Published in final edited form as:

Prev Med. 2011 May 1; 52(5): 326–331. doi:10.1016/j.ypmed.2011.02.020.

Neighborhood Environment Profiles Related to Physical Activity and Weight Status: A Latent Profile Analysis

Marc A. Adams, Ph.D.^a, James F. Sallis, Ph.D.^a, Jacqueline Kerr, Ph.D.^b, Terry L. Conway, Ph.D.^a, Brian E. Saelens, Ph.D.^c, Lawrence D. Frank, Ph.D.^d, Gregory J. Norman, Ph.D.^b, and Kelli L. Cain, M.A.^a

^(a)San Diego State University, 3900 Fifth Avenue, Suite 310, San Diego, CA 92103

^(b)University of California, San Diego, 9500 Gilman Drive (MC#0811), Atkinson Hall (Calit2), La Jolla, CA 92093

^(c)Seattle's Children's Hospital, University of Washington, MPW 8-1 Child, Health and Behavioral Development, 1100 Olive Way, Suite 500, Seattle, WA 98101

^(d)University of British Columbia, 1933 West Mall Room 231, Vancouver, BC, Canada V6T 1Z2

Abstract

Background—Neighborhood built environments (BE) include combinations of co-existing stimuli influencing physical activity (PA). Dealing with numerous environmental variables and complexity presents a significant challenge. The current analysis explored whether a range of reported BE features associated with adults' physical activity produced distinct multivariate patterns, and tested whether adults' PA and body mass differed by BE profiles.

Methods—Participants (20–65 years, 48.2% female, 26% ethnic minority) were recruited between 2002–2005 from 32 neighborhoods from Seattle-King County, WA (N= 1,287) and Baltimore, MD - Washington, DC regions (N=912). Independent Latent Profile Analyses were conducted in each region with 11 environmental variables from the Neighborhood Environment Walkability Scale. Validity of the neighborhood profiles was examined by their relationship to PA (accelerometer-derived moderate-to-vigorous minutes/day, self-reported minutes/week of walking for transportation and leisure) and self-reported BMI using ANCOVA models.

Results—Neighborhood profiles for Seattle and Baltimore regions were visually similar, suggesting generalizability. High-walkable recreationally-dense neighborhoods differed significantly from other neighborhood types by as much as 13 MVPA minutes/day, almost 60 minutes/week of walking for transportation, and 75 minutes/week of leisure-time activity. Neighborhood profiles also differed significantly for BMI.

Discussion—These findings could help identify optimal patterns of environmental attributes that facilitate physical activity and improve weight status.

© 2011 Elsevier Inc. All rights reserved.

Corresponding Author: Marc A. Adams, Ph.D., M.P.H., San Diego State University, 3500 5th Ave Suite 300, San Diego, CA, 92103, USA, Phone: 619-260-5540, Fax: 619-260-1510, madams@projects.sdsu.edu.

Conflict of Interest The authors declare that there are no conflicts of interest.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Keywords

environment; ecological; exercise; overweight; typology; latent class analysis

1.0. Introduction

Ecological models posit that macro-level features of built environments influence physical activity (Sallis et al., 2009a). Neighborhood built environments include combinations of co-existing stimuli that influence physical activity (Hovell et al, 2009). For example, it is common for some neighborhoods in urban areas to have high land use mix, street connectivity and residential density, while in other parts of the same city, neighborhoods have different combinations of the same features. A significant challenge is how to account for numerous variables and complex patterns of built environments. Several approaches have been reported (Cerin et al., 2009; Cervero and Duncan, 2003; Frank et al., 2010; Rosenberg et al., 2009).

The purposes of the current analysis were to (a) explore whether numerous built environment features hypothesized to be associated with adults' physical activity produced distinct neighborhood environment profiles, and (b) test whether adults' physical activity and weight status differed by the neighborhood environment profiles.

2.0. Methods

2.1. Design and Sampling

The design for the Neighborhood Quality of Life Study (NQLS) has been described (Sallis et al., 2009b). Briefly, NQLS was an epidemiological study of health outcomes among residents sampled from neighborhoods stratified on objectively-measured built environment factors indicating "walkability" (i.e. residential density, land use mix, intersection density, and retail floor area ratio) and median household income from the 2000 U.S. Census. Participants were recruited by systematic sampling methods between 2002 and 2005 from 16 neighborhoods from Seattle-King County, WA (n= 1,287) and 16 neighborhoods from Baltimore, MD - Washington, DC regions (n=912). Participants were recruited across all neighborhood types simultaneously to prevent seasonal bias. Eligible participants were between 20 and 65 years, literate in English, not living in a group living establishment, and physically able to walk. As reported earlier (Sallis et al., 2009b), the study sample was older, had fewer females, more whites, fewer Hispanics, and higher household incomes than census data for the same areas. Institutional Review Boards from participating institutions approved the study.

2.2. Measures

2.2.1. Neighborhood Environment Walkability Scale (NEWS)—The NEWS was developed to measure constructs from transportation and urban planning literatures related to physical activity, mostly for transportation purposes (Saelens et al., 2003). Subscales included residential density, land use mix-diversity, land use mix-access, street connectivity, walking and cycling facilities, aesthetics, pedestrian/traffic safety, and crime safety (scoring procedures at www.drjamessallis.sdsu.edu). As appropriate, response options were recoded so higher values were expected to be related to more physical activity. Housing type items for the residential density subscale were rated on a 5-point scale from 'none' to 'all,' with the scale computed as the sum of item responses weighted by values approximating density of households per unit area (relative to a single-family detached residence). Land use mix-diversity items measured walking time (proximity) from the home to 23 facilities/

establishments (e.g., grocery store, library) on a 5-point scale from '31 minutes or more' to from '1-5 minutes'; scale was computed as the mean. Participants rated items from remaining NEWS sections on a 4-point scale ranging from 'strongly disagree' to 'strongly agree;' scales were computed as the mean. Reliability and validity of the NEWS has been supported in multiple studies across several countries (Adams et al., 2009; Brownson et al., 2004; Cerin et al., 2009; Cerin et al., 2006; Saelens et al., 2003).

In addition to the NEWS subscales, individual NEWS items were selected a priori because of their hypothesized association with transportation or recreational physical activity as well their relevance to modifiable policies and environmental attributes that could support physical activity. These items included distance to the nearest 'bus or train stop', 'recreation center' and 'gym or fitness facility'. Distance was measured on the same recoded scale as land use mix-diversity.

2.2.2. Physical Activity—Moderate-to-vigorous physical activity (MVPA) was measured objectively with the Actigraph (model 7164 or 71256) accelerometer. Participants wore the accelerometer on their waist during waking hours for 7 days. A 'valid day' was at least 8 valid hours of wear, with a valid hour consisting of <30 consecutive zero values. Participants were asked to rewear the accelerometer if <5 valid days or a minimum of 66 valid hours across 7 days was observed. On valid days, each 1-minute epoch was scored as meeting or not meeting a criterion of at least moderate intensity physical activity based on the Freedson cut-point for adults (Freedson et al., 1998). Actigraph accelerometers produce reliable and valid measures of physical activity (Welk, 2002; Welk et al., 2004). Average MVPA minutes/day was used in analyses.

2.2.3. The International Physical Activity Questionnaire (IPAQ)—long form measured physical activity over the last 7 days. Participants reported the frequency and duration of walking for transportation and leisure-time physical activity. Leisure time minutes per week was operationalized as the sum of frequency (times per week) multiplied by duration (minutes per day) of walking, moderate-intensity, and vigorous-intensity physical activities done for leisure. A similar variable was computed for minutes per week of walking for transportation. IPAQ reliability and validity when compared to accelerometers was similar to other self-report measures of physical activity (Craig et al., 2003).

2.2.4. Body mass index (BMI)—BMI (kg / m^2) was calculated using self-reported weight and height.

2.2.5. Demographics—The survey assessed sex, age (years), ethnicity (non-Hispanic white versus non-white or Hispanic), annual household income (eleven levels from <10,000 to >100,000), education (five levels from >high school to graduate degree), number of motor vehicles per adults in household (continuous), marital or cohabitation status (married or living together versus other), number of people in household (continuous), and years at current address (continuous).

2.3. Analyses

Descriptive statistics (range, mean, SD) were examined for all variables. For each region (Seattle and Baltimore), a Latent Profile Analysis (LPA) was conducted independently with 11 environmental variables (8 NEWS subscales and 3 individual NEWS items). LPA statistically derives mutually exclusive classes that maximize between-group variance and minimize within-group variance based on model fit criteria (Collins and Lanza, 2010). These classes are a function of the patterns associated with the environmental variables.

Robust standard errors accounted for the non-normality of indicators and non-independence of observations.

We tested for latent profile solutions of 1 to 6 classes in Seattle and Baltimore regions, independently. We did not choose to conduct a pooled analysis because the LPA is an exploratory technique and conducting cross-validation a stronger approach. Models were compared to examine the best fit to the data; a bootstrapped Lo-Mendell-Rubin Test (LMRT), sample sizes, and interpretability of the classes determined the number of latent classes. A significant LMRT test (i.e. p -value $< .05$) indicated the “higher class” solution fit the data better (e.g., 2-class better than 1-class). Interpretation was based upon the z -scores of observed variables within and between classes. The LPA was conducted using Mplus 6.0 software.

Convergent validity of the neighborhood profiles was determined by examining the relationship of profiles to physical activity (accelerometer MVPA minutes/day, IPAQ walking for transportation and leisure-time minutes/week) and BMI using ANCOVA models with least significant difference (LSD) posthoc tests in SPSS (version 18). Because self-report physical activity distributions were skewed, natural log transformed variables were used in regression models and antilogged to report geometric means and 95% confidence intervals in tables. ANCOVA models were adjusted for sex, age, annual household income, education, ethnicity, motor vehicles/adults in household, marital status, number of people in household, and years at current address.

3.0. Results

Table 1 compares sample demographics for Seattle and Baltimore regions. A total of 1283 (99.7% of enrolled participants) adults from Seattle and 909 (99.7%) adults from Baltimore regions had complete survey data and were included in the LPA analysis.

For both Seattle and Baltimore regions, the bootstrapped LMR test (all $ps < .0001$), BIC and AIC values all supported a 4-class over 3-class solution. Although the model fit estimates indicated 5 and 6 class solutions were possible, we chose a 4-class solution because this produced reasonable sample sizes per class ($>5\%$ of the sample) and interpretable neighborhood profiles. Tables 2 and 3 show item model-based means and standard errors for each latent profile by region. Figures 1a and 1b present the profiles with variable means standardized to z -scores by region.

For Seattle and Baltimore regions, the independent profiles were similar and they were labeled similarly. For both regions, the first profile was labeled as “Low Walkable/Transit and Recreationally Sparse (LWTRS)” and included 10.7% and 18.4% of the samples, respectively. The profile was characterized by a combination of environmental factors including low values for residential density, land use mix-diversity and -access, intersection density, and extremely low values on public transit access relative to the average of these variables for each region. This profile also had limited access to walking and cycling facilities, parks, and recreational centers. However, this profile had the highest crime safety value in both regions. Profile two was characterized as “Low Walkable/Recreationally Sparse (LWRS)” and included 37.6% and 26.1% of the region samples. The second profile was characterized by moderately low values (z -scores less than zero) for all environmental variables except public transit access. The third profile was “Moderately Walkable/Recreationally Dense (MWRD)” and included 45.8% and 44.8% of the sample, respectively. Profile three was characterized by moderately positive values of a similar magnitude (z -score about 0.5) for all environmental variables, except residential density. Profile four was labeled “High Walkable/Recreationally Dense (HWRD)” and included 5.9% and 10.7% of

the samples. This profile was characterized by the highest values for residential density, land use mix and access, and intersection density, in addition to large values for nearest fitness facility and parks.

Table 4 presents ANCOVA-adjusted means for physical activity and BMI by latent profile and region. In Seattle and Baltimore regions, participants differed significantly on their accelerometer-derived MVPA activity by neighborhood profile after adjusting for covariates (both omnibus $p \leq .05$). In both regions, the highest MVPA occurred in the High Walkable/ Recreationally Dense profile. Participants in the highest-active profile (HWRD) compared to the lowest active profile (LWTRS) had 8.8 more MVPA mins/day in Seattle and 13.3 MVPA mins/day difference in Baltimore.

Self-reported minutes of walking for transportation also differed significantly between profiles after adjusting for covariates (both omnibus $p \leq .001$). In Seattle, participants in the HWRD neighborhoods reported 66.3 more minutes/week of walking than those living in the LWTRS neighborhoods. The difference observed in Baltimore was 64.1 minutes/week between HWRD and LWTRS profiles. Notably, for both regions, reported minutes of walking for transportation increased across profiles as reported neighborhood walkability increased. Self-reported leisure-time physical activity varied significantly across neighborhood profiles for Seattle after adjusting for covariates (omnibus $p \leq .001$). In Seattle, participants in HWRD neighborhoods reported 74.8 more minutes/week than those living in LWTRS. Participants in Seattle also differed significantly on their BMI by neighborhood profile after adjusting for covariates (omnibus $p \leq .001$). For both regions, the lowest BMI was observed in the HWRD and the highest in the LWRS profiles, although this difference was not significant in Baltimore. A marginally significant difference of 2.1 kg/m² was observed between HWRD and LWRS profiles in Seattle. Leisure-time physical activity did not differ across profiles in the Baltimore region.

4.0. Discussion

The main finding was that neighborhood profile patterns of built and social environment variables (Figures 1a and 1b) were similar for Seattle and Baltimore regions, suggesting generalizability of these neighborhood profiles, at least in major metropolitan areas within the U.S. Moreover, neighborhood profiles were associated with significant and meaningful differences in adults' accelerometer-assessed (~13 min/day) and self-reported physical activity (~60 to 75 min/week). Neighborhoods' profiles for the Seattle region also differed by 2.1 kg/m² (about 12 pounds) for self-reported BMI.

The present analysis adds to main findings from the NQLS study by examining the patterning of reported neighborhood environment factors and whether the resulting profiles relate to various outcomes. Previously-reported analyses found that individuals living in high-walkable neighborhoods had 5.8 MVPA minutes/day more activity, measured objectively, than individuals living in low-walkable neighborhoods (Sallis et al., 2009b). The main NQLS analysis also found a difference of 31.5 more minutes/week for self-reported walking for transportation and a difference of about 0.5 kg/m² for BMI between these strata. The current analysis based on self-reported environmental attributes from the NEWS measured a larger variety of built environment features and adjusted for similar covariates as previous analyses.

It is possible that larger differences in outcomes observed in the current analysis compared to the previous NQLS analyses were a result of a greater number of variables considered in defining neighborhoods. Perhaps the LPA method is responsible for the greater ability to explain outcomes by accounting for the patterning of built environment features. It is also

possible that self-reported, rather than macro-level objective built environment features, capture more subtle differences in neighborhood characteristics that influence physical activity. It could be that the combination of these differences accounted for the stronger effects of the neighborhood profiles. In any case, the LPA method of creating neighborhood profiles is promising and worthy of further study.

Reported residential density, land use mix-diversity, land use mix-access, and street connectivity reflected components of the objective walkability index used to select study neighborhoods. As expected, self-reported measures of these same variables discriminated neighborhoods well. Thus, participants' reports of these four variables provided an independent validation of the objective sampling scheme of low and high walkable environments. Examining the entire pattern of self-reported measures of the built and social environments revealed novel patterns of coexisting transportation, safety, and recreational features of neighborhoods.

The magnitude of reported residential density, land mix use, and street connectivity for the HWRD profile is remarkable, relative to the differences across profiles on other variables. High residential density is needed to support a retail area with a variety of shops, services, and private recreation facilities (Ewing et al., 1996). The MWRD profile approximates the HWRD profile, except for level of residential density and crime safety. This observation may be of interest to urban designers and community members because these profiles mainly differed on modifiable housing density/walkability and crime. Importantly, individuals with the HWRD profile had the best health characteristics (i.e. highest physical activity and lowest BMI).

Examination of the LWTRS and the LWRS profiles reveals that these profiles differed importantly from each other and the other profiles. Public transit was similar across profiles except for LWTRS. This suggests that access to public transit may be a critical indicator of activity-friendliness that goes beyond the core concept of walkability and an important variable for future environmental measures and summary scores. Although the LWTRS profile also had the lowest residential density, it is possible that improving public transit options would increase physical activity in neighborhoods with this pattern. Previous research showed that users of public transportation lost about 6 pounds compared with non-users, and walked on average 17 minutes each trip (Besser and Dannenberg, 2005; MacDonald et al., 2010). However, it is well known that high residential density is needed to support acceptable frequency of transit service (Newman and Kenworthy, 2006), so a simple solution to low-walkable neighborhoods may not be feasible.

Low access to walking/cycling facilities, recreation facilities and parks clustered with other variables that indicated a low-walkable environment. Recreation facilities and parks have been associated with higher physical activity and lower BMI for adults (Kaczynski and Henderson, 2008) and should be considered when characterizing neighborhoods and considering environmental changes that could improve recreational activity.

The ranking of aesthetics and pedestrian/traffic safety across profiles was inconsistent, except for the LWRS profile that ranked the lowest on these features in both regions. In both regions the LWRS profile was lower on crime safety than the mean for each region, and the LWTRS profile was strongest profile for crime safety. It may be that aesthetics and pedestrian/traffic safety factors were difficult for participants to evaluate and therefore inconsistent. Crime safety likely varied more by neighborhood income than by objective walkability (Lovasi et al., 2009).

The similarity of the profiles between two U.S. regions suggests that these neighborhood types might be found in other cities or regions of the country. "Profiling neighborhoods"

using statistical patterning approaches, even if based on self-report measures, may reveal neighborhoods types for more targeted improvements for public health interventions or policy actions. For example, profiling neighborhoods within cities may help researchers convey to policy makers more effectively the relationships between the multitude of environmental characteristics and health outcomes. Before such efforts are considered, further examination of patterns of social and physical environments is needed across different cities to evaluate generalizability. The NEWS is an inexpensive measurement tool that might facilitate this effort.

4.1. Methodological Strengths and Considerations

Strengths included the use of validated measures of numerous built and social environment characteristics and use of two samples from different regions of the U.S. This cross-region replication is initial evidence of the external validity of the profiles. The neighborhood profiles were shown to have practical significance due to the strong associations with objective and self-reported health outcomes.

The analysis was constrained by a lack of study staff blinding during profile creation and a neighborhood sampling approach developed for the larger study that maximized the range of built environment attributes. Moreover, studies have found mismatch when examining concordance between reported and objectively-measured built environments (Gebel, Bauman, & Owen, 2009). Concordance seems to be affected by physical activity and demographic variables (Adams et al., 2009; Gebel et al., 2009). If physical activity improves awareness of the environment, then the associations between self-reported environment and physical activity may be upwardly biased compared to an analysis that uses GIS-based environment variables. Additionally, unmeasured variables could confound the results for BMI. Further study including intake and food-related environmental variables is needed to improve explanation of BMI outcomes. If we assumed a random sample from each city, the proportion of individuals associated with each profile would likely represent the prevalence of specific neighborhoods in each region. Because of the current study's sampling approach, proportions of individuals classified into specific profiles should not be interpreted as the prevalence of that profile in each region.

4.2. Conclusions

The present study found that unique neighborhood profiles could be derived from a range of built and social environment measures. These profiles based on 11 self-reported environmental variables were more strongly associated with physical activity and BMI than a 4-component GIS-based walkability index. A research implication is that more comprehensive neighborhood assessments may lead to stronger associations with health outcomes.

Acknowledgments

This project was supported by grants from the National Heart, Lung and Blood Institute (HL67350 & T32HL079891). We thank the anonymous reviewers for their helpful comments.

References

- Adams MA, Ryan S, Kerr J, Sallis JF, Patrick K, Frank L, et al. Validation of the Neighborhood Environment Walkability Scale (NEWS) items using Geographic Information Systems. *J Phys Act Health*. 2009; 6(Supp 1):S113–S123. [PubMed: 19998857]
- Besser LM, Dannenberg AL. Walking to public transit: steps to help meet physical activity recommendations. *Am J Prev Med*. 2005; 29:273–280. [PubMed: 16242589]

- Brownson RC, Chang JJ, Eyler AA, Ainsworth BE, Kirtland KA, Saelens BE, et al. Measuring the environment for friendliness toward physical activity: a comparison of the reliability of 3 questionnaires. *Am J Public Health*. 2004; 94:473–483. [PubMed: 14998817]
- Cerin E, Conway TL, Saelens BE, Frank LD, Sallis JF. Cross-validation of the factorial structure of the Neighborhood Environment Walkability Scale (NEWS) and its abbreviated form (NEWS-A). *Int J Behav Nutr Phys Act*. 2009; 6:32.10.1186/1479-5868-6-32 [PubMed: 19508724]
- Cerin E, Saelens BE, Sallis JF, Frank LD. Neighborhood Environment Walkability Scale: validity and development of a short form. *Med Sci Sports Exerc*. 2006; 38:1682–1691. [PubMed: 16960531]
- Cervero R, Duncan M. Walking, bicycling, and urban landscapes: evidence from the San Francisco Bay area. *Am J Public Health*. 2003; 93:1478–1483. [PubMed: 12948966]
- Collins, LM.; Lanza, ST. Latent class and latent transition analysis with application in the social, behavioral, and health sciences. Hoboken, New Jersey: John Wiley & Sons; 2010.
- Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, et al. International Physical Activity Questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc*. 2003; 35:1381–1395. [PubMed: 12900694]
- Ewing, RH.; DeAnna, M.; Heflin, CC.; Porter, D. Best development practices :doing the right thing and making money at the same time. Chicago: American Planning Association; 1996.
- Frank LD, Sallis JF, Saelens BE, Leary L, Cain K, Conway TL, et al. The development of a walkability index: application to the Neighborhood Quality of Life Study. *Br J Sports Med*. 2010; 44:924–933. [PubMed: 19406732]
- Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. *Med Sci Sports Exerc*. 1998; 30:777–781. [PubMed: 9588623]
- Gebel K, Bauman A, Owen N. Correlates of non-concordance between perceived and objective measures of walkability. *Ann Behav Med*. 2009; 37:228–238. [PubMed: 19396503]
- Hovell, MF.; Wahlgren, DR.; Adams, MA. The logical and empirical basis for the Behavioral Ecological Model. In: DiClemente, RJ., editor. *Emerging Theories in Health Promotion Practice and Research*. San Francisco: Jossey-Bass; 2009.
- Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. *Am J Prev Med*. 2002; 22:188–199. [PubMed: 11897464]
- Kaczynski AT, Henderson KA. Parks and recreation settings and active living: a review of associations with physical activity function and intensity. *J Phys Act Health*. 2008; 5:619–632. [PubMed: 18648125]
- Lovasi GS, Hutson MA, Guerra M, Neckerman KM. Built environments and obesity in disadvantaged populations. *Epidemiol Rev*. 2009; 31:7–20. [PubMed: 19589839]
- MacDonald JM, Stokes RJ, Cohen DA, Kofner A, Ridgeway GK. The effect of light rail transit on body mass index and physical activity. *Am J Prev Med*. 2010; 39:105–112. [PubMed: 20621257]
- Nelson MC, Gordon-Larsen P, Song Y, Popkin BM. Built and social environments associations with adolescent overweight and activity. *Am J Prev Med*. 2006; 31:109–117. [PubMed: 16829327]
- Newman P, Kenworthy J. Urban design to reduce automobile dependence. *Opolis*. 2006; 2:35–52.
- Norman GJ, Adams MA, Kerr J, Ryan S, Frank LD, Roesch SC. A latent profile analysis of neighborhood recreation environments in relation to adolescent physical activity, sedentary time, and obesity. *J Public Health Manag Pract*. 2010; 16:411–419. [PubMed: 20689390]
- Owen N, Cerin E, Leslie E, duToit L, Coffee N, Frank LD, et al. Neighborhood walkability and the walking behavior of Australian adults. *Am J Prev Med*. 2007; 33:387–395. [PubMed: 17950404]
- Rosenberg D, Ding D, Sallis JF, Kerr J, Norman GJ, Durant N, et al. Neighborhood Environment Walkability Scale for Youth (NEWS-Y): reliability and relationship with physical activity. *Prev Med*. 2009; 49:213–218. [PubMed: 19632263]
- Saelens BE, Sallis JF, Black JB, Chen D. Neighborhood-based differences in physical activity: an environment scale evaluation. *Am J Public Health*. 2003; 93:1552–1558. [PubMed: 12948979]
- Sallis, JF.; Kerr, J. Physical activity and the built environment. In: Young, D.; Pangrazi, RP.; Ainsworth, BE., editors. *President's Council on Physical Fitness and Sports Research Digest*. 2006.

- Sallis, JF.; Owen, N.; Fisher, E. Ecological models of health behavior. In: Glanz, K.; Rimer, BK.; Viswanath, K., editors. Health behavior and health education: Theory, Research, and Practice. San Francisco: Jossey-Bass; 2009a. p. 465-482.
- Sallis JF, Saelens BE, Frank LD, Conway TL, Slymen DJ, Cain KL, et al. Neighborhood built environment and income: examining multiple health outcomes. *Soc Sci Med*. 2009b; 68:1285–1293. [PubMed: 19232809]
- Van Dyck D, Cardon G, Deforche B, Sallis JF, Owen N, De Bourdeaudhuij I. Neighborhood SES and walkability are related to physical activity behavior in Belgian adults. *Prev Med*. 2010; 50:S74–S79. [PubMed: 19751757]
- Welk, G. Use of accelerometry-based activity monitors to assess physical activity. In: Welk, G., editor. Physical activity assessments for health-related research. Champaign, IL: Human Kinetics Publishers; 2002. p. 125-141.
- Welk GJ, Schaben JA, Morrow JR Jr. Reliability of accelerometry-based activity monitors: a generalizability study. *Med Sci Sports Exerc*. 2004; 36:1637–1645. [PubMed: 15354049]
- Yan AF, Voorhees CC, Clifton K, Burnier C. “Do you see what I see?” - correlates of multidimensional measures of neighborhood types and perceived physical activity-related neighborhood barriers and facilitators for urban youth. *Prev Med*. 2010; 50:S18–S23. [PubMed: 19799931]

Figure 1.

a. Four latent neighborhood profiles for the Seattle region (Z-scores), 2002-2005.

b. Four latent neighborhood profiles for the Baltimore region (Z-scores), 2002-2005.

Note: LWTRS = Low Walkable, Transit and Recreationally Sparse profile. LWRS = Low Walkable and Recreationally Sparse profile. MWRD = Moderately Walkable and Recreationally Dense profile. HWRD = High Walkable and Recreationally Dense profile.

¹Example interpretation: A z-score equal to one means that the indicator variable was one standard deviation greater than the mean value of that indicator for the region.

Table 1
Participant demographics and personal characteristics for Seattle and Baltimore, 2002-2005.

	Seattle (n=1283) ¹	Baltimore (n=909) ¹
Sex (% female)	45.2	52.3
Age	44.0 (11.0)	46.6 (10.7)
Income (\$ year - median)	60,000-69,000	70,000-79,000
Education (% at least college degree)	63.2	67.6
Race/Ethnicity (% non-white)	18.0	37.4
Vehicles per adult	1.1 (0.6)	1.0 (0.5)
Married or living w/partner (%)	63.2	60.5
# people in household	2.6 (1.4)	2.7 (1.4)
How long at current address (years)	9.3 (9.2)	12.3 (8.9)
Accelerometer MVPA min/d ²	35.90 (24.9)	28.74 (21.8)
IPAQ transport walking min/wk	173.95 (359.4)	171.41 (302.8)
IPAQ leisure min/wk	255.38 (363.1)	220.43 (324.0)
BMI (kg/m ²)	26.6 (5.5)	27.2 (5.9)

¹ Values are means (SD) unless noted.

² Valid accelerometer data was available for 1233 (95.8%) adults from Seattle and 888 (97.4%) adults from Baltimore.

Table 2

Item response means and standard errors from the latent profile analysis for the Seattle region, 2002–2005.

	Low Walk / Transit & Rec Sparse Mean (SE)	Low Walk / Rec Sparse Mean (SE)	Mod. Walk / Rec Dense Mean (SE)	High Walk / Rec Dense Mean (SE)	Total Sample Mean (SD)
	n = 137 (10.7%)	n = 482 (37.6%)	n = 588 (45.8%)	n = 76 (5.9%)	n = 1283
Residential Density	190.53 (2.24)	202.07 (1.80)	215.16 (4.47)	400.89 (30.03)	218.67 (60.93)
Land Use Mix Diversity	2.37 (0.07)	2.75 (0.05)	3.85 (0.05)	4.16 (0.07)	3.29 (0.86)
Land Use Mix Access	2.34 (0.06)	2.64 (0.03)	3.23 (0.03)	3.46 (0.05)	2.93 (0.60)
Street Connectivity	2.24 (0.06)	2.51 (0.04)	3.13 (0.03)	3.29 (0.06)	2.81 (0.64)
Walking & Cycling Facilities	2.44 (0.07)	2.50 (0.05)	3.19 (0.03)	3.15 (0.08)	2.85 (0.69)
Aesthetics	3.03 (0.05)	2.73 (0.04)	3.32 (0.04)	3.32 (0.09)	3.07 (0.64)
Pedestrian Traffic Safety	2.76 (0.04)	2.67 (0.04)	3.11 (0.03)	3.02 (0.08)	2.90 (0.51)
Crime Safety	3.54 (0.05)	3.22 (0.04)	3.49 (0.03)	3.13 (0.12)	3.37 (0.61)
Bus or Train Stop	2.31 (0.10)	4.58 (0.04)	4.89 (0.02)	4.95 (0.04)	4.50 (0.92)
Nearest Park	3.00 (0.14)	3.47 (0.07)	4.64 (0.03)	4.60 (0.08)	4.02 (1.16)
Nearest Fitness Facility	1.92 (0.08)	1.95 (0.06)	3.66 (0.07)	3.65 (0.16)	2.83 (1.26)

Table 3

Item response means and standard errors from the latent profile analysis for the Baltimore region, 2002-2005.

	Low Walk / Transit & Rec Sparse Mean (SE)	Low Walk / Rec Sparse (SE)	Mod. Walk / Rec Dense Mean (SE)	High Walk / Rec Dense (SE)	Total Sample Mean (SD)
	n = 167 (18.4%)	n = 237 (26.1%)	n = 407 (44.8%)	n = 98 (10.7%)	n = 909
Residential Density	208.25 (4.82)	228.87 (4.85)	217.47 (2.76)	433.65 (13.70)	241.99 (83.59)
Land Use Mix Diversity	1.98 (0.06)	2.83 (0.14)	3.40 (0.11)	3.73 (0.07)	3.03 (0.90)
Land Use Mix Access	2.38 (0.05)	2.81 (0.05)	3.13 (0.04)	3.39 (0.05)	2.94 (0.55)
Street Connectivity	2.37 (0.05)	2.77 (0.05)	3.00 (0.05)	3.13 (0.06)	2.84 (0.62)
Walking & Cycling Facilities	2.90 (0.06)	2.71 (0.07)	3.27 (0.03)	2.91 (0.05)	3.02 (0.60)
Aesthetics	3.24 (0.04)	2.61 (0.08)	3.44 (0.03)	3.08 (0.07)	3.15 (0.59)
Pedestrian Traffic Safety	2.83 (0.05)	2.58 (0.08)	3.17 (0.02)	2.83 (0.05)	2.92 (0.48)
Crime Safety	3.60 (0.04)	2.77 (0.14)	3.57 (0.03)	3.18 (0.07)	3.32 (0.64)
Bus or Train Stop	1.60 (0.11)	4.64 (0.06)	4.59 (0.05)	4.54 (0.10)	4.05 (1.36)
Nearest Park	2.88 (0.13)	3.48 (0.17)	4.32 (0.12)	4.41 (0.13)	3.85 (1.34)
Nearest Fitness Facility	1.60 (0.07)	2.13 (0.20)	2.95 (0.15)	3.23 (0.14)	2.52 (1.26)

Note: Low Walk / Transit & Rec Sparse = Low Walkable, Transit and Recreationally Sparse profile. Low Walk / Rec Sparse = Low Walkable and Recreationally Sparse profile. Mod. Walk / Rec Dense = Moderately Walkable and Recreationally Dense profile. High Walk / Rec Dense = High Walkable and Recreationally Dense profile.

Table 4
Adjusted means for physical activity and body mass variables by latent profile for Seattle and Baltimore regions, 2002-2005.

	Seattle Region				
	Low Walk / Transit & Rec Sparse ^a Mean (95% CI)	Low Walk / Rec Sparse ^b Mean (95% CI)	Mod. Walk / Rec Dense ^c Mean (95% CI)	High Walk / Rec Dense ^d Mean (95% CI)	
MVPA min/d	31.99 ^{a,b} (27.66 - 36.30)	34.69 ^{a,b,c,d} (32.42 - 36.96)	37.14 ^{b,c,d} (35.09 - 39.18)	40.78 ^{b,c,d} (34.56 - 46.98)	
IPAQ transport walking min/wk	9.75 ^a (6.44 - 14.72)	18.63 ^b (14.99 - 23.15)	43.15 ^{c,d} (35.51 - 52.43)	76.04 ^{c,d} (43.04 - 134.33)	
IPAQ leisure min/wk ^{***}	43.07 ^{a,b} (29.04 - 63.82)	58.91 ^{a,b} (47.90 - 72.44)	86.31 ^{c,d} (71.69 - 103.9)	117.91 ^{c,d} (68.56 - 202.77)	
BMI ^{*,**}	26.92 ^{a,b,c} (25.98 - 27.84)	27.44 ^{a,b} (26.95 - 27.92)	26.01 ^{a,c,d} (25.57 - 26.45)	25.32 ^{c,d} (24.03 - 26.6)	
	Baltimore Region				
	Low Walk / Transit & Rec Sparse ^a Mean (95% CI)	Low Walk / Rec Sparse ^b Mean (95% CI)	Mod. Walk / Rec Dense ^c Mean (95% CI)	High Walk / Rec Dense ^d Mean (95% CI)	
MVPA min/d	29.00 ^{a,b,c} (25.7 - 32.28)	25.37 ^{a,b} (22.45 - 28.28)	30.07 ^{a,c} (27.99 - 32.14)	38.65 ^d (34.17 - 43.12)	
IPAQ transport walking min/wk	16.60 ^{a,b} (11.26 - 24.45)	24.52 ^{a,b,c} (17.39 - 34.56)	32.16 ^{b,c} (25.14 - 41.13)	80.72 ^d (47.59 - 136.88)	
IPAQ leisure min/wk	43.89 ^{a,b,c,d} (29.88 - 64.44)	33.98 ^{a,b} (24.19 - 47.72)	51.79 ^{a,c,d} (40.57 - 66.10)	66.39 ^{a,c,d} (39.33 - 112.06)	
BMI ^{***}	27.40 ^{a,b,c,d} (26.5 - 28.28)	27.51 ^{a,b,c} (26.71 - 28.29)	27.12 ^{a,b,c,d} (26.55 - 27.67)	26.08 ^{a,c,d} (24.86 - 27.29)	

Note: Low Walk / Transit Sparse = Low Walkable, Transit and Recreationally Sparse profile. Low Walk / Rec Sparse = Low Walkable and Recreationally Sparse profile. Mod. Walk / Rec Dense = Moderately Walkable and Recreationally Dense profile. High Walk / Rec Dense = High Walkable and Recreationally Dense profile.

Superscripted letters next to profile labels show the letter's reference profile. Mean values with similar superscript letters on the horizontal plane are not statistically different based on post hoc follow-up tests. Post hoc tests performed within city only. All models were adjusted for sex, age, ethnicity, annual household income, education, # motor vehicles/adults in household, marital status, number of people in household, and length of time at current address.

* Posthoc difference between LWTRS and HWRD marginally significant (p < .06).

** Posthoc difference between LWRS and MWRD marginally significant (p < .06).

*** Posthoc difference between LWRS and HWRD marginally significant (p < .06).