Published in final edited form as:

Ann Epidemiol. 2014 July ; 24(7): 545–550. doi:10.1016/j.annepidem.2014.05.003.

Disability and the Built Environment: An Investigation of Community and Neighborhood Land Uses and Participation for Physically Impaired Adults

Amanda L. Botticello, PhD^{1,2}, Tanya Rohrbach, MS³, and Nicolette Cobbold, BS¹

¹Kessler Foundation Research Center, Outcomes and Assessment Department, West Orange, NJ

²Rutgers New Jersey Medical School, Department of Physical Medicine and Rehabilitation, Newark, NJ

³Raritan Valley Community College, Department of Science and Engineering, Branchburg, NJ

Abstract

Purpose—There is a need for empirical support of the association between the built environment and disability-related outcomes. This study explores the associations between community and neighborhood land uses and community participation among adults with acquired physical disability.

Methods—Cross-sectional data from 508 community-living, chronically disabled adults in New Jersey were obtained from among participants in national Spinal Cord Injury Model Systems database. Participants' residential addresses were geocoded to link individual survey data with Geographic Information Systems (GIS) data on land use and destinations. The influence of residential density, land use mix, destination counts, and open space on four domains of participation were modeled at two geographic scales—the neighborhood (i.e., half mile buffer) and community (i.e., five mile) using multivariate logistic regression. All analyses were adjusted for demographic and impairment-related differences.

Results—Living in communities with greater land use mix and more destinations was associated with a decreased likelihood of reporting optimum social and physical activity. Conversely, living in neighborhoods with large portions of open space was positively associated with the likelihood of reporting full physical, occupational, and social participation.

Conclusions—These findings suggest that the overall living conditions of the built environment may be relevant to social inclusion for persons with physical disabilities.

© 2014 Elsevier Inc. All rights reserved.

CORRESPONDING AUTHOR: Amanda L. Botticello, PhD, Senior Research Scientist, Outcomes & Assessment Department, Kessler Foundation Research Center, 1199 Pleasant Valley Way, West Orange, NJ 07052 Phone: 973-243-6973; Fax: 973-324-3527; abotticello@kesslerfoundation.org.

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.

CONFLICT OF INTEREST: None

Keywords

Disability; Neighborhood/Place; GIS; Participation

INTRODUCTION

Differences in the built environment—which refers to the physical features of geographic areas— may have particular relevance to disability. Conceptual models emphasize the salience of environmental features to the experience of participation restrictions, activity limitations, and social exclusion(1, 2). Although there is growing evidence supporting the association between the neighborhood built environment and late-life disability (3, 4), the link between the built environment and disability experiences among other segments of this diverse population are unknown. The purpose of this study is to explore the relationship between the built characteristics of communities and neighborhoods and participation among young and middle-age adults with acquired, chronic, physical impairment.

Studies of built environment influences on disability later in life have found that neighborhood characteristics such as poor street conditions, homogeneous land use, traffic, and ambient hazards are largely predictive of more reported health problems, functional limitations, inactivity, and social isolation (5–10). For instance, Clarke and colleagues identified that living in neighborhoods with more land use mix (i.e., combined residential, commercial, and recreational uses in one area) predicted functional independence among persons over age 65(11) whereas living in areas with poor infrastructure was associated with more mobility limitations (12) and less social participation (13) among physically and visually impaired older adults. Huang and colleagues (2012) indicated that multi-use locations (i.e., areas with multiple establishments) and proximity of food destinations were prioritized by older adults with mobility impairments when engaging in community participatory behavior such as shopping and dining out (14). Perceived neighborhood aesthetics and greenspace has also been reported as promoting social interaction among older adults (13, 15). This suggests that built environment features that are indicative of opportunity for activity and social interaction may promote the ability of older persons— particularly those with limitations—to physically and socially participate in community life. The link between the built environment and late-life disability is also consistent with patterns reported in the general population suggesting that greater neighborhood density,(16) land use mix,(17) and number of destinations (18–21) may provide cues that promote activity(14) and social interaction (22, 23).

Although activity limitations and disabling chronic conditions increase in prevalence later in life, disability is a lifecourse issue. The purpose of this investigation is to add to our knowledge of the relationship between the built environment and disability by exploring this association among a sample of persons who largely acquire physical impairment in young and middle-adulthood. A cross-sectional sample of adults with spinal cord injury (SCI) was obtained from a large-scale registry of persons with chronic paralysis. SCI is most frequently experienced in early adulthood and commonly results in extensive, lifelong impairment (24, 25). Persons in this population are particularly vulnerable to social

exclusion, as evidenced by low rates of participation (26, 27), employment(28), and physical activity (29). Geographic Information Systems (GIS) data on land use and destinations were used to construct measures of the built environment for five-mile and half-mile buffer areas around participant addresses representing the local neighborhood and community, respectively. We hypothesized that disabled adults living in places that are residentially dense, with more mixed land use, and with many destinations would be more likely to report optimal participation. In addition, we explored the association between open space in the local area and participation in order to better understand the relationship between neighborhood and community aesthetics and disability-related outcomes.

METHODS

Data

Individual data was obtained from the Spinal Cord Injury Model Systems (SCIMS) database, a registry of persons with traumatic SCI from across the United States (30). Participants consent to participate in prospective follow-up and complete telephone interviews at 1-year post-injury and then at 5-year intervals. The use of this data for the current project was approved by the local institutional review board for the ethical conduct of human subjects research. The data includes confirmed diagnostic and impairment-related data and detailed information on background, health, and functioning. This analysis focused on a cross-sectional subset of SCIMS participants age 18 or older in New Jersey who were living in the community and completed a follow-up interview between 2000 and 2011. Individual survey data and objective, GIS-based measures were linked by geocoding residential addresses at participants' most recent interview. Of 540 addresses, 97% were successfully matched. Eighteen cases with incomplete addresses were unmatched and excluded from the analysis. Fourteen cases with systematically missing values on key variables were also dropped, yielding a final analytic sample of N=508.

GIS data on land use/land cover (LU/LC) data were acquired from the New Jersey Department of Environmental Protection (NJDEP)^a and the United States Geological Survey (USGS) databases (31, 32). LU/LC data combines information on how land is being used (e.g., development, agriculture) with information about landscape characteristics (e.g., forests, water, impervious surfaces). The LU/LC data used for this analysis was classified based on a modified Anderson Classification System (33), one of the first geographic taxonomies developed to categorize remotely sensed imagery by the USGS. LU/LC is dynamic and the individual interview data were completed over the span of a decade. Therefore two raster files were created using 2001/2002 and 2006/2007 LU/LC values and assigned to interviews completed prior to or during 2005 and completed after 2005 respectively. Point locations for destinations were acquired from spatial data published by ESRI (34–36). Informed by prior small-scale GIS studies(37, 38) the environment was defined at two scales using *half-mile* and *five-mile* buffers around addresses as proxies for neighborhoods and communities, respectively. A small (8.4%) percentage of the five-mile

^aThis analysis was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been verified by NJDEP and is not state-authorized.

(i.e., community) buffer areas extended into neighboring states, which made the use of the USGS LU/LC data necessary.

Measures

Dependent Variables—Participation is measured by the Craig Handicap Assessment and Reporting Technique (CHART), a multidimensional, comprehensive instrument integrated with the ICF model (39). Four domains are assessed for the SCIMS and were used for this study: *physical independence (PI)* which measures autonomy in daily and instrumental activities; *mobility* which assesses the ability to move effectively both in and outside the home; *occupation* which measures productivity (e.g., gainful employment, schooling, homemaking, and volunteering); and *social integration (SI)* which assesses the ability to engage in the expected social relationships with family, friends, and colleagues. The CHART has been used with diverse impairment groups and has well established validity and reliability (40, 41). Domain scores range from 0 to 100 with maximum scores representing the expected level of participation for an average able-bodied individual. Typically CHART scores are skewed toward maximum participation. Following the analytic approaches of prior studies using this measure, each domain was dichotomized for analysis with scores less than 95 indicated restricted participation and scores of 95–100 indicated full participation (42).

Independent Variables—Built environment predictors included *residential density* as a sum of the proportion of residential land use types within each area. Higher scores corresponded with a higher proportion of aggregate residential area. *Land use mix* was assessed using a weighted index of six developed land uses following the approach described by Song and Rodriguez (2005)^b: single family residential, multi-family residential, commercial, industrial, mixed urban, and recreational areas. Scores represent the mix of land uses in the geographic area ranging from zero (homogeneous) to 1 (heterogeneous) (43).

A count of the *number of destinations* was evaluated as point locations. Destination types were determined based on potential relevance to participation opportunity and included entertainment (e.g., casino, theater, museum), landmark, retail (e.g., plaza, mall), and religious locations. Summated destination counts yielded a left-skewed variable that was dichotomized using a median split for analysis at the community (high=greater than 50, low = less than or equal to 50 places) and neighborhood (high = 1–4 places, low = no places) scale. *The proportion of open space* was calculated by summing all natural LU/LC proportions including undeveloped forest and wetlands, cultivated farmland, and beach or waterfront (i.e., ocean, lake, or river). Due to a skewed distribution, this measure was dichotomized at the 75th percentile to indicate large or small amounts of open space in the built environment (large= 50% or more community open space; large=30% or more neighborhood open space).

^b $Land\ Use\ Mix = \{(-1) \sum_{i=1}^k [p_i(\ln p_i)]\} / (\ln k)$ where p_i is the area proportion of a developed land use type and k is the total of developed land uses

Individual characteristics included demographic and impairment-related characteristics hypothesized to covary with participation and community selection. Demographic measures included gender, race/ethnicity (Non-Hispanic White, African American, and Hispanic, Asian, or Other), highest education level (less than high school, high school degree, and some college or more), marital status (not married, married), and current employment status (employed full or part time, not employed). The average age was approximately 44 years (SD=16.6) and highly skewed, as SCI largely occurs in young and middle adulthood(44). For the analysis, age was dichotomized as under 55 and 55 years and above. An index of socioeconomic (SES) advantage used in prior research (45, 46) was created from six tract-level SES indicators (household income, home values, percentages residents with interest income, high school degrees, college degrees, and in high status occupations) extracted from five-year estimates from the American Community Survey released in 2011(47) and added as a proxy of individual SES.

Impairment severity was assessed as paraplegia (i.e., lower limb impairment) and tetraplegia (i.e., upper and lower limb impairment). Duration of impairment was divided into recent (one year or less) versus long-term (two years or more) injury. Assistive technology use was assessed as whether the person used a wheelchair 40 hours or more a week or not. Self-rated health was dichotomized into ratings of poor or fair health versus good health or better. Functional independence was assessed by trained interviewers using the 13-item motor functioning subscale of the Functional Independence Measure (FIM)(48) which gauges independence in activities of daily living. Items are rated on a seven point ordinal scale where 1 indicates total assistance and 7 indicates complete independence.

Analysis

All data analysis was conducted in 2013. GIS extraction and initial spatial analyses of built environment characteristics were performed using ArcMap version 10.0 with a Spatial Analyst extension (©ESRI) in State Plane projection (49) and Geospatial Modeling Environment (GME) (©Spatial Ecology LLC).(50) All statistical analysis was conducted using Stata/SE version 13.(51) Logit models were used to sequentially test the relationships between the four participation domains and the four built environment predictors separately at the community and neighborhood scales. Model I in each sequence estimated the unadjusted relationship between each built environment predictor and participation domain. Subsequent models adjusted for the potential confounding influence of individual differences in background and resources (Model II) and impairment-related predictors (Model III). Covariates that were significant at the $p = 0.05$ level were retained for final multivariate models for parsimony (Model IV). Likelihood ratio tests were used for comparisons of model fit.

RESULTS

The descriptive characteristics of the sample are reported on Table 1. Demographically, this sample is largely consistent with population characteristics of adults with SCI in the US(52). The majority of persons was of working-age, identified as Non-Hispanic White, and attained at least a high school diploma. The rates of marriage and post-injury paid employment were

low (33.27% and 21.46%, respectively), which is indicative of the toll that acquired disability can take on the fulfillment of adult social roles. The sample was evenly split between persons with paraplegia and tetraplegia and most reported long-term impairment and the use of a wheelchair. Overall this sample was relatively healthy, with only one in four persons reporting poor health, and moderately functionally independent. For the dependent measures approximately half of the sample reported attaining full PI. A smaller proportion (33.67%) reported full mobility, which is expected among a group of persons with chronic physical impairment due to paralysis. The experience of full occupational activity is similarly low (30.2%) and reflects the low employment rate among this population as well as restricted productivity other occupational activities such as education, homemaking, and volunteering. In comparison, a larger portion of this sample reported experiencing full SI (60.8%).

Considerable variation was observed for the built characteristics at both scales. The average value representing the density of residential land use was more moderate at the community (0.37) scale compared to the neighborhood (0.53) scale and the wide range at both scales represents the variation in residential density in New Jersey, which includes urban and less densely populated rural areas. The standardized land use mix score indicates that on average the communities and neighborhoods where people lived were moderately mixed (0.63 and 0.54, respectively) although the range in these scores indicated that people lived in places that varied from homogeneous to quite heterogeneous.

Built Environment Predictors and Participation

The relationships between the built environment characteristics of the *community* and participation are reported on Table 2. The series of models testing the effect of *residential density* indicates initial negative associations with PI, occupation, and SI are largely accounted for by differences in individual background and impairment-related characteristics. The second series of models indicated that living in a community characterized by a large (versus small) portion of *open space* approximately doubled the odds of participation across all participation domains in the unadjusted models. Only the relationship between PI and open space was robust to individual differences in background and impairment ($OR_{IV} = 2.04$, 95% CI, 1.08–3.85). An opposite pattern was observed in the series of models testing *land use mix*, which significantly decreased the odds of full PI in the fully adjusted models ($OR_{IV} = 0.10$, 95% CI, 0.02–0.54). Finally, the presence of more *destinations* in the community was shown to modestly decrease the odds of occupational participation ($OR_{IV} = 0.57$, 95% CI, 0.34–0.96) and SI ($OR_{IV} = 0.60$, 95% CI, 0.39–0.93).

The relationships between the built environment predictors and participation at the **neighborhood** scale are reported on Table 3. In comparison to the community-level analysis, *residential density* had a robust negative relationship with SI ($OR_{IV} = 0.22$, 95% CI, 0.07–0.71). Results of the analysis examining the association between *open space* and PI were comparable to the pattern observed at the community scale such that living in a neighborhood with a large amount of open space doubled the odds of full PI ($OR_{IV} = 2.32$, 95% CI, 1.26–4.28) compared to living in a neighborhood with less open space. Open space also positively predicted occupation ($OR_{IV} = 2.10$, 95% CI, 1.18–3.75) SI at the

neighborhood scale ($OR_{IV} = 2.13$, 95% CI, 1.26–3.60) after adjusting for background and impairment-related differences. *Land use mix* and *destination counts* at the neighborhood scale did not predict any domain of participation in the fully adjusted multivariate models.

DISCUSSION

These findings indicate that land uses differences in the local environment are significantly associated with the likelihood of participation for physically disabled adults, albeit in patterns contrary to expectations. Residing in communities with hypothetically more opportunities for participation—such as mixed land use and more destinations—was associated with lower odds of reporting optimal PI and SI. Greater residential density in the neighborhood was inversely associated with full SI whereas a large amount of open space was associated with significantly higher odds of reporting full physical, occupational, and social aspects of participation.

The overall pattern of results suggests that the probability of community participation among this sample is better among disabled adults residing in communities and neighborhoods that are less developed but may offer better living conditions. The positive relationships between open space and participation are consistent with general population studies reporting positive associations of community open space with physical activity (20, 53, 54) and quality of life (55, 56) in the general population as well as studies of aging and disabled populations that have cited neighborhood aesthetics as important to promoting activity (13–15, 57). Collectively this work suggests that relative differences in the quality of the built environment, including greenspace, may be important in promoting activity among persons with mobility limitations. The associations in this analysis should be interpreted cautiously, however, as it is possible that individual characteristics and preferences that may have influenced into selection into neighborhoods and communities based on greenspace may also be correlated with better adjustment following acquired disability. This analysis controlled for a range of background, health, and functioning characteristics, but it is possible that other, unexplored factors such as residential preferences, pre-disability differences in community participation and independence, individual motivation, personal resources, transportation, and physical and mental health are likely to covary with both community selection and successful readjustment post-disability in the areas of physical, occupational, and social participation.

The associations between density, heterogeneity, and opportunity and participation observed in this analysis deviate from prior research suggesting that more development in the local community increases physical and social participation (3, 12, 13). This could be due in part to the heterogeneity of the disabled population; that is, the patterns found in studies of late-life disability may not be readily generalizable to other disability groups. Studies of older adults largely define disability based on reports of accumulated functional limitations. This investigation based a sample on a group of adults with a confirmed physical impairment (SCI), who generally experience severe and chronic mobility limitations and rely on assistive technology such as wheelchairs for ambulation. For this population, the presence of opportunity for participation in the community alone may not promote social inclusion and actually may be prohibitive if community places are inaccessible. Community accessibility

as well as deficits in the quality of community infrastructure identified in prior research (12, 13), such as poor street conditions and a lack of safety, were not included in this study but are important to pursue to further understand the built environment-disablement association.

Key among the limitations of this investigation is the use of a cross-sectional data. This design limits the ability to draw conclusions about the temporality of the association between communities and participation and rule out the potentially confounding influence of selection effects. The use of a sample of physically disabled adults from a single impairment group may also lead to underestimation of these associations tested by this analysis. The intention of this study was to investigate the relative importance of the built environment among a segment of the disabled population that has not been captured in previous investigations. Relative to other disabled groups, the SCI population is relatively young (42) and typically becomes injured during a crucial, formative period of development when the key aspects of the adult social are attained. Community participation remains a considerable challenge for younger disabled adults and it is particularly important to understand the determinants of social inclusion at this stage in order to improve quality of life over the lifecourse. The results of this investigation are also limited in generalizability to the select geographic area of New Jersey. This constraint is partially a methodological necessity for using small-scale GIS data—a strength of this study—to capture local spheres of daily activity.

This study included a number of covariates but the selected variables were by no means exhaustive. The secondary analysis of previously collected data limited our inclusion of covariates. For instance, in the absence of complete data on individual income, we substituted an area-level measure of SES from Census tract data in order to adjust for the important confounding effects of SES differences. Also, a lack of sufficient data in the SCIMS database on driving and transportation access prevented us from assessing the importance of transportation to community participation, particularly among individuals living in less developed areas. Future investigations would benefit from more in-depth information on assistive technology use, transportation access, and indicators of physical and emotional health which are likely correlated with participation outcomes.

In order to prevent disability among person with chronic impairments, it is necessary to identify and understand the barriers to community participation among all segments of the diverse disability population. This study suggests that the local environment may be important to promoting the social inclusion and that the importance of the quality of neighborhood and community living conditions to the health and well-being is in need of further exploration for persons with disabilities.

Acknowledgments

This research is supported by funding from the Eunice Kennedy Shriver National Institute of Child Health and Development (grant #: 4R00HD065957-03) and National Institute for Disability and Rehabilitation Research (grant #:H133N110020).

ABBREVIATIONS

GIS	Geographic Information Systems
SCI	spinal cord injury
SCIMS	Spinal Cord Injury Model Systems
PI	physical independence
SI	social integration
LU/LC	land use/land cover

REFERENCES

1. WHO. The International Classification of Functioning, Disability and Health (ICF). Geneva: WHO; 2001.
2. Lollar DJ. Public health and disability: Emerging opportunities. *Public Health Reports*. 2002; 117:3.
3. Rosso AL, Auchincloss AH, Michael YL. The Urban Built Environment and Mobility in Older Adults: A Comprehensive Review. *J Aging Res*. 2011; 2011:1–10.
4. Yen IH, Michael YL, Perdue L. Neighborhood environment in studies of health of older adults: a systematic review. *Am J Prev Med*. 2009; 37(5):455–463. [PubMed: 19840702]
5. Beard JR, Blaney S, Cerda M, Frye V, Lovasi GS, Ompad D, et al. Neighborhood Characteristics and Disability in Older Adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*. 2009; 64B(2):252–257.
6. Rimmer JH. Use of the ICF in identifying factors that impact participation in physical activity/rehabilitation among people with disabilities. *Disabil Rehabil*. 2006; 28(17):1087–1095. [PubMed: 16950739]
7. Theis KA, Furner SE. Shut-In? Impact of Chronic Conditions on Community Participation Restriction among Older Adults. *J Aging Res*. 2011; 2011:759158. [PubMed: 21837277]
8. Balfour JL, Kaplan GA. Neighborhood environment and loss of physical function in older adults: Evidence from the Alameda County study. *Am J Epidemiol*. 2002; 155(6):9.
9. Freedman VA, Grafova IB, Schoeni RF, Rogowski J. Neighborhoods and disability in later life. *SSM*. 2008; 66(11):2253–2267.
10. Keysor JJ, Jette AM, LaValley MP, Lewis CE, Torner JC, Nevitt MC, et al. Community environmental factors are associated with disability in older adults with functional limitations: the MOST study. *The journals of gerontology. Series A, Biological sciences and medical sciences*. 2010; 65(4):393–399.
11. Clarke P, George LK. Role of the built environment disablement process. *Am J Public Health*. 2005; 95(11):17.
12. Clarke P, Ailshire JA, Bader M, Morenoff JD, House JS. Mobility Disability and the Urban Built Environment. *Am J Epidemiol*. 2008; 168(5):506–513. [PubMed: 18667526]
13. Clarke PJ, Ailshire JA, Nieuwenhuijsen ER, de Kleijn-de Vrankrijker MW. Participation among adults with disability: the role of the urban environment. *SSM*. 2011; 72(10):1674–1684.
14. Huang DL, Rosenberg DE, Simonovich SD, Belza B. Food Access Patterns and Barriers among Midlife and Older Adults with Mobility Disabilities. *J Aging Res*. 2012; 2012:231489. [PubMed: 23056944]
15. Rosenberg DE, Huang DL, Simonovich SD, Belza B. Outdoor built environment barriers and facilitators to activity among midlife and older adults with mobility disabilities. *The Gerontologist*. 2013; 53(2):268–279. [PubMed: 23010096]
16. Forsyth A, Hearst M, Oakes JM, Schmitz KH. Design and Destinations: Factors Influencing Walking and Total Physical Activity. *Urban Stud*. 2008; 45(9):1973–1996.

17. Frank LD, Schmid TL, Sallis JF, Chapman J, Saelens BE. Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. *Am J Prev Med*. 2005; 28(2 Suppl 2):117–125. [PubMed: 15694519]
18. Moudon AV, Lee C, Cheadle AD, Garvin C, Johnson D, Schmid TL, et al. Operational Definitions of Walkable Neighborhood: Theoretical and empirical insights. *J Phys Act Health*. 2006; 3(Suppl 1):19.
19. Frank LD, Sallis JF, Conway TL, Chapman JE, Saelens BE, Bachman W. Many pathways from land use to health. *J Am Plann Assoc*. 2006; 72(1):13.
20. Duncan M, Mummery K. Psychosocial and environmental factors associated with physical activity among city dwellers in regional Queensland. *Prev Med*. 2005; 40(4):363–372. [PubMed: 15530589]
21. King W, Belle S, Brach J, Simkinsilverman L, Soska T, Kriska A. Objective Measures of Neighborhood Environment and Physical Activity in Older Women. *Am J Prev Med*. 2005; 28(5):461–469. [PubMed: 15894150]
22. Ross NA, Tremblay S, Khan S, Crouse D, Tremblay M, Berthelot J-M. Body mass index in urban Canada: neighborhood and metropolitan area effects. *American Journal of Public Health*. 2007; 97(3):500–508.
23. Nelson MC, Gordon-Larsen P, Song Y, Popkin BM. Built and social environments associations with adolescent overweight and activity. *American Journal of Preventive Med*. 2006; 31(2):109–17.
24. DeVivo MJ. Epidemiology of traumatic spinal cord injury: trends and future implications. *Spinal Cord*. 2012; 50(5):8. [PubMed: 22042300]
25. DeVivo MJ, Chen Y-y. Trends in new injuries, prevalent cases, and aging with spinal cord injury. *Arch Phys Med Rehabil*. 2011; 92(3):7. [PubMed: 21187200]
26. Whiteneck G, Meade MA, Dijkers M, Tate DG, Bushnik T, Forchheimer MB. Environmental factors and their role in participation and life satisfaction after spinal cord injury. *Arch Phys Med Rehabil*. 2004; 85(11):1793–1803. [PubMed: 15520974]
27. McKinley WO, Meade MA. Community integration following SCI. *NeuroRehabilitation*. 2004; 19:79–80.
28. Krause JS. Years to employment after spinal cord injury. *Arch Phys Med Rehabil*. 2003; 84:8.
29. Steins SA, Kirshblum SC, Groah SL, McKinley WO, Gittler MS. Spinal Cord Injury Medicine: 4. Optimal participation in life after spinal cord injury: Physical, psychosocial, and economic reintegration into the environment. *Arch Phys Med Rehabil*. 2002; 83(Supplement 1):S72–S81. [PubMed: 11973700]
30. Chen Y, Deutsch A, DeVivo MJ, Johnson K, Kalpakjian CZ, Nemunaitis G, et al. Current research outcomes from the Spinal Cord Injury Model Systems. *Arch Phys Med Rehabil*. 2011; 92(3):3.
31. Fry, J.; Xian, G.; Jin, S.; Dewitz, J.; Homer, C.; Yang, L., et al. Completion of the 2006 National Land Cover Database for the Conterminous United States. Sensing, PEaR, editor. 2011. p. 7
32. Homer, C.; Dewitz, J.; Fry, J.; Coan, M.; Hossain, N.; Larson, C., et al. Completion of the 2001 National Land Cover Database for the Conterminous United States. Sensing, PEaR, editor. 2007. p. 5
33. Anderson, JR.; Hardy, EE.; Roach, JT.; Witmer, RE. A land use and land cover classification system for use with remote sensor data. Interior, USDot, editor. Washington, DC: U.S. Government Printing Office; 1976. p. 41
34. ESRI/Tele Atlas North America I, cartographer U.S. and Canada Retail Centers Redlands. California: USA ESRI;
35. ESRI/Tele Atlas North America I, cartographer U.S. and Canada Recreation. Areas Redlands, CA: ESRI;
36. ESRI/Tele Atlas North America I, cartographer U.S. and Canada Large Area. Landmarks Redlands, CA: ESRI;
37. Forsyth A, Oakes JM, Schmitz KH, Hearst M. Does residential density increase walking and physical activity? *Urban Stud*. 2007; 44(4):20.
38. Curtis AJ, Lee W-AA. Spatial patterns of diabetes related health problems for vulnerable populations in Los Angeles. *Int J Health Geogr*. 2010; 9:10. [PubMed: 20158886]

39. Whiteneck, GG.; Brooks, C.; Charlifue, SW. Guide for the Use of the CHART: Craig Hospital Assessment and Reporting Technique. Englewood, CO: Craig Hospital; 1992.
40. Hall KM, Dijkers M, Whiteneck GG, Brooks CA, Krause JS. The Craig Handicap Assessment and Reporting Technique (CHART): Metric Properties and Scoring. *Top Spinal Cord Inj Rehabil.* 1998; 4(1):15.
41. Whiteneck GG, Charlifue SW, Gerhart KA, Overholser JD, Richardson GN. Quantifying handicap: A new measure of long-term rehabilitation outcomes. *Arch Phys Med Rehabil.* 1992; 73:519–526. [PubMed: 1622299]
42. Hall KM, Bushnik T, Lakisic-Kazacic B, Wright J, Cantagallo A. Assessing Traumatic Brain Injury Outcome Measures for Long-Term Follow-Up of Community-Based Individuals. *Arch Phys Med Rehabil.* 2001; 82(3):8.
43. Song Y, Rodríguez DA. The Measurement of the Level of Mixed Land Uses: A Synthetic Approach Chapel Hill, NC 2005. Feb 27, 2011
44. Jackson AB, Dijkers M, DeVivo MJ, Pocztatek RB. A Demographic Profile of New Traumatic Spinal Cord Injuries: Change and Stability over 30 Years. *Arch Phys Med Rehabil.* 2004; 85:1740–1748. [PubMed: 15520968]
45. Botticello AL, Chen Y, Cao Y, Tulskey DS. Do communities matter after rehabilitation? The effect of socioeconomic and urban stratification on well-being after spinal cord injury. *Arch Phys Med Rehabil.* 2011; 92(3):8.
46. Diez, Roux A.; Merkin, SS.; Arnett, D.; Chambless, L.; Massing, M.; Nieto, J., et al. Neighborhood residence and incidence of coronary heart disease. *New Engl J Med.* 2001; 345(2): 99–106. [PubMed: 11450679]
47. U.S. Census Bureau. [accessed April 2, 2013] American Community Survey, 2007–2011. <http://factfinder.census.gov/home>;
48. Hamilton, B.; Granger, C.; Sherwin, F.; Zielezny, M.; Tashman, J. A uniform national data system for medical rehabilitation. In: Fuhrer, M., editor. *Rehabilitation Outcomes: Analysis and Measurement.* Baltimore: Paul H. Brooks Publishing Company; 1987. p. 9
49. ESRI. ArcGIS Desktop: release 10. Redlands, CA: Environmental Systems Research Institute; 2011.
50. Beyer, HL. Geospatial Modelling Environment (Version 0.7.2.0). (software). 2013. URL: <http://www.spatialecology.com/gme>
51. StataCorp. Stata SE 13.0 for Windows (64-bit x86-64). College Station, TX 2013:
52. National Spinal Cord Injury Statistical Center. Spinal Cord Injury Facts and Figures at a Glance. Birmingham, AL: National Spinal Cord Injury Statistical Center; 2013.
53. Handy S, Cao X, Mokhtarian PL. Self-selection in relationship between built environment and walking. *J Am Plann Assoc.* 2006; 72(1):21.
54. Brennan, Ramirez LK.; Hoehner, CM.; Brownson, RC.; Cook, R.; Orleans, CT.; Hollander, M., et al. Indicators of activity-friendly communities: an evidence-based consensus process. *American Journal Preventive Medicine.* 2006; 31(6):515–524.
55. Sugiyama T, Thompson CW, Alves S. Association between Neighborhood Open Space Attributes and Quality of Life for Older People in Britain. *Environ Behav.* 2009; 41(1):19.
56. De Sousa CA. Unearthing the Benefits of Brownfield to Green Space Projects: An Examination of Project Use and Quality of Life Impacts. *Loc Environ.* 2006; 11(5):26.
57. Rimmer JH, Riley B, Wang E, Rauworth A, Jurkowski J. Physical activity participation among persons with disabilities: barriers and facilitators. *Am J Prev Med.* 2004; 26(5):419–425. [PubMed: 15165658]

Table 1

Sample characteristics for adults with spinal cord injury residing in New Jersey, 2000–2012

Total Sample (N=508)	Percent or Mean	SD	Range
<u>Participant characteristics</u>			
<i>Demographic</i>			
% 55 years or older (versus 54 or younger)	27.17		
% Male (versus female)	80.51		
Race/Ethnicity			
% Non-Hispanic White	58.07		
% African American	29.33		
% Hispanic/Asian Pacific Islander/Other	12.60		
Education			
% Less than high school	12.80		
% High school diploma	53.74		
% Some college or more	33.46		
% Married (versus unmarried)	33.27		
% Employed post-injury (versus unemployed)	21.46		
Census tract SES	0.31	4.38	−10.80 – 14.02
<i>Impairment-related</i>			
% Paraplegic (versus tetraplegic)	48.62		
% Recent injury (versus injured > 2 years)	37.01		
% Wheelchair user (versus other assistive devices)	65.35		
% Poor self-rated health (versus good health)	26.18		
Functional Independence Score	5.24	1.58	1–7
<u>Dependent Variables</u>			
% Physical Independence (PI)	48.30		
% Mobility	33.67		
% Occupation	30.16		
% Social Integration (SI)	60.83		
<u>Environment characteristics</u>			
<i>Community (5-mile buffer)</i>			
Proportion residential	0.37	0.13	0.06 – 0.62
% Open space (large versus small)	23.82		
Land use mix	0.63	0.17	0.18 – 0.85
% Destination count (versus low)	49.80		
<i>Neighborhood (half-mile buffer)</i>			
Proportion residential	0.53	0.18	0.04 – 0.91
% Open space (large versus small)	24.61		
Land use mix	0.54	0.16	0.09 – 0.91
% Destinations (high versus low)	41.14		

Table 2

Odds of full (versus restricted) participation by **community (i.e. five-mile buffer)** built environment indicators

	PI	Mobility	Occupation	SI
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Proportion residential				
I. Unadjusted model	0.20 (0.05 – 0.78)	0.31 (0.08 – 1.30)	0.19 (0.04 – 0.84)	0.13 (0.03 – 0.52)
II. Adjusted for SES and demographic variables ^a	0.25 (0.06 – 1.09)	0.57 (0.11 – 2.96)	0.32 (0.05 – 1.91)	0.18 (0.39 – 0.82)
III. Adjusted for impairment variables ^b	0.16 (0.03 – 0.93)	0.30 (0.06 – 1.50)	0.22 (0.05 – 1.00)	0.13 (0.03 – 0.57)
IV. Fully adjusted model	0.29 (0.04 – 1.96)	0.63 (0.10 – 3.91)	0.45 (0.07 – 2.85)	0.21 (0.04 – 1.04)
Open space (large versus small)				
I. Unadjusted model	2.30 (1.50 – 3.52)	1.94 (1.27 – 2.95)	1.79 (1.17 – 2.76)	2.32 (1.46 – 3.67)
II. Adjusted for SES and demographic variables ^a	1.81 (1.13 – 2.91)	1.26 (0.76 – 2.10)	1.28 (0.74 – 2.23)	1.62 (0.98 – 2.70)
III. Adjusted for impairment variables ^b	2.94 (1.67 – 5.20)	1.76 (1.09 – 2.85)	1.65 (1.05 – 2.58)	2.11 (1.32 – 3.39)
IV. Fully adjusted model	2.03 (1.08 – 3.85)	1.16 (0.6 – 2.05)	1.17 (0.66 – 2.09)	1.47 (0.87 – 2.49)
Land use mix				
I. Unadjusted model	0.12 (0.04 – 0.36)	0.33 (0.11 – 0.99)	0.27 (0.08 – 0.86)	0.08 (0.02 – 0.24)
II. Adjusted for SES and demographic variables ^a	0.28 (0.08 – 0.97)	1.68 (0.42 – 6.67)	0.78 (0.18 – 3.50)	0.25 (0.07 – 0.95)
III. Adjusted for impairment variables ^b	0.03 (0.01 – 0.14)	0.36 (0.10 – 1.25)	0.27 (0.08 – 0.86)	0.10 (0.03 – 0.31)
IV. Fully adjusted model	0.10 (0.02 – 0.54)	1.94 (0.41 – 9.08)	0.86 (0.18 – 4.01)	0.34 (0.09 – 1.36)
Destinations (high versus low)				
I. Unadjusted model	0.60 (0.42 – 0.86)	0.76 (0.53 – 1.11)	0.57 (0.39 – 0.84)	0.44 (0.30 – 0.63)
II. Adjusted for SES and demographic variables ^a	0.79 (0.53 – 1.20)	1.20 (0.76 – 1.91)	0.62 (0.37 – 1.03)	0.60 (0.40 – 0.92)
III. Adjusted for impairment variables ^b	0.36 (0.22 – 0.58)	0.70 (0.46 – 1.07)	0.52 (0.34 – 0.78)	0.44 (0.30 – 0.64)
IV. Fully adjusted model	0.80 (0.53 – 1.20)	1.12 (0.67 – 1.88)	0.57 (0.34 – 0.96)	0.60 (0.39 – 0.93)

^aDemographic models adjusted for tract SES, race, education, employment status, and age.

^bImpairment models adjusted for impairment severity, functional independence, length of disability, self-rated health and wheelchair use.

Table 3

Odds of full (versus restricted) participation by **neighborhood (i.e. half-mile buffer)** built environment indicators

	PI	Mobility	Occupation	SI
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Proportion residential				
I. Unadjusted model	0.81 (0.30 – 2.18)	1.19 (0.42 – 3.38)	1.06 (0.36 – 3.12)	0.24 (0.09 – 0.68)
II. Adjusted for SES and demographic variables ^a	0.72 (0.25 – 2.09)	1.11 (0.33 – 3.76)	0.96 (0.26 – 3.58)	0.19 (0.06 – 0.59)
III. Adjusted for impairment variables ^b	0.45 (0.12 – 1.64)	1.06 (0.32 – 3.48)	1.04 (0.33 – 3.18)	0.24 (0.08 – 0.72)
IV. Fully adjusted model	0.57 (0.14 – 2.29)	1.23 (0.33 – 4.61)	1.12 (0.29 – 4.32)	0.22 (0.07 – 0.71)
Open space (large versus small)				
I. Unadjusted model	2.12 (1.40 – 3.23)	1.33 (0.87 – 2.02)	1.73 (1.13 – 2.66)	2.57 (1.62 – 4.08)
II. Adjusted for SES and demographic variables ^a	2.00 (1.26 – 3.17)	1.16 (0.71 – 1.92)	2.28 (1.31 – 3.97)	2.21 (1.33 – 3.66)
III. Adjusted for impairment variables ^b	3.02 (1.74 – 5.26)	1.31 (0.81 – 2.13)	1.70 (1.09 – 2.66)	2.54 (1.58 – 4.10)
IV. Fully adjusted model	2.32 (1.26 – 4.28)	1.03 (0.58 – 1.81)	2.10 (1.18 – 3.75)	2.13 (1.26 – 3.60)
Land use mix				
I. Unadjusted model	0.17 (0.05 – 0.53)	0.38 (0.12 – 1.22)	0.38 (0.11 – 1.26)	0.18 (0.06 – 0.59)
II. Adjusted for SES and demographic variables ^a	0.27 (0.07 – 0.94)	0.61 (0.15 – 2.46)	0.29 (0.06 – 1.34)	0.40 (0.11 – 1.47)
III. Adjusted for impairment variables ^b	0.16 (0.04 – 0.70)	0.50 (0.13 – 1.95)	0.47 (0.13 – 1.69)	0.19 (0.06 – 0.63)
IV. Fully adjusted model	0.36 (0.07 – 1.81)	0.82 (0.18 – 3.79)	0.37 (0.08 – 1.79)	0.44 (0.11 – 1.71)
Destinations (high versus low)				
I. Unadjusted model	0.73 (0.51 – 1.04)	0.75 (0.51 – 1.10)	0.80 (0.54 – 1.18)	0.63 (0.44 – 0.91)
II. Adjusted for SES and demographic variables ^a	0.79 (0.54 – 1.16)	0.81 (0.52 – 1.26)	0.70 (0.43 – 1.13)	0.73 (0.49 – 1.08)
III. Adjusted for impairment variables ^b	0.50 (0.31 – 0.81)	0.68 (0.44 – 1.06)	0.77 (0.51 – 1.16)	0.64 (0.44 – 0.93)
IV. Fully adjusted model	0.61 (0.36 – 1.01)	0.74 (0.45 – 1.22)	0.68 (0.41 – 1.12)	0.75 (0.50 – 1.12)

^aDemographic models adjusted for tract SES, race, education, employment status, and age.

^bImpairment models adjusted for impairment severity, functional independence, length of disability, self-rated health and wheelchair use.