

Health Promoting Community Design

Promoting Active Community Environments Through Land Use and Transportation Planning

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Abstract

Purpose. To examine the role of land use and transportation plans as policy instruments for promoting active community environments.

Design. Cross-sectional analysis using multilevel models to examine whether active community environment scores were associated with leisure and transportation-related physical activity (PA) and whether associations varied by household income.

Setting. 67 North Carolina counties

Subjects. Adults ($n = 6694$) from pooled 2000 and 2002 North Carolina Behavioral Risk Factor Surveillance System (BRFSS) surveys.

Measures. Active community environment scores, derived from a 2003 survey of planning directors, representing the presence of nonmotorized transportation improvements, mixed land use classification, and comprehensiveness of implementation tools. Dependent variables were self-reported PA measures from the BRFSS. Sociodemographic variables were derived from the 2000 U.S. Census of Population.

Results. After adjustment for sociodemographic factors, more favorable active community environment scores were significantly associated with leisure PA ($p = .001$), transportation PA ($p < .01$), bicycling ($p < .05$), walking 150 minutes/week ($p < .001$), and meeting PA recommendations ($p < .0001$). In stratified analyses, lower-income individuals ($< \$25,000$) living in high scoring counties were three times more likely to participate in transportation PA compared with those living in low scoring counties (95% confidence interval, 1.4, 7.3).

Conclusions. This study identifies previously unexamined policy and institutional correlates of PA related to land use and transportation planning. Plans may provide a means to incorporate community support for active living into public policy. (*Am J Health Promot* 2007;21[4 Supplement]:397-407.)

Key Words: Physical Activity, Policy, Urban Planning, Health Disparities, Prevention Research. Format: research; Research purpose: modeling/relationship testing; Study design: nonexperimental; Outcome measure: behavioral; Setting: local community; Health focus: fitness/physical activity; Strategy: policy, built

environment; Target population: adults; Target population circumstances: income level, geographic location, race/ethnicity

PURPOSE

The role of the built environment in supporting healthy lifestyles has become a focus of public health research and practice.^{1,2} Recognizing that health promotion requires both individually oriented and community-based approaches, the Centers for Disease Control and Prevention recently initiated the Active Community Environment (ACE) program to promote policy and environmental interventions that create more accessible places for physical activity (PA).³ Activity-friendly environments depend upon appropriate integration of land use and transportation infrastructure, including higher densities,^{4,5} a mix of residential and commercial land use,⁶⁻⁹ and connected systems of sidewalks, bikeways, greenways, and transit.⁶⁻¹² Although prior research had identified microlevel environmental correlates of PA,¹¹ the planning and policy processes that result in such attributes have been largely overlooked. By applying specific implementation tools to shape the pattern of growth, planners can encourage more compact urban forms, increase the viability of nonmotorized transportation modes, preserve green space, and enhance the convenience and accessibility of public places for PA. Therefore, policies set forth by land use and transportation plans may influence both leisure and transportation PA (e.g., walking or bicycling to work or school). However, little is known empirically about the

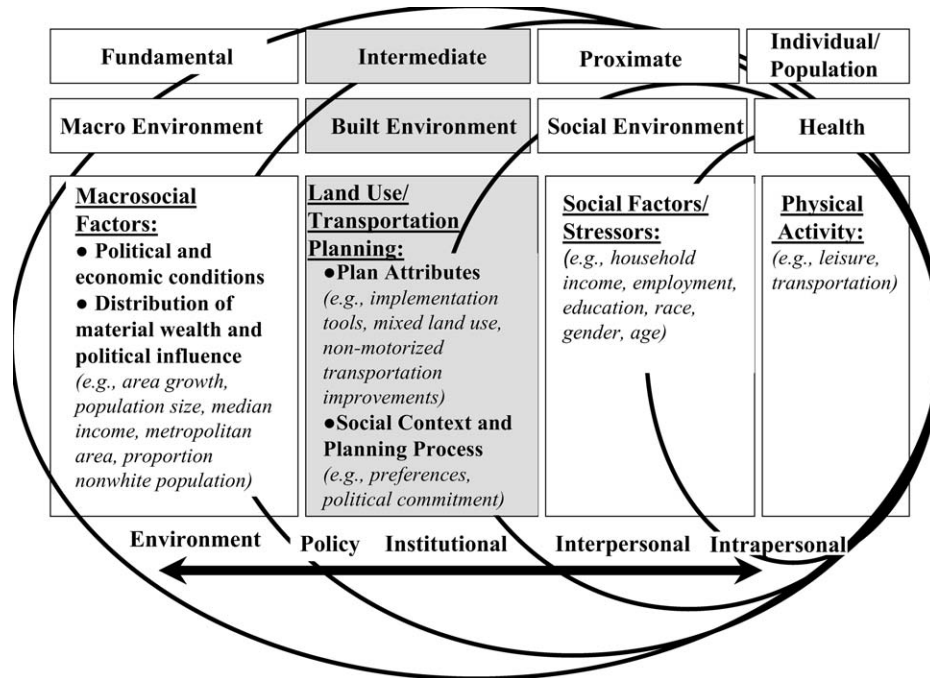
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This manuscript was submitted May 1, 2006; revisions were requested August 14, 2006; the manuscript was accepted for publication August 20, 2006.

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0890-1171/07/\$5.00 + 0

Figure 1
Socioecologic Framework



extent to which specific land-use policies complement nonmotorized transportation improvements (NMTI) to promote active community environments.

The purpose of this study was to examine whether the presence of land-use policies and implementation tools supportive of NMTI and/or mixed land use was associated with PA, including leisure-time PA, transportation PA, walking, and bicycling. We also examined whether associations varied by household income.

The theoretic framework for this study is derived from a socioecologic model, adapted from the work of Schulz and Northridge,¹³ Northridge et al,¹⁴ and Stokols¹⁵ (Figure 1). This model delineates potential pathways through which macrosocial, political, and economic processes interface with the built environment to affect health by mediating differential access to power and community resources. Because prior studies suggested that area-level factors such as population growth, income, and metropolitan status are associated with the adoption of PA-friendly land-use policies¹⁶ and pedestrian facilities,^{17,18} these factors com-

plement individual-level socioeconomic attributes in our framework. We focus on land use and transportation planning as elements of the institutional context, which may influence PA through the built environment as well as through dynamic, bidirectional processes operating at the fundamental and proximate levels.

Although researchers have previously explored the role of the connection between land use and transportation with respect to built environments and travel behavior,^{4,19-24} we extend this work by examining how land-use plans in North Carolina incorporate policies potentially supportive of NMTI. As guides for the location, intensity, and characteristics of land development and community infrastructure,²⁵ land-use plans play important roles in shaping the built environment. Our premise, therefore, is that land-use plans should explicitly account for nonmotorized transportation modes²⁶ if they are to be effective policy instruments for promoting active community environments.

As in most of the United States, land-use plans in North Carolina are drawn at the municipal and county levels.

North Carolina mandates land-use planning only in certain environmentally sensitive areas in coastal counties. In contrast, transportation plans are usually drawn at the regional level by metropolitan planning organizations (MPOs), who determine the transportation improvements to fund at the local level. Implementation is facilitated by the North Carolina Department of Transportation (NCDOT), which has authority over 80% of the roads in the state. NCDOT has ultimate discretion over road characteristics, including the presence of sidewalks and bike lanes on local streets. Cities and counties also play an important role in directing funding toward NMTI, yet to be maximally effective these improvements should be coordinated with MPOs and NCDOT plans. Thus, transportation-related decisions occur at multiple geographic levels, while land-use decisions take place primarily at the county and city levels.

METHODS

Design

This cross-sectional study examined the role of land use and transportation plans as policy instruments for promoting active community environments in a representative sample of North Carolina counties during 2000 to 2003. Several data sources were combined, including individual-level PA and sociodemographic data from the Behavioral Risk Factor Surveillance System (BRFSS),^{27,28} county-level sociodemographic data from the U.S. Census of Population, and primary data collected from a survey of planning directors in North Carolina.

Sample

Information on land use and transportation plans was gathered from a 2003 survey mailed to planning directors in all North Carolina counties (n = 100) and municipalities with >10,000 residents (n = 64). The survey, sponsored by NCDOT, examined the prevalence of land-use plans and the inclusion of implementation tools and transportation improvements by local jurisdictions.²⁹ Responses were received from planning directors in 80 counties and 47 municipalities (overall response rate = 77%). Analyses were restricted to 67 counties with land-use

plans because this was the scale at which data could be linked to the BRFSS with sufficient sample size. In five cases, cities were used as proxies for nonresponding counties if they were central cities and part of the MPO for that county.

Measures

Independent Variables. To operationalize the extent to which land use and transportation plans provided institutional support for active community environments, we focused on the presence of three key plan attributes: NMTI, mixed land use classification, and the comprehensiveness of implementation tools to guide land development. These attributes were chosen *a priori* based on existing literature which suggests that mixed land uses, compact development, open space, and supportive transportation infrastructure are positively associated with PA.^{4,6-8,12,30} Planners were asked to report whether specific policies and implementation tools (e.g., designated growth areas, capital improvement programs, planned unit developments, land trusts, concurrency requirements, impact fees, transfer/purchase of development rights)³¹ were being used to manage the location and timing of development in their communities. In addition, planners were asked whether their plans included NMTI (e.g., sidewalks, bicycle paths, greenways) and whether the “mixed use” land classification was designated by the land-use plan.

To measure the comprehensiveness of implementation tools, plans were classified according to the number and types of tools included. Tools such as concurrency requirements, impact fees, and transfer/purchase of development rights involve financial leverage through expenditures from either developers or local governments. These types of investment-based tools were considered indicative of higher plan quality^{25,32} and/or greater political commitment to implementation. For example, concurrency requirements attempt to manage the timing of development so that it coincides with the availability of infrastructure capacity for community facilities such as transportation, water, and sewer.

Guided by prior analyses that confirmed the importance of investment-based tools to PA,³¹ we derived three categories of comprehensiveness as follows: (1) Plans with the least comprehensive implementation tool sets were those that included no tools supportive of nonmotorized modes to guide land development; (2) moderately comprehensive implementation tool sets included at least one tool but did not include investment-based tools; and (3) the most comprehensive tool sets included at least five tools overall with at least one investment-based tool.

The ACE composite score was derived as follows

- 1 = No mixed-use classification, no NMTI, no implementation tools
- 2 = Mixed-use classification or NMTI; 0–4 implementation tools
- 3 = Mixed-use classification and NMTI; moderately comprehensive implementation tool set (1–4 tools)
- 4 = Mixed-use classification and NMTI; most comprehensive implementation tool set (≥ 5 tools)

The first category consisted of plans that did not include any of the three key attributes, while the second category was comprised of plans that included one or two attributes but did not include all three. Categories 3 and 4 both consisted of plans that included all three land use and transportation attributes, but category 4 included the most comprehensive implementation tool sets. Categorical variables were created with the lowest active community environment score designated as the referent group.

Sociodemographic Characteristics.

Individual-level Sociodemographic Measures. Individual-level sociodemographic variables known to be correlated with PA (age, gender, education, employment status, income, and race) were obtained from the BRFSS. Self-reported information for these variables from the BRFSS has been shown to be reliable.^{33,34} Race was collapsed into a dichotomous variable representing white or nonwhite. Education was collapsed to represent less than or equal to high school education or greater than high school education.

Employment status was collapsed to represent those who were currently employed for wages and those who were not. Age was dichotomized as <60 and ≥ 60 years (corresponding to the 75th percentile of the distribution).

Each respondent’s household income was centered around the median income for their county.³¹ This method was also used to impute income categories for respondents who did not report their household income (approximately 15%) based on the median income for a person of similar age, race, gender, and education level in each county. For stratified analyses, a dichotomous variable was derived representing household income $\geq \$25,000$ or $< \$25,000$; this cutpoint corresponded to the lowest quartile of the distribution and facilitated comparison with other studies.^{6,35}

County-level Sociodemographic Measures.

A centered county income variable was derived by subtracting each county’s median income level from the state median income level. High area growth was defined as $>25\%$ increase in population from 1990 to 2000. Large population size was defined as $\geq 50,000$. The percentage of nonwhite residents in each county was determined from the 2000 U.S. Census of Population and collapsed into an ordinal variable approximately representing quartiles of the distribution: (1) 0% to 14% nonwhite, (2) 15% to 27% nonwhite, (3) 28% to 34% nonwhite, and (4) $\geq 35\%$ nonwhite. Indicator variables were also used to designate whether an area was part of a metropolitan area³⁶ or part of an MPO.

Dependent Variables. The BRFSS is a population-based, random-digit-dialed telephone survey of the civilian, noninstitutionalized population aged ≥ 18 years.²⁷ The sampling procedure accounts for the number of telephone numbers per household and randomly selects one adult from each household. As such, the BRFSS provides population-level estimates of PA with sufficient sample size to analyze prevalences at the state and substate levels. Information regarding the North Carolina BRFSS is published elsewhere.³⁷

Self-reported PA measures derived from the North Carolina BRFSS included the prevalence of any leisure PA in the past month, leisure-time walking and bicycling in the past month, and transportation PA in the past week.^{31,38} The transportation PA question, which was added to North Carolina's BRFSS module in 2000 and 2002, asked respondents how much time they spent walking or bicycling for transportation in the past week, such as to and from work or shopping. However, more than 85% of adults reported no transportation-related activity; therefore, a dichotomous variable (any transportation PA versus none) was used.

Additionally, we calculated the proportion of adults achieving recommended levels of PA in each county according to guidelines published by the Centers for Disease Control and Prevention.³⁹ Using measures of frequency, duration, and intensity,⁴⁰ the proportion of individuals performing recommended levels of PA was derived as follows: (1) no leisure-time PA, (2) some activity but insufficient to meet recommendations, and (3) meets recommendations. To measure the proportion of adults achieving recommended PA levels specifically by walking, we created another ordinal variable representing (1) no leisure-time PA, (2) leisure-time walking <150 minutes per week, and (3) ≥150 minutes of leisure-time walking per week. Respondents who reported no walking but may have reported other types of PA were not included in this measure. Recommended PA and walking variables were restricted to the 2000 BRFSS (n = 2187), due to changes made to the core PA questions in 2001.

Reliability of the leisure PA measures derived from the BRFSS has been shown to be acceptable in several studies (κ range, 0.50–0.77)^{34,38,41} and across race and gender groups (intra-class correlation coefficients [ICC], 0.36–0.63).⁴² A recent study that assessed the reliability of the BRFSS measures of recommended PA showed acceptable reliability (ICC for meeting moderate leisure-time activity recommendations, 0.46; ICC for meeting vigorous leisure-time activity recommendations, 0.68).⁴²

Analysis

To examine bivariate relationships between the ACE score and socio-demographic factors, SAS-callable SUDDAAN⁴³ was used to obtain weighted prevalences which account for the BRFSS sampling design. Because we conceptualized land use and transportation planning as part of each resident's institutional and environmental context, these prevalences reflect the proportion of North Carolina adults living in counties with low, medium, or high ACE scores.

Multilevel models were used to examine associations between PA outcomes and ACE scores while controlling for individual (level 1) and county (level 2) sociodemographic characteristics. Multilevel models appropriately account for the clustering of individuals within counties. Generalized linear models with a logit link were used for multilevel analysis of binary outcomes (any leisure PA, any transportation PA, and any bicycling). The SAS GLIMMIX (version 8.2) macro was used to estimate model parameters based on penalized quasi-likelihood methods. Stratified analyses were also conducted to evaluate whether relationships between ACE scores and transportation PA varied by household income since lower-income groups have limited access to private vehicles⁴⁴ and are more likely to participate in nonleisure PA.^{45,46} Marginal models fitted by generalized estimating equations⁴⁷ were used to analyze three-level ordered categorical outcomes (e.g., recommended PA, walking ≥150 minutes/week).

Using random-intercept models, we allowed each county to have its own intercept to describe the relationship between individual (level 1) characteristics and PA within that county. Next models incorporating random slope terms were examined, which allowed regression coefficients to vary and permitted interactions between individual (level 1) and county (level 2) factors. However, the random slope terms were not statistically significant ($\alpha = 0.05$) and did not appreciably improve the model fit; therefore, the more parsimonious random-intercept models are presented.

A series of random-intercept models was run for each PA outcome. The

first was an unadjusted model including only the ACE variables, followed by full models adjusted for all individual- and county-level sociodemographic covariates and any significant interaction terms. The third was a reduced model that retained certain sociodemographic characteristics that were statistically significant ($p < .05$), were considered substantively important, or affected the precision of the main exposure (ACE) estimates.

The multilevel models estimated the probability of being physically active as a function of the ACE score while controlling for sociodemographic characteristics. For a binary outcome, the multilevel regression parameter for the ACE score can be interpreted as the change in an individual's log odds of engaging in PA associated with a unit change in the county's ACE score. For a three-level outcome (e.g., recommended PA and walking ≥150 minutes/week), the interpretation of the ACE coefficient is the population average effect on the log odds of being in a higher versus lower PA recommendation category.

Model results are reported in terms of prevalence odds ratio (POR), which represent the odds of being physically active for individuals residing in higher ACE counties compared with individuals residing in the lowest ACE counties. This presentation facilitates comparison with other recent studies of environmental correlates of PA; however, when the outcome of interest is not rare, the odds ratio can overestimate the relative risk.^{48,49} Since several of the PA outcomes in our study have prevalences >15%, we also provide corrected measures of relative risk for these outcomes using a method developed by Zhang.⁴⁹

RESULTS

Eighty-four percent of county planners (67 out of 80 counties) who responded to the survey reported having a land-use plan, representing approximately 73% of the adult population of North Carolina. Sociodemographic characteristics of counties included in our sample were generally representative of the state, although our sample included a higher per-

Table 1
PA Prevalence and Sociodemographic Characteristics by ACE Score

	Overall	ACE Score			
		Low	Medium		High
		1	2	3	4
BRFSS sample size	n = 6694*	n = 1040	n = 3000	n = 1518	n = 1136
Weighted population percentage (SE)	100	14 (0.6)	50 (0.8)	22 (0.7)	14 (0.4)
PA					
Any leisure-time PA in past month	71 (0.7)	69 (2.1)	70 (1.2)	71 (1.7)	82 (1.6)
Any transportation PA in past week	14 (0.5)	13(1.5)	14 (0.9)	14 (1.1)	20 (1.8)
Any bicycling in past month	4 (0.3)	2 (0.6)	4 (0.5)	4 (0.6)	6 (1.1)
Meets recommendation for leisure PA	24 (1.0)	12 (1.8)	26 (1.5)	25 (2.2)	31 (3.3)
Walking ≥ 150 minutes/week	17 (1.1)	11 (2.0)	18 (1.6)	17 (2.3)	20 (3.4)
Population size					
Large (≥50,000)	80 (0.7)	11(0.5)	46 (0.9)	27 (0.8)	17 (0.5)
Small (<50,000)	20 (0.7)	25 (2.0)	69 (2.0)	6 (0.8)	0
Metropolitan area†					
No	23 (0.7)	32 (1.8)	64 (1.9)	4 (0.6)	0
Yes	77 (0.7)	8 (0.5)	46 (0.9)	28 (0.8)	18 (0.5)
Growth‡					
High	51 (0.8)	4 (0.5)	40 (0.9)	29 (0.9)	26 (0.8)
Low	49 (0.8)	24 (1.1)	61 (1.3)	15 (1.0)	0
County income level					
Below NC median	17 (0.6)	51 (2.1)	44 (2.0)	5 (0.8)	0
Equal to NC median§	58 (0.8)	8 (0.7)	70 (1.1)	18 (0.9)	3 (0.2)
Above NC median	25 (0.5)	0	7 (1.0)	45 (1.3)	48(1.2)
Proportion nonwhite residents					
3%–14%	19 (0.6)	19 (1.3)	53 (1.7)	27 (1.4)	0
15%–27%	24 (0.8)	7 (1.1)	63 (2.0)	22 (1.9)	7 (0.6)
28%–34%	23 (0.6)	4 (0.9)	45 (1.5)	0	51 (1.5)
35%–63%	34 (0.8)	22 (1.2)	43 (1.5)	35 (1.2)	0

ACE indicates Active Community Environment; BRFSS indicates Behavioral Risk Factor Surveillance System; NC indicates North Carolina; and PA, physical activity.

* BRFSS data from 2000 and 2002 combined, weighted to reflect the 2000 North Carolina population and to account for the sampling design.

Recommended PA and walking models are restricted to the 2000 BRFSS (n = 2186).

† Metropolitan area as defined by the 2000 U.S. Census of Population.

‡ High growth is defined as >25% increase in population from 1990 to 2000.

§ The median county income for our sample was \$40,089 (range, \$25,854–\$58,099). This corresponds to BRFSS category 6 (\$35,000–<\$50,000). Low county income corresponds to <\$35,000; high county income corresponds to >\$50,000.

|| The median proportion nonwhite was 28 (range, 2.8–62.5).

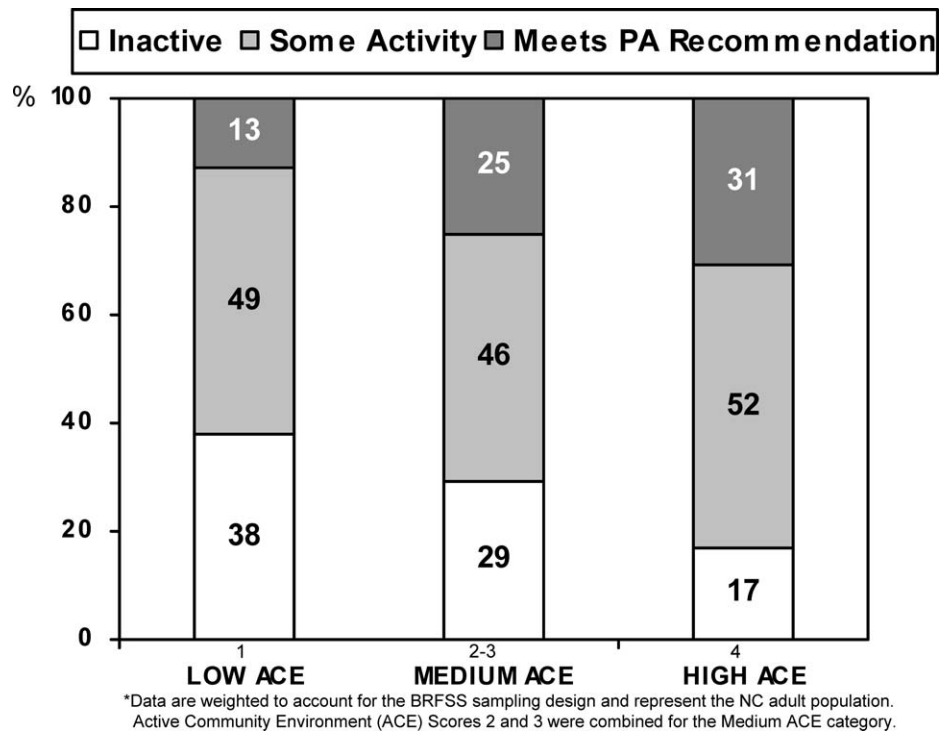
centage of metropolitan counties (48% versus 36% in the state overall) and had higher median income (\$40,089 versus \$34,635). Counties without land-use plans tended to have lower population growth rates, median household incomes below \$35,000, and were more likely to be located in nonmetropolitan areas. No statistically significant differences were observed between counties with and without land-use plans in terms of overall population size or the proportion of nonwhite residents.

Table 1 presents the distribution of ACE scores with respect to PA and sociodemographic characteristics. The majority of North Carolina adults live in counties with low to moderate scores. Higher scores were predominantly found in faster-growing metropolitan areas with higher median income levels.

Overall, 71% of North Carolina adults reported participating in any leisure PA in the past month, while 14% reported performing transportation PA and 4% reported any bicycling

in the past month (Table 1). Approximately one-quarter of North Carolina adults achieved recommended levels of leisure PA, and 17% reported walking at least 150 minutes per week. Higher prevalences of PA were observed in counties with higher ACE scores. Figure 2 illustrates the weighted population prevalence of North Carolina adults achieving recommended levels of PA across ACE scores. While approximately one-third of adults living in high-scoring counties met public health recom-

Figure 2
Proportion of North Carolina Adults Meeting Recommendations for Leisure Physical Activity by Active Community Environment Score



recommendations for PA, 87% of those living in counties with the lowest ACE scores fell short of meeting public health guidelines.

Associations between the ACE score and selected PA outcomes are shown in Table 2. Unadjusted models are shown in the first row, followed by full models adjusted for all individual- and county-level sociodemographic covariates and any significant interaction terms. The third row shows the final reduced models that retain sociodemographic characteristics that remained statistically significant ($p < .05$) or were considered substantively important.

Results suggest that high ACE scores were consistently associated with both leisure and transportation PA outcomes. The strongest associations in the adjusted models were observed for transportation PA and bicycling; individuals living in counties with the highest ACE scores had more than twice the odds of engaging in these types of PA compared with residents of counties with the lowest ACE scores.

When analyses were restricted to lower-income individuals (household incomes $< \$25,000$), the association was even stronger: the likelihood of engaging in transportation PA for persons living in high ACE counties was three times greater than the odds for those living in low ACE counties (POR = 3.2 [95% confidence interval (CI), 1.4, 7.3]; data not shown). The corresponding odds ratio for individuals with household incomes $\geq \$25,000$ was 1.8 (95% CI, 1.1, 3.1).

Associations between the ACE score, recommended PA levels and walking ≥ 150 minutes per week are shown in the last two columns of Table 2. Residents of high ACE counties were 1.9 times more likely to be in a more favorable PA recommendation category (indicative of a population-level shift along the continuum from no leisure PA to some leisure PA to meeting PA recommendations) and 1.7 times more likely to be in a higher walking category compared with residents of the lowest ACE counties.

As shown in Table 3, significant between-county variation existed with respect to the prevalence of PA in North Carolina (leisure PA $p < .01$; transportation PA $p < .01$; bicycling $p < .05$). The multilevel models including ACE variables and sociodemographic covariates explained 71% of the between-county variation in transportation PA, 82% of the between-county variation in leisure PA, and 83% of the between-county variation in bicycling. The ACE variables helped to explain additional between-county variance above and beyond that explained by traditional sociodemographic factors.

DISCUSSION

North Carolina is a rapidly growing state with a diverse population and considerable geographic variation in PA. The proportion of residents reporting no leisure-time PA varied substantially across different counties, ranging from 18.4% to 40.9% in 2002 (compared with the national average of 25.3%).³⁷

Although the literature regarding policy correlates of PA is relatively limited to date, the observed associations between higher ACE scores and higher population prevalences of leisure and transportation PA are consistent with the results from several recent international studies. Studies conducted in the Netherlands and Germany have shown that policies related to urban form and transportation infrastructure are associated with bicycling.⁵⁰⁻⁵² Researchers in the United States have found similar relationships.⁵³⁻⁵⁵ In the present study, individual-level bicycling and transportation PA showed stronger associations with ACE scores compared with other types of leisure PA. This may reflect the emphasis of the ACE score on planning factors such as public infrastructure and mixed land use, while availability of private clubs, gyms, parks, and other unmeasured facilities may be important for leisure activities.

Furthermore, the composite ACE score showed stronger associations with PA compared with implementation tools or non-motorized transportation improvements examined as separate factors.³¹ Certain types of

Table 2
Multilevel Models for PA Outcomes by ACE Score

Model	ACE Score	Any Leisure PA§ POR (95% CI)	Any Transportation PA	Any Bicycling¶	Recommended PA#	Leisure Walking 150 Minutes/Week**
Unadjusted model 1						
	4 (Highest)	2.19 (1.52, 3.15)	2.15 (1.29, 3.59)	2.87 (1.54, 5.43)	2.23 (1.70, 2.92)	1.96 (1.45, 2.63)
	3	1.24 (0.94, 1.64)	1.19 (0.79, 1.79)	1.68 (0.94, 3.02)	1.56 (1.22, 1.99)	1.53 (1.12, 2.09)
	2	1.15 (0.92, 1.43)	1.21 (0.87, 1.67)	1.48 (0.88, 2.47)	1.41 (1.11, 1.80)	1.28 (0.93, 1.77)
	1 (Lowest)	1.00	1.00	1.00	1.00	1.00
Full model 2*						
	4 (Highest)	1.54 (1.09, 2.19)	2.13 (1.24, 3.65)	2.16 (1.05, 4.43)	1.83 (1.21, 2.75)	1.66 (1.05, 2.61)
	3	1.21 (0.91, 1.59)	1.25 (0.81, 1.94)	1.70 (0.83, 3.48)	1.44 (1.02, 2.02)	1.46 (0.96, 2.21)
	2	1.12 (0.90, 1.39)	1.26 (0.90, 1.76)	1.49 (0.84, 2.65)	1.35 (1.00, 1.82)	1.20 (0.83, 1.76)
	1 (Lowest)	1.00	1.00	1.00	1.00	1.00
Final model 3†						
	4 (Highest)	1.58 (1.11, 2.23)	2.24 (1.25, 4.00)	2.42 (1.13, 5.16)	1.94 (1.44, 2.62)	1.75 (1.35, 2.36)
	3	1.22 (0.92, 1.61)	1.26 (0.80, 1.98)	1.61 (0.79, 3.31)	1.52 (1.16, 1.99)	1.56 (1.14, 2.12)
	2	1.10 (0.89, 1.36)	1.27 (0.90, 1.81)	1.49 (0.84, 2.63)	1.36 (1.04, 1.78)	1.20 (0.88, 1.64)
	1 (Lowest)	1.00	1.00	1.00	1.00	1.00
Corrected relative risk‡						
	4 (Highest)	1.14 (1.06, 1.20)	—	—	1.74 (1.37, 2.18)	1.47 (1.11, 1.92)
	3	1.06 (0.99, 1.13)	—	—	1.44 (1.15, 1.78)	1.40 (1.06, 1.81)
	2	1.03 (0.97, 1.09)	—	—	1.31 (1.04, 1.63)	1.09 (0.82, 1.44)
	1 (Lowest)	1.00	—	—	1.00	1.00

ACE indicates Active Community Environment; CI, confidence interval; PA, physical activity; and POR, prevalence odds ratio.

* Full models are adjusted for all individual (Level 1) and county (Level 2) covariates: age, gender, race, education, household income, employment, county income, growth, population size, metropolitan area, proportion nonwhite, and significant interaction terms as specified in italics in the final models.

† Final models were adjusted for age, race, gender, and education for consistency with the literature; other covariates and interaction terms were retained if they remained statistically significant ($p < .05$) or if they affected the precision of the main exposure (ACE) estimate. Interactions were not included in the generalized estimating equations (models for recommended PA and walking ≥ 150 minutes/week) since these analyses were restricted to 2000 Behavioral Risk Factor Surveillance System data and sample sizes and power were reduced.

‡ Relative risk (95% CI) for ACE scores for outcomes with prevalence $>15\%$ (using correction method developed by Zhang⁴⁹): Relative risk = $(POR_{adjusted}) / ([1 - Prevalence_{nonexposed}] + [Prevalence_{nonexposed} \times POR])$.

§ Leisure PA final model adjusted for gender, race, education, household income, proportion nonwhite population, *age*race*, *age*education*.

|| Transportation PA final model adjusted for age, gender, race, education, household income, employment, county income, growth, population size, metropolitan area, proportion nonwhite, *age*race*, *race*education*.

¶ Bicycling final model adjusted for age, gender, race, education, county income, proportion nonwhite, *proportion nonwhite*county income*

Recommended PA final model adjusted for age, gender, race, education, employment, and household income.

** Walking ≥ 150 minutes/week final model adjusted for age, gender, race, education, employment, household income, and proportion nonwhite.

implementation tools, such as investment-based tools, may provide leverage for communities to influence features of the built environment that have been associated with PA in other studies, including convenient exercise facilities (such as streets and public open spaces),^{6,9,13,55-67} safe places to walk,^{8,56-59} a mix of residential and commercial land uses,^{6,7,60,61} and supportive transportation infrastructure.^{10,19,52-54,62}

Our finding that higher ACE scores showed positive relationships with recommended PA levels and negative relationships with inactivity supports findings from another study conducted in six North Carolina counties, which reported that perceived access to places for PA and neighborhood trails

was significantly associated with recommended levels of PA.⁶³ Other researchers have reported a positive dose-response relationship between the number of places to exercise and the likelihood of meeting PA recommendations.⁶⁴

However, it is important to frame our results in light of underlying sociodemographic patterns. Counties with the highest ACE scores were almost exclusively those with higher median income levels and higher growth rates.³⁸ Although different types of transportation improvements and land-use policies may be feasible in low-growth areas compared with high-growth areas, planners and policymakers should consider the potential health and equity impacts of land use

and transportation decisions with respect to local and regional demographic trends. Lower-income populations may benefit most from land use and transportation planning that supports walking and bicycling, as they are less likely to own private vehicles,^{44,65} more likely to engage in PA for transportation purposes,^{6,10,46,66,67} and more likely to suffer from diabetes, cardiovascular disease, and chronic health conditions associated with inactivity.^{68,69} Stratified analyses showed stronger associations between ACE scores and transportation PA among individuals with lower household incomes ($< \$25,000$) compared with individuals with incomes $\geq \$25,000$. Thus, lower-income persons may be more likely to use nonmotorized modes in

Table 3
ICC* and Percent of Between-county Variance Explained for Binary PA Outcomes

Variance	Any Leisure PA	Any Transportation PA	Any Bicycling
Between-county variance	0.0742	0.1041	0.1566
Within-county variance	0.9921	0.9810	0.9416
ICC	0.0696	0.0959	0.1426
Percent of between-county variance explained by ACE score (model 1)	48%	33%	62%
Percent of between-county variance explained by ACE score and sociodemographics (model 2)†	82%	71%	83%

ACE indicates Active Community Environment; ICC, intraclass correlation coefficients; and PA, physical activity.

* The ICC quantifies the proportion of the total variation in PA that is due to between-county variation.

† In models including ACE variables and sociodemographic covariates, no statistically significant between-county variation remained for leisure-time PA ($p = .1197$) and bicycling ($p = .2996$), and only borderline significant variation remained for transportation-related PA ($p = .0470$).

areas where supportive land use and transportation infrastructure exists.

For higher-income individuals, the odds of performing transportation PA almost doubled for residents of high-scoring counties compared with the lowest scoring counties. Although the overall prevalence of transportation PA was quite low, transportation PA was an important source of activity for individuals who engaged in it (median 100 minutes per week [interquartile range, 30–300 minutes]). Additionally, individuals engaging in transportation PA were significantly more likely to meet public health guidelines for leisure PA ($p < .001$; analyses not shown). This lends support to the role of land use and transportation planning as a population-wide strategy to promote active living.

However, interactions among several sociodemographic variables in our models raise important questions for consideration with respect to future public health interventions. For example, among nonwhite individuals, older age and higher education were inversely related to transportation PA (POR 0.51 [95% CI, 0.31, 0.83]); among whites, older individuals with higher education levels were more likely to walk or bicycle for transportation (POR 1.97 [95% CI, 1.20, 3.23]). Although not assessed in this study, attitudes, beliefs, and social support may vary across population subgroups regarding participation in transportation versus leisure PA. In the model for bicycling, interactions between county income level and the proportion non-

white residents suggested that in counties with higher income levels, a higher proportion of nonwhite residents was associated with increased odds of bicycling (POR 1.44 [95% CI, 1.04, 2.00]); however, in counties with lower income levels, a higher proportion of nonwhite residents was inversely related to bicycling (POR 0.82 [95% CI, 0.60, 1.00]). Taken together with the transportation PA results, this finding lends support to the assertion that low income and nonwhite populations may be particularly sensitive to environment and policy supports for bicycling and walking. For example, in lower-income areas where supportive infrastructure is less likely to exist,^{31,70} nonwhite residents may be less inclined to use nonmotorized modes due to safety concerns, lack of social support, or being differentially affected by the spatial configuration resulting from regional development patterns. Conversely, if higher-income areas generally provide more supportive infrastructure (and/or develop better quality plans that consider the needs of diverse populations in the planning process), low income and nonwhite populations may be more likely to take advantage of nonmotorized modes. Another recent study reported complex nonlinear relationships between walking for transportation and sociodemographic factors such as age, income, and education.⁴⁵ Other researchers have found that metropolitan residents are more likely to commute by bicycle if designated lanes and paths are available to

them.^{53,54} These examples underscore the importance of considering multidimensional public health interventions including policy and environmental components along with individual-level health promotion strategies. Future studies could test hypotheses related to these issues more specifically in diverse communities.

Limitations

Several limitations are inherent in this study. First, because the cross-sectional design precludes the assessment of temporal relationships and limits causal inferences, several alternative explanations warrant mention. Our findings could reflect the fact that residents who are more physically active may have successfully advocated for supportive policies and transportation improvements in their communities. This interpretation supports the view of other planning researchers^{71–74} who consider plans as indicators of community preferences, especially with respect to the distribution of public facilities. Furthermore, this interpretation remains consistent with our theoretic framework which postulates that planning is embedded in a dynamic system of social, economic, and political factors operating bidirectionally at multiple levels. Plans may operate not only through the mechanism of physical infrastructure but also by influencing the social context and public policy processes that potentially reinforce active community environments over time.

A second set of limitations pertains to measurement. Although PA was self-reported in this study, our research questions focused on the *relative* amount of PA in different counties, not the *absolute* amount. Any bias inherent in the self-reported responses should be nondifferential with respect to geographic area, thus the gross ranking of different counties should be largely unaffected.

The measures of plan attributes were also self-reported. To assess validity, a detailed content evaluation was conducted on a subset of 30 plans comparing planners' self-reported information to the documentation contained within the plans.²⁹ This analysis included an assessment of the plans' goals and policies with respect to walking and bicycling and lent support to planners' survey responses. For example, sensitivity and specificity for attributes pertaining to the inclusion of NMTI were 83% and 73%, respectively. This suggests that planners accurately reported the presence of NMTI when they were documented in the land-use plans and correctly reported these attributes as missing when they were absent from the plans. However, the validity of other plan characteristics has not been fully assessed.

Third, our study does not distinguish how well the policies have been enforced or the extent to which they have affected land-development patterns on the ground. Although research that examines plan implementation is relatively limited to date, prior studies have shown that plans appear to exert considerable influence in achieving a variety of public goals including hazard mitigation,^{75,76} ecosystem management,⁷⁷ and environmental protection.³² Factors affecting plan implementation and outcomes include local governments' political commitment,^{78,79} plan quality⁸⁰ (including consistency and clarity of goals and policies), resources of planning agencies,^{80,81} and interactions between organizations.⁸² While our study did not directly measure these factors, it is plausible that the ACE score captures several dimensions including community preferences, resources, plan quality, and political commitment to active living.

Additionally, we cannot determine whether the relationships we observed are primarily due to characteristics of county-level plans or due to better municipal planning in the counties we studied. To assess consistency between county plans and city plans, we examined more than 30 pairs of city-county plans. We found a strong correlation (Spearman $r = .93$) between the ACE scores of the city and county plans, suggesting that city and county plans reinforced each other with respect to activity-friendly attributes. Questions exploring consistency in planning, intergovernmental coordination, and public participation remain important areas for future study.

Fourth, although the multilevel models explained a considerable proportion of the between-county variance in PA, they did not explain a significant proportion of the within-county (individual-level) variation. This is consistent with our theoretic framework in which the ACE variables constitute the distal environment, policy, and institutional context of the socioecologic model. Because we did not measure more proximal interpersonal and psychosocial factors such as social support, self-efficacy, and perceptions of the neighborhood environment, the models would not be expected to explain a significant portion of the individual-level variance.

Last, our analyses were restricted to North Carolina counties with land-use plans and therefore may not be generalizable to other states.

Future research should evaluate these relationships in different geographic locations, use prospective designs or natural experiments, and attempt to include the perceptions of community members and policy-makers in addition to those of planners.

CONCLUSION

This study identifies previously unexamined policy and institutional correlates of PA related to land use and transportation planning. While we cannot conclude that planning causes behavior change, our findings demonstrate that counties with higher ACE scores have higher prevalences of

both leisure and transportation PA. Because a higher score indicates a more comprehensive implementation tool set complementing NMTI and mixed land use classification, this suggests that counties with land-use policies and implementation tools that support nonmotorized modes may foster diverse environments conducive to various types of PA (e.g., greenways, parks, open space, and walkable downtown areas). Improving the quality of local land-use plans may provide a means for communities to integrate transportation projects with appropriate land uses and improve access to health-promoting infrastructure.

Partnerships between public health and urban planning professionals could translate into innovative interventions tailored to meet the needs of diverse communities. Future health-promotion efforts should consider the implications of transportation and land-use policies, especially with respect to the distribution of resources that support transportation PA as well as leisure PA. Transdisciplinary collaboration may contribute to more comprehensive methodologic frameworks and inform policy recommendations to promote active community environments.

SO WHAT? Implications for Practitioners and Researchers

This study appears to indicate that land use and transportation planning may play a role in supporting active community environments. After controlling for socio-demographic factors, higher ACE scores were associated with leisure-time PA, transportation-related PA, and meeting public health recommendations for PA in North Carolina. If this assertion holds true, land-use and transportation plans may provide a means through which community support for active living can be incorporated into the public policy process. Additionally, these findings could be used to tailor transdisciplinary interventions to promote active living in diverse populations.

Acknowledgments

This study was conducted while the first author was supported by a dissertation grant from the Robert Wood Johnson Foundation's Active Living Research Program. Support for the planning survey was provided by the North Carolina Department of Transportation.

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