et al.* Patterns of neighborhood environment attributes related to physical activity across 11 countries: a latent class analysis. *Int J Behav Nutr Phys Act* 2013;**10**(**1**):34.

19 Adams MA, Sallis JF, Conway TL *et al.* Neighborhood environment profiles for physical activity among older adults. *Am J Health Behav* 2012;**36**(**6**):757–69.

20 Adams MA, Sallis JF, Kerr J *et al.* Neighborhood environment profiles related to physical activity and weight status: a latent profile analysis. *Prev Med* 2011;**52**(**5**):326–31.

21 Todd M, Adams MA, Kurka J *et al.* GIS-measured walkability, transit, and recreation environments in relation to older Adults' physical activity: a latent profile analysis. *Prev Med* 2016;**93**:57–63.

22 Barnett A, Zhang CJP, Johnston JM *et al.* Relationships between the neighborhood environment and depression in older adults: a systematic review and meta-analysis. *Int Psychogeriatr* 2018;**30**(**8**):1153–76.

23 Cerin E, Nathan A, Van Cauwenberg J *et al.* The neighbourhood physical environment and active travel in older adults: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act* 2017;**14**(**1**):15.

24 King AC, Sallis JF, Frank LD *et al.* Aging in neighborhoods differing in walkability and income: associations with physical activity and obesity in older adults. *Soc Sci Med* 2011;**73**(**10**):1525–33.

25 Szende A, Oppe M, Devlin NJ. *EQ-5D Value Sets: Inventory, Comparative Review and User Guide*. Dordrecht, The Netherlands: Springer, 2007.

26 Parker EA, Lichtenstein RL, Schulz AJ *et al.* Disentangling measures of individual perceptions of community social dynamics: results of a community survey. *Health Educ Behav* 2001;**28**(**4**):462–86.

27 Collins LM, Lanza ST. *Latent class and latent transition analysis: with applications in the social, behavioral, and health sciences*. Hoboken, NJ: John Wiley & Sons, Inc., 2010.

28 Cerin E, Saelens BE, Sallis JF *et al.* Neighborhood environment walkability scale: validity and development of a short form. *Med Sci Sports Exerc* 2006;**38**(**9**):1682–91.

29 Saelens BE, Sallis JF, Black JB *et al.* Neighborhood-based differences in physical activity: an environment scale evaluation. *Am J Public Health* 2003;**93**(**9**):1552–8.

30 Brownson RC, Chang JJ, Eyler AA *et al.* Measuring the environment for friendliness toward physical activity: a comparison of the reliability of 3 questionnaires. *Am J Public Health* 2004;**94**(**3**):473–83. doi: 10.2105/ajph.94.3.473.

31 Cain KL, Millstein RA, Sallis JF *et al.* Contribution of streetscape audits to explanation of physical activity in four age groups based on the microscale audit of pedestrian streetscapes (MAPS). *Soc Sci Med* 2014;**116**:82–92.

32 Sallis JF, Bowles HR, Bauman A *et al.* Neighborhood environments and physical activity among adults in 11 countries. *Am J Prev Med* 2009;**36**(**6**):484–90.

33 Glonti K, Mackenbach JD, Ng J *et al.* Psychosocial environment: definitions, measures and associations with weight status—a systematic review. *Obes Rev* 2016;**17**:81–95.

34 Sallis JF, Spoon C, Cavill N *et al.* Co-benefits of designing communities for active living: an exploration of literature. *Int J Behav Nutr Phys Act* 2015;**12**(**1**):30.

35 Chrisinger BW, King AC, Hua J *et al.* How well do seniors estimate distance to food? The accuracy of older adults' reported proximity to local grocery stores. *Geriatrics* 2019;**4**(**1**):11.

36 Hong A, Sallis JF, King AC *et al.* Linking green space to neighborhood social capital in older adults: the role of perceived safety. *Soc Sci Med* 2018;**207**:38–45.

37 Schaeffer K. *The most common age among whites in the U.S. is 58- more than double that of racial and ethnic minorities*. Washington, DC: Pew Research Center; 2019. https://www.pewresearch.org/fact-tank/2019/07/30/most-common-age-among-us-racial-ethnic-groups/ (22 April 2020, datelast accessed).

38 Giles-Corti B, Foster S, Shilton T, Falconer R. The co-benefits for health of investing in active transportation. *N S W Public Health Bull* 2010;**21**(**6**):122–7.