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Discrete Land Uses and Transportation Walking in Two U.S. Cities: The Multi-Ethnic Study of Atherosclerosis

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Abstract

This study examines associations of disaggregate land uses with self-reported walking for transportation among participants of the Multi-Ethnic Study of Atherosclerosis (MESA) in Forsyth County, NC and New York, NY. Network distance to each use (in miles), intensity (number of uses per ½-mile network buffer) of each use and diversity (number of different uses per ½-mile network buffer) of uses were calculated using Geographic Information Systems (GIS). Associations with odds of meeting recommended physical activity levels (150 min/week) were examined after controlling for individual- and census-tract-level covariates. Greater distance to and lower intensity of pedestrian-oriented uses, specifically those for social interactions, were associated with lower odds of meeting recommendations in NY. Results suggest that land uses linked to social interactions may be useful for encouraging increased transportation walking.

Keywords

Land use; Walking; Transportation; Geographic Information Systems (GIS)

Introduction

More than half of American adults fail to meet the current recommendations for at least 30 minutes, five or more days per week, in moderate-intensity physical activity, such as brisk walking (Macera et al., 2005). Walking for transportation (or transportation walking), defined as walking to engage in activities at the trip end, such as going to work or shopping (Ewing et al., 2008), may be key to meeting recommended levels of physical activity. This

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concept is reflected in Healthy People 2020 objective PA-13.1, calling for adults to walk more frequently for transportation (Aungst, 2011).

Numerous studies in the urban planning and public health literature have reported associations between aspects of the built environment and utilitarian walking (Handy, 2005). Specifically, transportation walking is consistently found to be more prevalent in dense, mixed-use neighborhoods (Ewing and Cervero, 2010; Saelens and Handy, 2008; Saelens et al., 2003). However, most existing studies of land use and physical activity use broad land use categories, such as residential or commercial (Ewing et al., 2008; Rodríguez et al., 2009; Rundle et al., 2007). These broad classifications are not specific enough to guide the design of the built environment because they cannot identify the specific types of uses that may be most strongly related to walking behaviors. The desire to create meaningful interventions has led researchers and practitioners to seek more well-defined recommendations on the types and locations of destinations that motivate physical activity.

Lee and Moudon concluded that individual land uses are often as or more predictive of walking than complicated composite indices (Lee and Moudon, 2006). However, very few studies have investigated the differential impact of different types of land uses (Cerin et al., 2007; Giles-Corti and Donovan, 2002a; Lovasi et al., 2008; McCormack et al., 2008; Wen et al., 2007). McConville et al. found that after adjustment for individual-level characteristics, the adjusted odds of walking ≥150 minutes per week (compared to not walking at all) were significantly lower for greater distances to the closest bank, bus stop, physical activity use, rail station and social uses of land (McConville et al., 2011). Land use intensity and diversity were also positively associated with transportation walking. However, their sample was moderately sized (n=260), and geographically concentrated (Montgomery County, MD), limiting generalizability to the U.S. population. Further research is needed to investigate these relationships in a larger sample, and across multiple cities.

Associations of disaggregate land use characteristics with self-reported walking for transportation in a large, racially-diverse cohort residing in more than one region were examined. We hypothesized that participants living in neighborhoods with pedestrian-related uses (such as social, night, or physical activity uses) in close proximity, with high intensity of pedestrian-related uses, and with a high diversity of uses would report higher levels of transportation walking than participants living in neighborhoods with other land use patterns. Additionally, we hypothesized that not all types of uses would be similarly associated with walking for transportation. Proximity to auto-oriented uses and parking may be indicative of an auto-centric pattern of land development so we hypothesized that it would be associated with less walking for transportation.

Methods

Study Sample

The Multi-Ethnic Study of Atherosclerosis (MESA) is a longitudinal study of cardiovascular disease among adults aged 45–84 years at six field sites in the U.S. (Bild et al., 2002) Persons with a history of clinically overt cardiovascular disease at baseline were excluded. The baseline visit for MESA, on which these analyses are based, took place between July 2000 and September 2002. The study was approved by the IRBs at each site and all participants gave written informed consent.

The sample consists of MESA participants from Forsyth County, NC and New York, NY (baseline n=2179) because suitable land use codes with individual codes for specific destinations were available at these two sites. These two cities also allow the investigation of this research question under contrasting contexts, including regional, population size, urbanicity, and land area differences. Participants were excluded if they did not consent to have their address geocoded (91 in NY, 87 in NC), did not overlap geographically with the built environment data available (3 in NY, 18 in NC) or did not have the walking measures of interest at baseline (1 in NY, 2 in NC). Chinese participants were excluded due to small sample size (n=2). This left a total of 1005 in NY and 970 in NC for analysis. The NY site was used for additional in-depth analyses of more disaggregated destinations because of the greater availability of land use data at this site.

Land Use Exposures

Neighborhood information was collected by the MESA Neighborhood Study, an ancillary study to MESA aimed at investigating the effect of neighborhood physical and social factors on cardiovascular health. All objective measures were derived using ArcGIS 9.3 (ESRI, Redlands, CA). Parcel-based land use files dated 2005 were obtained from the City of New York and the Forsyth County Tax assessor (Figure 1). Road networks for all calculations were obtained as a PolyLine file from the U.S. Census Bureau Topologically Integrated Geographic Encoding and Referencing (TIGER) database (U.S. Bureau, 2000).

An investigator classified the land-use codes of each site into five nonexclusive categories (see table 1): the auto-related uses, auto-oriented and parking; and the pedestrian-related uses, social, night, and physical activity uses. These categories were determined based on a priori expectations of potential associations between land uses and walking behaviors and verified by a second team investigator. In NY, the additional data available made it possible to classify the land-use codes into ten discrete land uses: beaches, community centers, food stands, libraries and museums, stores w/mixed use, parks, post offices, schools, malls with parking, and theaters or concert halls.

Three measures were created for each MESA participant: accessibility of a particular land use, intensity of a particular land use, and diversity of uses. Since examination of land use variables in quartiles showed no clear evidence of thresholds, all three measures were examined as continuous variables.

Accessibility (Distance)—Geographic accessibility was measured by the street-distance from home to the nearest instance of a land use (McConville et al., 2011). Street distances were calculated using ArcGIS Network Analyst's closest facility function (ArcView 9.3, ESRI, Redlands, CA) and represent the distance to the closest point along the edge of the parcel. U-turns were allowed everywhere within the network to accommodate pedestrian, rather than automobile, traffic patterns. Distances were measured in miles and are accurate within 66 feet.

Intensity (Count)—Intensity was measured as the number of instances of a land use within a set street distance of a participant's home. Street distance buffers around each participant's home were created using Arc GIS Network Analyst's Service Area (ESRI, Redlands, CA) at ½-mile distance and land uses were counted using Hawth's tools polygon-in-polygon extension (Beyer, 2004). Areas beyond ½-mile were not examined because that is not generally considered an acceptable distance for walking (Cervero and Radisch, 1996; Frank, 2004; Hoehner et al., 2005; Pikora et al., 2002; Saelens et al., 2003; Sallis et al., 1990).

Diversity (Variety)—Land-use diversity was measured as the number of different types of land uses within ½-mile street distance of the participant's home (McConville et al., 2011). This resulted in a scale from 0 to 5 for the five land use categories available at both sites, and a scale of 0 to 10 for the more disaggregated categories available in New York.

Sensitivity analyses were performed for all intensities and diversities using a ¼-mile distance instead of ½-mile.

Walking Outcomes

Walking was assessed at baseline via the MESA Typical Week Physical Activity Survey (TWPAS), a detailed interviewer-administered, semi-quantitative questionnaire adapted from the Cross-Cultural Activity Participation Study (Ainsworth et al., 2000; Ainsworth et al., 1999; LaMonte et al., 2001).

The outcome examined is minutes per week of walking for transport, defined as walking to places (e.g. to the bus, school, work, or store). Given the skewed distribution of this data, walking was dichotomized as (1) those meeting recommended levels of physical activity (150 min/week) by transportation walking (Macera et al., 2005) and (2) those failing to meet recommendations.

Covariates

Individual-level MESA demographic data on age (continuous measure), gender, education, and income were self-reported during the baseline examination. Participants selected their total combined family income for the past 12 months from 13 income categories; a continuous family income was calculated from the interval midpoint of family income (in US dollars). Participants selected their education from eight categories; number of continuous years of education was computed from the interval midpoint of the education categories. Race/ethnicity was classified as Hispanic, non-Hispanic white, and non-Hispanic black.

Statistical Analyses

Adjusted odds ratios of meeting recommended levels of walking (150 min/week) with transportation walking for various land use variables were estimated using population average logistic regression models (Zeger and Liang, 1986). Associations were estimated unadjusted and after full adjustment for potential confounders including individual characteristic (race/ethnicity, age, gender, education and income), and mode of questionnaire administration. Only results for the fully adjusted model are shown. Clustering by census tract was accounted for using an exchangeable correlation structure. Due to high collinearity (Variance Inflation Factors>5), models were fit for each use separately rather than mutually adjusted. For accessibility and intensity, estimates reflect a site-specific, one-standard deviation increase. For accessibility and diversity, estimates correspond to a one mile increase in distance and a one unit increase in number of uses respectively. All analyses were conducted stratified by site using SAS Software®, v.9.2 (SAS Institute, Inc., Cary, NC).

Results

Age of study participants ranged from 45 to 84 years with a mean of 62 (Standard Deviation (SD) 9.9). Over half (54.7%) of participants were female with NY having a slightly higher percentage (56.1%) than NC (53.1%). Education and income were slightly higher in NC than in NY. While the entire sample contained a balance of races and ethnicities, almost all Hispanics represented in this sample were located in NY (Table 2). Overall, 331 census tracts were represented in the sample with an average of 13.86 and 3.85 participants per census tract in NC and NY, respectively.

The percentage of individuals meeting recommended physical activity levels by transportation walking was lower in NC (47.8%) than in NY (61.7%). NY participants reported a mean of 88.6 minutes more walking per week than NC participants.

Overall, participants lived relatively close to the five land use categories (median accessibility 0.1–0.9 miles). NC participants consistently lived farther from the five categories of land use (median range 0.3–0.9 miles) than NY participants (median range 0.1–0.6 miles). Intensities of the five land use categories varied widely (median range 0.0–64.0) with NC participants having fewer counts per land use types within ½-mile of their home (median range 0.0–2.0) than NY participants (median range 0.0–64.0). Fifty percent of participants had four of the five categories of uses within ½-mile of their home (median diversity 4.0). Participants in NY had significantly more different types of uses within ½-mile of their home (median diversity 4.0) than participants in NC (median diversity 2.0).

Analyses using the ten discrete land uses available in NY showed that participants lived farthest from beaches and malls with parking and closest to stores with mixed use, schools, and parks. Participants had more stores with mixed use, parks, and schools within ½-mile of their homes than other land uses. A median of six of these ten uses were present within ½-mile of participants' homes.

Adjusted associations of land use with the odds of meeting recommended levels of walking are shown in table 3. Overall, some aspects of discrete land use were associated with walking in New York, but no associations were observed in NC. In NC, none of the distances to discrete land uses were associated with odds of meeting recommended levels of walking. In NY, greater distances to pedestrian-related uses (social, night, and physical activity) were associated with decreased odds of meeting recommended levels of walking through transportation walking, although only the association with distance to social uses reached statistical significance. One standard deviation increase in distance to social uses was associated with a 15% reduced odds of meeting recommended levels of walking (Adjusted Odds Ratio 0.85, 95% confidence interval (CI) 0.73, 0.97).

Associations of greater intensity of uses with odds of meeting recommended walking in NC were weak and none were statistically significant. In NY, greater intensities of pedestrian-related uses were associated with higher odds of meeting recommendations whereas auto-related uses were associated with lower odds. However, these associations were not statistically significant (95% CI were wide and included the null value). Greater diversity of land use categories was weakly associated with increased odds of meeting recommendations in both sites. Associations were stronger in NC but neither was statistically significant.

Associations between the ten discrete land uses in NY and walking are shown in table 4. Greater distances to beaches and post offices were associated with decreased odds of meeting recommended levels of walking through transportation walking. The odds of meeting recommendations was lower for each standard deviation increase in distance to community centers, stores with mixed use, parks, and theaters, although associations are generally weak and not statistically significant. Intensities of these ten uses were not consistently or significantly associated with odds of meeting recommended levels of walking. Greater diversity of uses within ½-mile was also associated with increased odds of meeting recommendations but this association was not statistically significant (OR 1.05 95% CI 0.93, 1.18).

Results using ¼-mile intensities and diversities were similar to the results reported above for ½-mile.

Discussion

In NY, greater accessibility and greater intensity of pedestrian-related uses was associated with greater odds of meeting recommended levels of physical activity through transportation walking, although associations were often not statistically significant. Within the types of uses, social uses appeared to be more consistent predictors of walking than other types of uses. No statistically significant associations were observed in NC.

The associations between disaggregated land use measures and transportation walking observed in NY were small. This is logical, given the variety of other factors that influence an individual's transportation choice. Additionally, as individual components of land use patterns, and even smaller components of the entire built environment, it is likely that the location and intensity of land uses act in concert with other environmental features to encourage walking. The direction of many of the associations is consistent with what was expected, although few reached statistical significance. This may be the result of insufficient sample size to detect the small magnitude of effect.

The finding that, at least in one site, accessibility and intensity of pedestrian-oriented uses were weak but suggestive predictors of transportation walking is consistent with research on accessibility (Giles-Corti and Donovan, 2002a, b) and land use mix (Duncan et al., 2010). The associations observed between shorter distances to uses and greater diversity of uses and transportation walking is consistent with research both on specific uses (McConville et al., 2011) and a mixture of uses (Ewing et al., 2008; Rodríguez et al., 2009; Rundle et al., 2007). If the variety of destinations is greater, an individual may walk more because more errands can be accomplished by walking. Increased diversity may also encourage walking by allowing multiple trips to be joined into a series of errands. Some evidence of a weak association of diversity with walking was found in NC but it was not statistically significant. Although intensities of land use categories have been less frequently investigated (McConville et al., 2011), the associations found in this sample are consistent with previous research (Forsyth et al., 2008; McConville et al., 2011) and our hypotheses. High land use intensity may allow individuals to more easily combine multiple errands into a single trip, perhaps facilitating non-automotive transportation (Ye et al., 2007). Researchers should continue to explore this measure as a possible predictor of walking. Consideration of floor-space data may also enhance understanding of whether and how intensity of uses related to walking (Handy et al., 2002).

The use of data from NY and NC allowed investigation of associations in two very different spatial contexts (more vs. less urban, and more vs. les mixed land use). In addition it allows an investigation of the associations and in populations that live in very different kinds of cities. It is possible that people who walk more and enjoy walkable neighborhoods are more likely to choose to live in very dense urban areas like NY. This may make them more responsive to built environment features that facilitate walking. In addition, NY may also have a number of other features that may make residents more likely to walk to nearby destinations including other built environment characteristics (such as small building setbacks, sidewalks, and enclosure), lower car ownership (Burns and Golob, 1976), and greater density of land uses generally. In contrast, in NC a pattern of development in which residential housing is separated from non-residential uses may lead to a reliance on cars even for trips that would be feasible by foot. We were not able to control for car ownership, which may influence whether an individual walks for transportation, as this was not measured during this exam. Sensitivity analyses extrapolating car ownership information from subsequent exams showed no confounding by car ownership status. Previous research on stores concluded that local shopping was not a particularly effective strategy for reducing automobile dependence in suburban neighborhoods (Handy and Clifton, 2001). This is consistent with our finding of minimal associations between discrete land uses and transportation walking in the NC sample in our analyses.

Differences in associations across both sites may also reflect the fact that the distance investigated (½- mile) has different implications and meanings at both sites. The distribution of measures also differed across sites, restricting the ability to conduct pooled analyses. The estimation of associations with site specific SD has the disadvantage that the magnitudes of the associations are not directly comparable because the value of the SD differs in the two sites. However, it has the advantage that one can estimate associations with a difference that is relevant and meaningful given the distribution in each site.

It is possible, that the effect of a given change in the built environment is modified by the overall built environment characteristics in the area. For example, in a setting with very low accessibility and intensity of uses (such as NC in our analyses), a small increment may have virtually no impact on behavior determined by broader land use patterns, whereas the effect of even a small difference may be large in the context of high mixed land use. It is conceivable that the opposite effect occurs in the case of diversity: moving from a single use to two uses may have a larger impact on walking than increasing the uses from 4 to 5. This is compatible with our finding that the associations of diversity with walking appeared to be slightly stronger in NC (where diversity of uses is very low) than in NY (where diversity is much higher).

Consistent with our hypotheses, results suggest that land uses linked to social interactions are the ones most strongly related to transportation walking. Distance to and intensity of social uses was particularly salient in predicting odds of meeting recommendations in NY. These results indicate that land uses to encourage social interaction may significantly affect transportation walking. Participants may choose to walk to religious institutions, recreation facilities, or restaurants in close proximity rather than drive. It is also possible that accessibility of pedestrian-related land uses may be a proxy for a pattern of development that encourages walking generally rather than functioning as a destination for individuals.

Unfortunately, results from the ten specific sub-categories did not help to explain the associations seen in the larger groupings of land uses. Previous research, specifically relating to schools and parks, has either been inconsistent or did not investigate the effects of many of the discrete uses in this study (Cerin et al., 2007; Forsyth et al., 2008; McConville et al., 2011; McCormack et al., 2008). It is possible that these ten uses are not the main drivers of transportation walking in this cohort. This study included distance to and number of physical activity destinations, which may have more of an influence on “recreational walking,” commonly used as the opposite of walking for transport (Lee and Moudon, 2006). Additionally, specific land uses may play different roles in encouraging walking for different age groups. As our sample was middle age- to older-adults, there may be additional locations or facilities that encourage transportation walking in this population (Cauwenberg et al., 2012; Hess, 2009; Cunningham and Michael, 2004). Alternatively, land use codes may not be accurate enough to dissect such specific uses from the larger social category.

The cross-sectional nature of these analyses limits the ability to draw causal inferences. For example, individuals with a higher awareness of the importance of physical activity may have chosen to reside in areas more conducive to walking. Land use codes are not always comparable across locations limiting comparability across sites. The land use categories used were dictated in part by the codes available and may not reflect the types of uses or categories most meaningful for walking. Land use codes are also not indicative of other features of the built environment such as aesthetics which may modify the ways in which land use relates to walking. Land use data were compiled by the two municipalities and may not align perfectly with the timing of physical activity data. However, these land uses may remain stable over short periods of time.

The high correlation between different land use measures made it impossible to include all measures in the same model in order to disentangle their effects. Network distances did not exclude highways, although this should not have a large influence with the small buffer sizes used. The self-reported walking measure has important limitations and non-differential measurement error would likely bias estimates towards the null. Results observed in NY and NC are not necessarily generalizable to other areas although consistency with other research suggests that some general patterns of associations may be common across contexts.

The results of this study indicate a relationship between social uses and walking for transportation. More research that relies on more specific types of destinations, perhaps not solely reliant on land use codes, should be done to disentangle which features of the social environment most encourage walking. Although only suggestive, these findings support mixed-use development as a method for encouraging active lifestyles. However, the causal impact of these features on walking need to be further investigated using longitudinal analyses and quasi-experimental designs.

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References

Ainsworth B, Lamonte M, Drowatzky K, Cooper R, Thompson R, Irwin M, Whitt M, Gilman M. Evaluation of the CAPS Typical Week Physical Activity Survey among minority women. 2000:17.

Ainsworth BE, Irwin ML, Addy CL, Whitt MC, Stolarczyk LM. Moderate physical activity patterns of minority women: the Cross-Cultural Activity Participation Study. Journal of women's health & gender-based medicine. 1999; 8:805–813.

Aungst RB. Healthy People 2020. Perspectives on Audiology. 2011; 7:29–33.

Beyer HL. Hawth's Analysis Tools for ArcGIS, p. 2004 Available at http://www.spatialecology.com/htools.

Bild DE, Bluemke DA, Burke GL, Detrano R, Roux AVD, Folsom AR, Greenland P, Jacobs DR Jr, Kronmal R, Liu K. Multi-ethnic study of atherosclerosis: objectives and design. American Journal of Epidemiology. 2002; 156:871–881. [PubMed: 12397006]

Bureau, U.S.C. Topologically Integrated Geographic Encoding and Referencing (TIGER) database, 2000 ed. Washington, DC: 2000.

Burns LD, Golob TF. The role of accessibility in basic transportation choice behavior. Transportation. 1976; 5:175–198.

Cauwenberg JV, Clarys P, Bourdeaudhuij ID, Holle VV, Verte D, Witte ND, Donder LD, Buffel T, Dury S, Deforche B. Physical environmental factors related to walking and cycling in older adults: the Belgian aging studies. BMC Public Health. 2012; 12:142. [PubMed: 22361255]

Cerin E, Leslie E, Toit L, Owen N, Frank LD. Destinations that matter: associations with walking for transport. Health & place. 2007; 13:713–724. [PubMed: 17239654]

Cervero R, Radisch C. Travel choices in pedestrian versus automobile oriented neighborhoods. Transport Policy. 1996; 3:127–141.

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Cunningham GO, Michael YL. Concepts guiding the study of the impact of the built environment on physical activity for older adults: a review of the literature. American Journal of Health Promotion. 2004; 18:435–443. [PubMed: 15293929]

Duncan MJ, Winkler E, Sugiyama T, Cerin E, duToit L, Leslie E, Owen N. Relationships of land use mix with walking for transport: do land uses and geographical scale matter? Journal of urban health. 2010; 87:782–795. [PubMed: 20814757]

Ewing R, Cervero R. Travel and the built environment. Journal of the American Planning Association. 2010; 76:265–294.

Ewing R, Schmid T, Killingsworth R, Zlot A, Raudenbush S. Relationship between urban sprawl and physical activity, obesity, and morbidity. Urban Ecology. 2008:567–582.

Forsyth A, Hearst M, Oakes JM, Schmitz KH. Design and destinations: factors influencing walking and total physical activity. Urban Studies. 2008; 45:1973–1996.

Frank LD. Economic determinants of urban form: resulting trade-offs between active and sedentary forms of travel. American journal of preventive medicine. 2004; 27:146–153. [PubMed: 15450625]

Giles-Corti B, Donovan RJ. The relative influence of individual, social and physical environment determinants of physical activity. Social science & medicine. 2002a; 54:1793–1812. [PubMed: 12113436]

Giles-Corti B, Donovan RJ. Socioeconomic status differences in recreational physical activity levels and real and perceived access to a supportive physical environment. Preventive Medicine. 2002b; 35:601–611. [PubMed: 12460528]

Handy SL. Critical assessment of the literature on the relationships among transportation, land use, and physical activity. Transportation Research Board and the Institute of Medicine Committee on Physical Activity, Health, Transportation, and Land Use. Resource paper for TRB Special Report 282. 2005

Handy SL, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activity: Views from urban planning. American Journal of Preventive Medicine. 2002; 23:64–73. [PubMed: 12133739]

Handy SL, Clifton KJ. Local shopping as a strategy for reducing automobile travel. Transportation. 2001; 28:317–346.

Hess DB. Access to public transit and its influence on ridership for older adults in two U.S. cities. Journal of Transport and Land Use. 2009; 2(1)

Hoehner CM, Brennan Ramirez LK, Elliott MB, Handy SL, Brownson RC. Perceived and objective environmental measures and physical activity among urban adults. American Journal of Preventive Medicine. 2005; 28:105–116. [PubMed: 15694518]

LaMonte MJ, Durstine JL, Addy CL, Irwin ML, Ainsworth BE. Physical activity, physical fitness, and Framingham 10-year risk score: the cross-cultural activity participation study. Journal of Cardiopulmonary Rehabilitation and Prevention. 2001; 21:63–70.

Lee C, Moudon AV. The 3Ds+ R: Quantifying land use and urban form correlates of walking. Transportation Research Part D: Transport and Environment. 2006; 11:204–215.

Lovasi GS, Moudon AV, Pearson AL, Hurvitz PM, Larson EB, Siscovick DS, Berke EM, Lumley T, Psaty BM. Using built environment characteristics to predict walking for exercise. International Journal of Health Geographics. 2008; 7:10. [PubMed: 18312660]

Macera CA, Ham SA, Yore MM, Jones DA, Kimsey CD, Kohl HW III, Ainsworth BE III. Prevalence of Physical Activity in the United States: Behavioral Risk Factor Surveillance System, 2001. Preventing chronic disease. 2005:2. [electronic resource].

McConville ME, Rodríguez DA, Clifton K, Cho G, Fleischhacker S. Disaggregate land uses and walking. American journal of preventive medicine. 2011; 40:25–32. [PubMed: 21146764]

McCormack GR, Giles-Corti B, Bulsara M. The relationship between destination proximity, destination mix and physical activity behaviors. Preventive Medicine. 2008; 46:33–40. [PubMed: 17481721]

Pikora TJ, Bull FCL, Jamrozik K, Knuiman M, Giles-Corti B, Donovan RJ. Developing a reliable audit instrument to measure the physical environment for physical activity. American journal of preventive medicine. 2002; 23:187–194. [PubMed: 12350451]

Rodríguez DA, Evenson KR, Diez Roux AV, Brines SJ. Land use, residential density, and walking: the multi-ethnic study of atherosclerosis. American journal of preventive medicine. 2009; 37:397–404. [PubMed: 19840694]

Rundle A, Diez Roux AV, Freeman LM, Miller D, Neckerman KM, Weiss CC. The urban built environment and obesity in New York City: a multilevel analysis. American Journal of Health Promotion. 2007; 21:326–334. [PubMed: 17465178]

Saelens BE, Handy SL. Built environment correlates of walking: a review. Medicine and science in sports and exercise. 2008; 40:S550. [PubMed: 18562973]

Saelens BE, Sallis JF, Frank LD. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. Annals of behavioral medicine. 2003; 25:80–91. [PubMed: 12704009]

Sallis JF, Hovell MF, Hofstetter CR, Elder JP, Hackley M, Caspersen CJ, Powell KE. Distance between homes and exercise facilities related to frequency of exercise among San Diego residents. Public health reports. 1990; 105:179. [PubMed: 2108465]

Wen M, Kandula NR, Lauderdale DS. Walking for transportation or leisure: what difference does the neighborhood make? Journal of general internal medicine. 2007; 22:1674–1680. [PubMed: 17932724]

Ye X, Pendyala RM, Gottardi G. An exploration of the relationship between mode choice and complexity of trip chaining patterns. Transportation Research Part B: Methodological. 2007; 41:96–113.

Zeger SL, Liang KY. Longitudinal data analysis for discrete and continuous outcomes. Biometrics. 1986:121–130. [PubMed: 3719049]

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Highlights

- Use of specific land use categories may identify modifiable environmental features
- Land uses for social engagement had the strongest association with transport walking
- Findings support mixed-use development as a method for encouraging active lifestyles

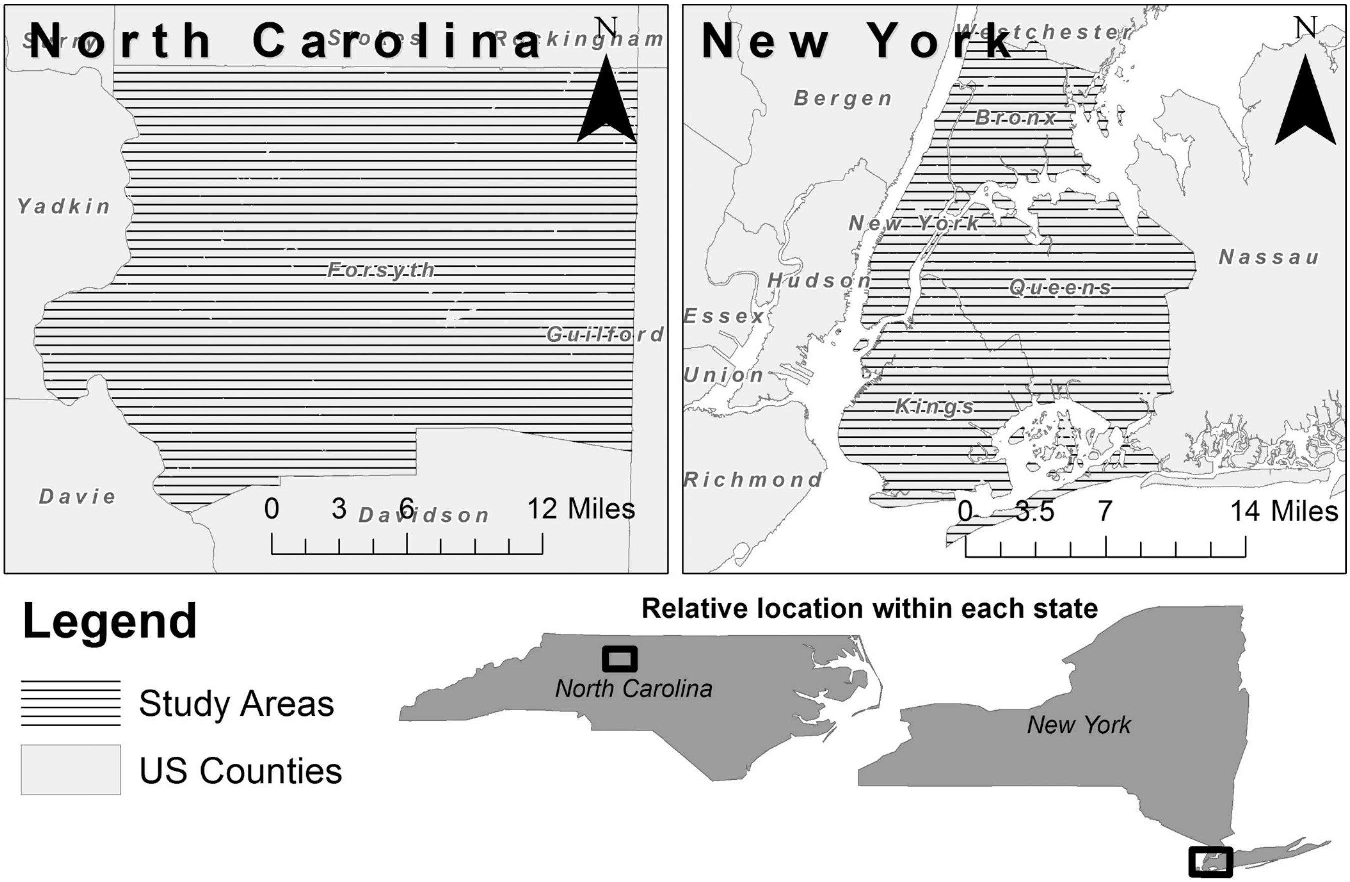

Figure 1.
Study areas in Forsyth, NC and New York City, NY. Land uses obtained by county from the City of New York and the Forsyth County Tax assessor.

Table 1

Land Use Categories and Examples

	Land Use Category	Example of Land Use
Auto-related Uses	Auto-oriented	Industry with trucking, malls with parking
	Parking	Parking lots, parking structures
Pedestrian-related Uses	Social	Community centers, religious institutions, schools, gathering places
	Night	Restaurants, bars, theaters, sports arenas
	Physical Activity	Parks, playgrounds, athletic properties

Table 2

Individual, Neighborhood, Land use and Outcome characteristics of participants included in analyses, MESA, 2000–2002 (n=1975)

	North Carolina	New York
	Mean (SD), Median	**Mean (SD), Median**
INDIVIDUALS (n)	970	1005
Age (years)	62.4 (9.7), 62	61.6 (10.1), 61
Education (years)	14.1 (2.8), 13	12.5 (4.2), 13
Family Income (dollars, missing=112)	58035 (32496), 62500	42439 (29721), 32500
Gender (% female)	53.1	56.1
Race/Ethnicity (% distribution)		
Non-Hispanic White	53.8	20.7
Non-Hispanic Black	45.9	34.5
Hispanic	0.3	44.8
NEIGHBORHOODS (n)	70	261
Number of participants in neighborhood	13.86 (9.53), 11	3.85 (3.86), 3
FIVE LAND USE CATEGORIES		
Accessibility (miles)		
Social Uses	0.4 (0.3), 0.3	0.1 (0.1), 0.1
Night Uses	0.8 (0.7), 0.6	0.7 (0.5), 0.6
Physical Activity Uses	0.7 (0.6), 0.6	0.1 (0.1), 0.1
Auto-Oriented Uses	0.4 (0.4), 0.3	0.1 (0.1), 0.1
Parking Uses	1.2 (1.0), 0.9	0.1 (0.1), 0.1
Intensity (1/2-mile buffer; number of uses)		
Social Uses	5.9 (9.4), 2.0	36.6 (25.2), 30.0
Night Uses	2.1 (5.1), 0.0	2.0 (3.8), 0.0
Physical Activity Uses	2.2 (6.4), 0.0	21.3 (17.6), 16.0
Auto-Oriented Uses	11.4 (25.2), 2.0	99.5 (95.9), 64.0
Parking Uses	2.4 (7.1), 0.0	32.8 (33.6), 21.0
Diversity (1/2-mile buffer; number of different uses 1–5)	2.5 (1.7), 2.0	4.4 (0.5), 4.0
TEN DISCRETE LAND USES		
Accessibility (miles)		
Beaches		8.90 (2.62), 8.92
Community Centers		0.41 (0.28), 0.32
Food Stands		0.61 (0.38), 0.53
Libraries and Museums		0.39 (0.22), 0.35
Malls with Parking		2.05 (1.18), 1.78
Stores with Mixed Use		0.10 (0.08), 0.08
Parks		0.13 (0.09), 0.12
Post Offices		0.50 (0.30), 0.44
Schools		0.12 (0.09), 0.10
Theaters		1.03 (0.76), 0.85

	North Carolina	New York
	Mean (SD), Median	**Mean (SD), Median**
Intensity (1/2-mile buffer; number of uses)		
Beaches		0.00 (0.00), 0.00
Community Centers		1.55 (1.64), 1.00
Food Stands		0.72 (1.03), 0.00
Libraries and Museums		1.42 (1.59), 1.00
Malls with Parking		0.07 (0.28), 0.00
Stores with Mixed Use		31.31 (22.23), 22.00
Parks		7.61 (5.18), 6.00
Post Offices		0.62 (0.57), 1.00
Schools		10.42 (6.54), 9.00
Theaters		0.60 (1.47), 0.00
Diversity (1/2-mile buffer; number of different uses 1–10)		5.71 (1.26), 6.00
OUTCOMES		
Percentage of participants meeting recommended levels of physical activity (150 minutes/week) using transportation walking	47.8%	61.7%

Table 3

Odds ratios of meeting recommended levels of walking (≥150 min/week) by transportation walking associated with accessibility, intensity, and diversity of five discrete land use categories in MESA 2000–2002. (n=1975, neighborhood n=331)

		North Carolina[a] (n=970)	New York[a] (n=1005)
	Discrete Land Use	**OR (95% CI)**	**OR (95% CI)**
Accessibility (1 site-specific standard deviation increase in distance)	Social	0.96 (0.87, 1.06)	0.85 (0.73, 0.97)**
	Night	0.98 (0.90, 1.07)	0.95 (0.82, 1.10)
	Physical Activity	1.02 (0.92, 1.14)	0.93 (0.81, 1.08)
	Auto-Oriented	0.93 (0.81, 1.06)	1.00 (0.85, 1.18)
	Parking	0.97 (0.87, 1.09)	1.03 (0.88, 1.21)
Intensity (1 site-specific standard deviation increase in count)	Social	1.05 (0.92, 1.20)	1.09 (0.95, 1.26)
	Night	0.99 (0.88, 1.11)	1.15 (0.99, 1.35)*
	Physical Activity	1.00(0.84, 1.18)	1.16 (0.99, 1.35)*
	Auto-Oriented	1.02 (0.92, 1.14)	0.96 (0.83, 1.12)
	Parking	0.98 (0.90, 1.08)	0.91 (0.78, 1.05)
Diversity (1 type of land use increase)	All five uses	1.06 (0.99, 1.14)	1.03 (0.77, 1.38)

[a]Model adjusted for individual characteristics: age, race/ethnicity, gender, income, education and mode of questionnaire administration. Accounts for clustering by census tract.

*p<0.1

**p<0.05

Table 4

Odds ratios meeting recommended levels of walking (≥150 min/week) by transportation walking associated with accessibility, intensity, and diversity of ten discrete land uses in NY MESA site. (n=1005, neighborhood n=261)

Measure	Land Use	OR[a](95% CI)
Accessibility (1 standard deviation increase in distance)	Beaches	0.87 (0.75, 1.00)[*]
	Community Centers	0.95 (0.82, 1.09)
	Food Stands	1.10 (0.95, 1.28)
	Libraries and Museums	1.01 (0.87, 1.18)
	Malls with Parking	1.09 (0.92, 1.30)
	Stores with Mixed Use	0.98 (0.86, 1.11)
	Parks	0.98 (0.85, 1.13)
	Post Offices	0.86 (0.74, 0.99)[**]
	Schools	1.03 (0.90, 1.18)
	Theaters	0.90 (0.77, 1.04)
Intensity (1 standard deviation increase in count)	Beaches[b]	---------------------
	Community Centers	0.96 (0.83, 1.12)
	Food Stands	0.93 (0.82, 1.06)
	Libraries and Museums	0.93 (0.81, 1.07)
	Malls with Parking	1.00 (0.86, 1.17)
	Stores with Mixed Use	0.98 (0.85, 1.12)
	Parks	0.99 (0.85, 1.14)
	Post Offices	1.12 (0.97, 1.29)
	Schools	1.01 (0.85, 1.19)
	Theaters	1.00 (0.87, 1.15)
Diversity (1 type of land use increase)	All ten uses	1.05 (0.93, 1.18)

[a]Model adjusted for individual characteristics: age, race/ethnicity, gender, income, education and mode of questionnaire administration. Accounts for clustering by census tract.

[b]No beaches within ½-mile of any participant.

[*]p<0.1

[**]p<0.05