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Sociodemographic and Environmental Correlates of Active Commuting in Rural America

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Abstract

Purpose: This research investigated participation rates in 3 modes of active commuting (AC) and their sociodemographic and physical environmental correlates in rural America.

Methods: The 2000 Census supplemented with other data sets were used to analyze AC rates in percentage of workers walking, biking, and taking public transportation to work in 14,209 nonmetropolitan rural tracts identified by RUCA codes, including 4,067 small rural and 10,142 town-micropolitan rural tracts. Sociodemographic and physical environmental variables were correlated with 3 AC modes simultaneously using Seemingly Unrelated Regression for nonmetro rural, and for small rural and town-micropolitan rural separately.

Findings: The average AC rates in rural tracts were 3.63%, 0.26%, and 0.56% for walking, biking, and public transportation to work, respectively, with small rural tracts having a higher rate of walking but lower rates of biking and public transportation to work than town-micropolitan tracts. In general, better economic well-being was negatively associated with AC but percentage of college-educated was a positive correlate. Population density was positively associated with AC but greenness and proximity to parks were negative correlates. However, significant differences existed for different AC modes, and between small rural and town-micropolitan rural tracts.

Conclusions: Sociodemographic factors explained more variance in AC than physical environmental factors but the detailed relationships were complex, varying by AC mode and by degree of rurality. Any strategy to promote AC in rural America needs to be sensitive to the population size of the area and assessed in a comprehensive manner to avoid a "one size fits all" approach.

Key words epidemiology, health promotion, rural, social determinants of health.

Active commuting (AC), defined as walking, biking, or taking public transportation to work or school, offers a viable method to increase physical activity (PA) by incorporating the needed activity into normal daily life.[1-3] Together with other forms of active transportation such as walking to shopping destinations, AC is an important part of the transportation domain of PA. There are many well-documented health benefits of AC, including a reduced risk of all-cause mortality,[4] obesity,[5] and cardiovascular disease and risk factors.[6,7] In addition, AC can indirectly benefit health by reducing carbon dioxide emissions through less use of vehicles and less traffic congestion.[1,8] There are also economic benefits to individuals through reduced vehicle operating and maintenance costs.[1,9] However, despite the multiple benefits, the rate of AC in the United States remains low, both in terms of historical trend and when compared with other countries.[10-12]

Among the potential correlates or determinants of AC, physical environmental factors have received considerable attention in recent years due to their perceived modifiability for public health policy purposes, with sociodemographic factors often only used as controls.[10,12,13] Studies using sociodemographic factors as controls have reported age, gender, and education to be associated with AC, although the findings have been inconsistent. For example, whereas 1 study found that older age and being a woman were negatively associated with AC,[3] another study reported null relationships.[2] Higher levels of education were reported to be positively associated with biking to work but not related to walking to work.[14] Few studies investigated the association between income and AC. In 1 study, Bopp et al[2] found economic concerns to be an insignificant factor in AC decisions.

For physical environmental factors, it has been hypothesized that better infrastructure (eg, sidewalks, bike lanes), higher street connectivity, better traffic safety (ie, lower speed limit, less traffic volume), pleasant neighborhood aesthetics (ie, more greenness), higher population density, and diversified land-use mix are positively associated with AC. Yet, empirical results have been mixed, with some studies finding associations in the expected directions, while others finding null or even opposite relationships.[12]

One potentially important environmental correlate of AC that is understudied in the literature is rurality. Government statistics show that rural areas have lower population density and lower levels of economic well-being than urban areas.[15] These differences are likely to lead to differences in AC in rural areas compared with urban areas. However, given that the majority of the US population live in urban areas, studies on AC at the national level tend be dominated by urban patterns.[16] Little is known if correlates or determinants of PA in general and AC in particular in rural settings are different from those in urban settings.[17] Furthermore, within rural America, there is variability in "rurality." Some rural residents live in small towns whereas others live in more isolated settings with very few neighbors. We know virtually nothing about how AC patterns may differ by the level of rurality within rural areas.

This research addresses these knowledge gaps by (1) estimating the participation rates in 3 modes of AC in rural America, (2) analyzing sociodemographic and physical environmental correlates of AC in rural settings, and (3) investigating potential differences in AC between small rural areas and relatively more populated small towns and micropolitan areas. Understanding sociodemographic and environmental correlates of AC in rural settings can provide insights into rural-urban differences in AC correlates. Given that rural areas have been found to have higher rates of overweight and obesity, coronary heart disease, hypertension rates, stroke, cancer, and diabetes than urban areas,[18-24] research considering all domains of PA in rural areas can help us better understand important contributors to this rural-urban health disparity and to potentially develop public health policies and strategies to address this disparity.[18,25-27]

Methods

Our primary data set was the 2000 Decennial Census, collected by the US Census Bureau.[28] Our unit of analysis was Census tracts, although some of our measures were at the county level when tract-level variables were unavailable.

Rural Definition

Rurality has been defined in many ways, most often in terms of nonurban status. The 2010 US Census defines 2 urban areas: (1) Urbanized Areas (UAs) of 50,000 or more people, and (2) Urban Clusters (UCs) of between 2,500 and 50,000 people. "Rural" thus encompasses all population, housing, and territories not included within urban areas.[29] On the other hand, the White House Office of Management and Budget (OMB) designates counties with an urban core of 50,000 people as metropolitan and defines rural as all nonmetropolitan areas.[30] Thus, the OMB definition of rural includes more individuals and areas than the Census definition. In most health-related studies, the broader OMB definition of "rural = nonmetropolitan" has been used.[15,24,27]

For this study, we used the US Department of Agriculture (USDA) 2000 primary rural-urban commuting areas (RUCA) codes to define rurality.[31] The use of RUCA codes allowed the creation of both the Census and OMB definitions of rurality at the Census tract level. The primary RUCA codes have 10 categories, with 1-3 being metropolitan tracts (in UAs with 50,000 or more people), 4-6 being micropolitan tracts (in large UCs between 10,000 and 49,999 people), 7-9 being small towns (in small UCs between 2,500 and 10,000 people), and 10 being small rural (in population clusters of less than 2,500 people). We first followed the OBM definition and defined rural as all nonmetropolitan tracts with RUCA codes between 4 and 10. Next we created a variable "small rural" to indicate the Census definition of rural (RUCA = 10), while naming the difference between these 2 definitions as "town-micropolitan rural." Total number of rural tracts included in this study was 14,209, including 4,067 small rural tracts and 10,412 town-micropolitan rural tracts.

Active Commuting

The 2000 Census included 3 aggregate AC measures at the tract level: (1) percentage of workers 16 and over who walked to work, (2) percentage of workers 16 and over who biked to work, and (3) percentage of workers 16 and over who took public transportation to work. We used all 3 variables in our study in order to capture the multiple dimensions of AC.

Sociodemographic Variables

In the context of an ecological study, sociodemographic variables may capture both the aggregate of individual characteristics and their interactions at the interpersonal and neighborhood levels such as social support,[2,3,12,13,32,33] which have been found to affect AC decisions. The 2000 Census included an extensive list of variables on sociodemographic characteristics. For this study, demographic variables included tract-level residents' median age, percentage of Asian Americans, percentage of non-Hispanic blacks, percentage of Hispanics, percentage of foreign-born population, percentage of people who lived in college dorms, and percentage of people who lived in military quarters. Socioeconomic variables included tract-level median household income (in $1,000), median housing value (in $10,000), percentage of housing units that were owner occupied, and percentage of residents 25+ with a college degree or higher. In addition to the directly available variables in the 2000 Census, we also created a measure of income inequality, the Gini coefficient,[34] using data from the 2000 US Census Population and Housing Summary File and applying a program developed in STATA.[35] In addition, number of crimes per 1,000 persons at the county level was created from the 1999 to 2008 Uniform Crime Reporting Program data from the National Archive of Criminal Justice Data, which contained detailed arrest data for both Part I (eg, murder, rape, robbery) and Part II (eg, vandalism, weapons violations, sex offenses, drug and alcohol abuse violations) offences.

Physical Environment

The physical environment included the built environment described by the neighborhood 3Ds: population density, destination diversity, and pedestrian-friendly design.[36] Additional environmental factors included air quality and regional indicators to capture regional differences such as weather and vegetation.[27] Measurements of the physical environment were limited in the US Census. We obtained and/or constructed additional physical environmental characteristics from a variety of other data sources at the tract level, or at the county level when tract-level data were not available. Population density (1,000 persons per square mile) at both the tract and county levels were obtained from the US Census to measure the density aspect of the 3Ds because AC was likely affected by both the immediate neighborhood within the tract and the larger surrounding area, especially for biking and public transportation where long commutes might be involved. While we did not have a direct measure of destination diversity, we used tract median housing age as a proxy because neighborhoods with older housing stock were more likely to have mixed land use as they were built before strict enforcement of zoning laws separating residential and commercial uses. The design aspect of the 3Ds was captured by a tract-level street connectivity measure, defined as the number of intersections per square mile in the tract. Spatial data including census tracts and road networks were constructed from the data CD-ROMs distributed with ArcGIS 9.3 by the Environmental System Research Institute (ESRI) and the StreetMap USA file (a TIGER [**T**opologically **I**ntegrated **G**eographic **E**ncoding and **R**eferencing] 2000-based streets data set enhanced by ESRI and Tele Atlas).[37] Based on these data, an index of street connectivity was constructed for each census tract in the United States.[38] A greenness measure was derived from the tree canopy data set in the National Land Cover Database 2001 that provided tree canopy density at a spatial resolution of 30 m.[39] Using this data set, a tract-level aggregate tree canopy density measure was generated to represent the average of the percentages of tree canopy coverage associated with pixels that fell in each tract. A tract-level park access variable was constructed from the 2006 park Geographic Information System (GIS) layer in the ESRI ArcGIS 9.3 Data DVD.[37] Seven parks[40] closest to a Census block centroid were identified, and average distances from the Census block centroid to each of these parks weighted on population and park sizes were calculated. These distances were then aggregated to the Census tract level.[41] For air quality, we used data from the Environmental Protection Agency (EPA) to create a dummy variable to indicate EPA air quality nonattainment status at the county level.[42] Four Census region variables indicated if the tract was in the Northeast, Midwest, South, or West.

Analysis

Tract-level AC participation rates for all 3 modes were estimated first for all rural tracts, then separately for small rural tracts and town-micropolitan rural tracts. *t* Tests were conducted to test if the small rural and town-micropolitan estimates were significantly different. To estimate models correlating sociodemographic and environmental factors with AC, we utilized Seemingly Unrelated Regression (SUR) to estimate the 3 AC modes simultaneously because the 3 modes were likely jointly determined. Models were estimated first for all rural tracts, then separately for small rural tracts and town-micropolitan rural tracts. In order to assess the relative importance of sociodemographic and environmental factors, we estimated 3 sets of models: (1) sociodemographic factors only, (2) environmental factors only, and (3) both sociodemographic and environmental factors. We also estimated full interaction models to test if the correlates of AC were significantly different between small rural tracts and town-micropolitan rural tracts. The models were estimated using Proc Model in SAS 9.2[43] utilizing the Iterated Seemingly Unrelated Regression (ITSUR) method.

Results

Table 1 presents descriptive statistics. The average percentage of workers walking to work for all rural tracts was 3.63%, with the rate being higher for small rural tracts than town-micropolitan rural tracts (4.39% vs 3.32%, *t* test $P < .01$). The average percentage of rural workers biking to work was 0.26%, with small rural tracts having a lower rate than town-micropolitan rural tracts (0.18% vs 0.29%, *t* test $P < .01$). The average percentage of rural workers taking public transportation to work was 0.56%, with small rural tracts having a lower rate than town-micropolitan tracts (0.43% vs 0.62%, *t* test $P < .01$).

Compared with town-micropolitan tracts, small rural tracts had older residents, lower concentration of minorities and the foreign-born, lower median household income, lower median housing value, a higher rate of owner-occupied housing, a lower percentage of college-educated population, and a lower crime rate. For physical environments, compared with town-micropolitan tracts, small rural tracts had lower population density both at the tract and county levels, older housing stock, lower street connectivity, a higher percentage of tree canopy coverage, a longer average distance to parks, and better air quality. More than two-thirds of all rural tracts were located in the South and Midwest.

Multivariate SUR estimates are presented in Tables 2–4. Collinearity diagnostics revealed no problematic multicollinearity issues. For the overall rural models (Table 2), the walking to work model had the highest explanatory power (Adj. $R^2 = 0.548$), followed by biking to work (Adj. $R^2 = 0.185$) and public transportation to work (Adj. $R^2 = 0.127$). When sociodemographic variables and physical environmental variables were entered into the models separately, sociodemographic variables explained more variance than physical environmental variables. The difference was especially large for the walking to work model. Entered separately, sociodemographic variables explained 49.6% of the variance in percentage walking to work while physical environmental variables explained only 18.8% of the variance.

Sociodemographic Variables: Demographic Factors

Older median residents' age was associated with a higher rate of walking to work but lower rates of biking and public transportation to work. A higher percentage of blacks was correlated with lower rates of walking and biking to work but a higher rate of public transportation to work, while higher percentages of Asians and Hispanics but a lower rate of foreign-born were correlated with lower rates of all 3 modes of AC. The walking to work rate was higher when the tracts had a higher percentage of residents attending college or in the military.

Sociodemographic Variables: Socioeconomic Factors

Among the 6 socioeconomic factors, tract household income and tract percentage owner-occupied housing were negatively associated with all 3 AC modes while tract median housing value was positively associated with all 3 AC modes. The Gini coefficient was significant only for the percentage walking to work model (negative association), while percentage of college-educated was significant for both walking and biking (positive associations). Crime rate was negatively associated with percentage walking or public transportation to work, but positively associated with percentage biking to work.

Physical Environment: 3Ds

Variables representing the 3Ds of density, diversity, and design were all significantly associated with AC. For density, both tract-level and county-level population density were positively associated with all 3 AC modes with the exception of county-level density for the biking model. Proximity to parks was associated with lower rates of AC in all 3 modes. All other 3D variables had mixed associations with different modes of AC. Older median housing age was associated with higher rates of walking and biking to work but not significantly related to public transportation to work. Better street connectivity was associated with lower rates of walking and public transportation to work but a higher rate of biking to work.

Table 1 Descriptive Statistics: All Rural Tracts, Small Rural Tracts, and Town-Micropolitan Tracts

	All Rural Tracts (n = 14,209)		Small Rural (n = 4,067)		Town-Micropolitan (n = 10, 142)		
Variables	Mean	SD	Mean	SD	Mean	SD	*t* Test[a]
% workers 16+ walking to work	3.63	5.08	4.39	4.74	3.32	5.18	***
% workers 16+ biking to work	0.26	0.72	0.18	0.52	0.29	0.78	***
% workers 16+ public transportation to work	0.56	1.20	0.43	0.87	0.62	1.31	***
Tract residents' median age	37.68	5.32	39.33	5.00	37.01	5.30	***
Tract % Asians	0.71	2.73	0.32	1.04	0.87	3.15	***
Tract % Blacks	8.04	16.35	5.36	13.54	9.11	17.23	***
Tract % Hispanics	5.98	13.22	4.70	11.19	6.50	13.92	***
Tract % foreign-born	3.23	5.46	2.56	4.84	3.50	5.67	***
Tract % living in college dorms	0.75	5.32	0.19	2.13	0.98	6.14	***
Tract % living in military quarters	0.09	1.96	0.06	1.71	0.10	2.04	
Tract med. income (in $1,000)	33.75	8.87	32.36	7.60	34.31	9.28	***
Tract Gini coefficient (%)	39.78	3.95	39.82	4.04	39.76	3.91	
Tract med. housing value (in $10,000)	7.88	4.65	7.43	5.25	8.07	4.37	***
Tract % housing owner-occupied	73.27	13.85	77.77	9.25	71.47	14.94	***
Tract % 25+ college educated	15.09	8.97	13.82	7.39	15.59	9.48	***
County total crime/1,000 people	24.93	16.47	18.50	13.77	27.51	16.76	***
Tract pop. density (1,000/sq mile)	0.53	1.18	0.04	0.11	0.73	1.34	***
County pop. density (1,000/sq mile)	0.08	0.11	0.04	0.09	0.09	0.12	***
Tract median housing age	33.12	12.54	33.99	12.51	32.78	12.54	***
Tract intersection density/sq mile	30.29	47.13	8.20	10.85	39.14	52.83	***
Tract % area green canopy	29.32	23.58	32.65	26.74	27.98	22.05	***
Average distance to 7 closest parks	17.84	14.81	23.14	16.82	15.71	13.35	***
Northeast region	0.12	0.32	0.11	0.32	0.12	0.32	
Midwest region	0.32	0.47	0.36	0.48	0.31	0.46	***
South region	0.40	0.49	0.36	0.48	0.42	0.49	***
West region	0.15	0.36	0.17	0.37	0.15	0.36	***
EPA poor air quality status	0.15	0.36	0.08	0.28	0.18	0.38	***

*$P < 0.1$, **$P < .05$, ***$P < .01$.

[a]*t* Tests tested the significance of the difference between small rural tracts and town-micropolitan tracts.

A higher tree canopy density was associated with lower rates of walking and biking to work but a higher rate of public transportation to work.

Physical Environment: Regional Variations

Compared with the Northeast, rural tracts in the Midwest and South had lower rates of walking and public transportation to work but a higher rate of biking to work, while rural tracts in the West had higher rates of walking and biking to work but a lower rate of public transportation to work.

Comparison Between Small Rural and Town-Micropolitan Rural Tracts

Town-micropolitan tract models had substantially better fit than small rural models for all 3 AC modes (Tables 3 and 4). For walking to work, small rural tracts were significantly different from town-micropolitan tracts in 19 of the 23 variables, with opposite sign coefficients for 4 variables: median housing value (negative for small rural, positive for town-micropolitan rural), crime rate (positive for small rural, negative for town-micropolitan rural), tract population density (insignificant for small rural, positive for town-micropolitan rural), and Midwest location (positive for small rural, negative for town-micropolitan rural). For biking to work, 13 variables were significantly different, with opposite sign coefficients for 7 variables: percentage of blacks and Hispanics (insignificant for small rural, negative for town-micropolitan rural), percentage of foreign-born (negative for small rural, positive for town-micropolitan rural), median household income (positive for small rural, negative for town-micropolitan rural), Gini coefficient (positive for small rural, negative for town-micropolitan rural), county population density (positive for small rural, insignificant for town-micropolitan rural), and poor air

Table 2 Seemingly Unrelated Regression Results on Percentage Walking, Biking, and Taking Public Transportation to Work: All Rural Tracts

	Percentage Walking to Work			Percentage Biking to Work			Percentage Public Transportation to Work		
Variables	Estimate	SE		Estimate	SE		Estimate	SE	
Intercept	10.047	0.534	***	0.512	0.102	***	1.851	0.225	***
Tract residents' median age	0.049	0.007	***	−0.009	0.001	***	−0.007	0.003	**
Tract % Asians	−0.053	0.012	***	−0.003	0.002		−0.022	0.004	***
Tract % Blacks	−0.008	0.002	***	−0.002	0.000	***	0.012	0.001	***
Tract % Hispanics	−0.041	0.004	***	−0.004	0.001	***	−0.014	0.002	***
Tract % foreign-born	0.118	0.009	***	0.014	0.002	***	0.064	0.004	***
Tract % living in college dorms	0.480	0.007	***	−0.002	0.001		−0.011	0.003	***
Tract % living in military quarters	0.395	0.015	***	−0.001	0.003		−0.001	0.006	
Tract med. income (in $1,000)	−0.104	0.006	***	−0.009	0.001	***	−0.002	0.003	
Tract Gini coefficient (%)	−0.081	0.009	***	−0.002	0.002		−0.002	0.004	
Tract med. housing value (in $10,000)	0.032	0.010	***	0.034	0.002	***	0.022	0.005	***
Tract % housing owner-occupied	−0.063	0.003	***	−0.006	0.001	***	−0.014	0.001	***
Tract % 25+ college educated	0.076	0.005	***	0.010	0.001	***	−0.002	0.002	
County total crime/1,000 people	−0.015	0.002	***	0.002	0.000	***	−0.002	0.001	**
Tract pop. density (1,000/sq mile)	0.158	0.050	***	0.041	0.010	***	0.106	0.018	***
County pop. density (1,000/sq mile)	2.118	0.301	***	−0.052	0.057		0.631	0.119	***
Tract median housing age	0.049	0.003	***	0.005	0.001	***	−0.002	0.001	
Tract intersection density/sq mile	−0.008	0.001	***	0.001	0.000	***	−0.001	0.000	
Tract % area green canopy	−0.007	0.002	***	−0.001	0.000	*	0.002	0.001	***
Average distance to 7 closest parks	0.042	0.002	***	0.003	0.000	***	0.005	0.001	***
Midwest region	−0.415	0.116	***	0.165	0.022	***	−0.217	0.048	***
South region	−1.351	0.122	***	0.148	0.023	***	−0.480	0.051	***
West region	1.100	0.142	***	0.224	0.027	***	−0.068	0.060	
EPA poor air quality status	−0.050	0.093		−0.032	0.018	*	−0.105	0.036	***
Adj. R^2 full model	0.548			0.185			0.148		
Adj. R^2 social variables only	0.496			0.155			0.127		
Adj. R^2 physical variables only	0.188			0.106			0.059		

*s$P < .1$, **$P < .05$, ***$P < .01$.

quality (positive for small rural, negative for town-micropolitan rural). For public transportation to work, 10 variables were significantly different, with opposite sign coefficients for 4 variables: percentage of Hispanics (positive for small rural, negative for town-micropolitan rural), percentage of foreign-born (negative for small rural, positive for town-micropolitan rural), tract population density (negative for small rural, positive for town-micropolitan rural), and street connectivity (positive for small rural, insignificant for town-micropolitan rural). In all these cases, the overall rural models took the sign of the town-micropolitan coefficient, likely because there were substantially more town-micropolitan tracts than small rural tracts in rural America.

Discussion

Utilizing 2000 US Census tract-level data, this study investigated sociodemographic and environmental correlates of AC participation in rural America, including percentage walking to work, biking to work, and taking public transportation to work. Our key findings regarding our 3 research questions were: (1) Average tract-level AC participation rates in rural America in 2000 were 3.63% for walking to work, 0.26% for biking to work, and 0.56% for taking public transportation to work; (2) Both sociodemographic and physical environmental factors contributed to variations in AC participation rates in rural America, with sociodemographic factors explaining a larger proportion of variance in AC than physical environmental factors; and (3) Compared with town-micropolitan rural areas, small rural areas had a higher rate of walking to work but lower rates of biking or taking public transportation to work. The relationship between AC and sociodemographic and environmental variables varied in significance, size, and sometimes even direction for small rural areas than for town-micropolitan rural areas.

Table 3 Seemingly Unrelated Regression Results on Percentage Walking, Biking, and Taking Public Transportation to Work: Small Rural Tracts

	Percentage Walking to Work			Percentage Biking to Work			Percentage Public Transportation to Work		
Variables	Estimate	SE		Estimate	SE		Estimate	SE	
Intercept	14.308	1.156	***	0.003	0.151		0.849	0.253	***
Tract residents' median age	0.052	0.015	***	−0.004	0.002	*	−0.015	0.003	***
Tract % Asians	−0.240	0.062	***	−0.004	0.008		0.006	0.014	
Tract % Blacks	−0.006	0.005		0.000	0.001		0.006	0.001	***
Tract % Hispanics	−0.074	0.008	***	0.000	0.001		0.003	0.002	*
Tract % foreign-born	0.221	0.019	***	−0.001	0.002		−0.007	0.004	*
Tract % living in college dorms	0.343	0.032	***	0.002	0.004		−0.012	0.007	*
Tract % living in military quarters	0.453	0.037	***	−0.003	0.005		−0.014	0.008	*
Tract med. income (in $1,000)	−0.132	0.013	***	0.002	0.002		−0.002	0.003	
Tract Gini coefficient (%)	−0.110	0.018	***	0.006	0.002	**	0.007	0.004	*
Tract med. housing value (in $10,000)	−0.041	0.018	**	0.009	0.002	***	0.007	0.004	*
Tract % housing owner-occupied	−0.085	0.008	***	−0.004	0.001	***	−0.003	0.002	*
Tract % 25+ college educated	0.142	0.013	***	0.004	0.002	***	0.009	0.003	***
County total crime/1,000 people	0.008	0.005	*	0.001	0.001	**	0.000	0.001	
Tract pop. density (1,000/sq mile)	−1.574	1.063		0.214	0.139		−0.462	0.233	**
County pop. density (1,000/sq mile)	3.950	0.799	***	0.205	0.105	**	1.094	0.175	***
Tract median housing age	0.022	0.007	***	0.002	0.001	*	−0.002	0.002	
Tract intersection density/sq mile	−0.002	0.011		−0.001	0.001		0.005	0.002	**
Tract % area green canopy	−0.014	0.003	***	0.000	0.000		0.003	0.001	***
Average distance to 7 closest parks	0.046	0.004	***	0.001	0.001	*	0.004	0.001	***
Midwest region	0.324	0.257		0.146	0.034	***	−0.144	0.056	**
South region	−1.447	0.262	***	0.054	0.034		−0.262	0.057	***
West region	1.631	0.302	***	0.198	0.040	***	−0.050	0.066	
EPA poor air quality status	0.148	0.251		0.056	0.033	*	−0.044	0.055	
Adj. R^2 full model	0.349			0.069			0.064		
Adj. R^2 social variables only	0.248			0.048			0.036		
Adj. R^2 physical variables only	0.194			0.047			0.045		

*$P < .1$, **$P < .05$, ***$P < .01$.

It is important to note the caveats in our findings before discussing their implications. First, the cross-sectional nature of our data limited our ability to infer causal relationships. Some of the sociodemographic and environmental factors could be determinants to AC, but without longitudinal data we were only able to confirm associations. Future studies utilizing multiple years of Census data, including, for example, both 2000 and 2010 data when they become fully available, may provide insights into how changes in sociodemographic and physical environments may lead to changes in AC rates in rural America. Second, our variables were aggregate measures at the tract or county level. As such, individual factors affecting AC decision could not be investigated. However, while such an ecological approach cannot identify individual factors affecting the decision-making process of AC, it is valuable in identifying factors that are associated with aggregate AC participation rates, which is an important public health objective in itself regardless of which individuals in the aggregate are participating in AC. Third, while we studied a large set of sociodemographic and environmental variables, we still did not have measures of all relevant sociodemographic and environmental factors such as social support, neighborhood cohesion, ease of access to sidewalks and bike lanes, and traffic volume, which could be important correlates of AC in rural America. While measuring social support at the tract level for the whole country is difficult, developing tract-level GIS measures of bike lanes and sidewalks in future research is feasible and can further our understanding of how road infrastructure may affect AC participation.

Our study has multiple innovations and advantages. First, our study encompassed all rural Census tracts in the United States where there was a population, and as such our results have excellent generalizability, especially when compared to most previous AC studies covering smaller geographic areas. Second, we supplemented US Census data with a variety of data sets to construct

Table 4 Seemingly Unrelated Regression Results on Percentage Walking, Biking, and Taking Public Transportation to Work: Town-Metropolitan Tracts

	Percentage Walking to Work			Percentage Biking to Work			Percentage Public Transportation to Work		
Variables	Estimate	SE		Estimate	SE		Estimate	SE	
Intercept	9.099	0.576	***	0.713	0.129	***	1.851	0.225	***
Tract residents' median age	0.015	0.008	*	−0.010	0.002	***	−0.007	0.003	**
Tract % Asians	−0.018	0.011		−0.007	0.002	***	−0.022	0.004	***
Tract % Blacks	−0.008	0.002	***	−0.003	0.001	***	0.012	0.001	***
Tract % Hispanics	−0.023	0.004	***	−0.006	0.001	***	−0.014	0.002	***
Tract % foreign-born	0.060	0.010	***	0.019	0.002	***	0.064	0.004	***
Tract % living in college dorms	0.499	0.006	***	−0.004	0.001	***	−0.011	0.003	***
Tract % living in military quarters	0.371	0.016	***	−0.002	0.004		−0.001	0.006	
Tract med. income (in $1,000)	−0.069	0.007	***	−0.015	0.002	***	−0.002	0.003	
Tract Gini coefficient (%)	−0.048	0.010	***	−0.007	0.002	***	−0.002	0.004	
Tract med. housing value (in $10,000)	0.054	0.012	***	0.051	0.003	***	0.022	0.005	***
Tract % housing owner-occupied	−0.065	0.003	***	−0.005	0.001	***	−0.014	0.001	***
Tract % 25+ college educated	0.047	0.005	***	0.012	0.001	***	−0.002	0.002	
County total crime/1,000 people	−0.013	0.002	***	0.002	0.000	***	−0.002	0.001	**
Tract pop. density (1,000/sq mile)	0.154	0.047	***	0.035	0.010	***	0.106	0.018	***
County pop. density (1,000/sq mile)	1.753	0.304	***	−0.090	0.068		0.631	0.119	***
Tract median housing age	0.045	0.004	***	0.006	0.001	***	−0.002	0.001	
Tract intersection density/sq mile	−0.003	0.001	**	0.001	0.000	***	−0.001	0.000	
Tract % area green canopy	−0.003	0.002		−0.001	0.000	*	0.002	0.001	***
Average distance to 7 closest parks	0.023	0.002	***	0.004	0.001	***	0.005	0.001	***
Midwest region	−0.616	0.122	***	0.164	0.027	***	−0.217	0.048	***
South region	−1.202	0.131	***	0.178	0.029	***	−0.480	0.051	***
West region	0.628	0.153	***	0.231	0.034	***	−0.068	0.060	
EPA poor air quality status	−0.113	0.093		−0.044	0.021	***	−0.105	0.036	***
Adj. R^2 full model	0.644			0.219			0.148		
Adj. R^2 social variables only	0.618			0.189			0.127		
Adj. R^2 physical variables only	0.205			0.115			0.059		

*$P < .1$, **$P < .05$, ***$P < .01$.

multiple sociodemographic and physical environmental variables, which, to our knowledge, has not been done before in the context of AC. Third, we presented a more comprehensive picture of AC in rural America than previously done by analyzing all 3 AC modes simultaneously. Fourth, we investigated AC for small rural and town-micropolitan rural tracts separately, and we were able to provide insights into similarities and differences in sociodemographic and environmental correlates of AC for different degrees of rurality.

The finding that sociodemographic variables explained more variance in rural AC than physical environmental variables has not been discussed in the literature, probably because recent research has considered physical environmental factors to be easier or less controversial to modify than sociodemographic factors for public health policy purposes. This is true to some extent. For example, better economic well-being in rural tracts is negatively associated with AC participation, an unfortunate negative side effect of economic development. Obviously it would not make sense to develop public health policy to promote AC by decreasing the economic well-being of the rural population. However, 1 sociodemographic variable that stands out in our analysis is the percentage of population that are college educated, which is positively associated with participation rates in both walking and biking to work for all rural tracts. This suggests that improving education in rural America may lead to positive changes in AC participation while bringing other social and economic benefits as well, a win-win situation that is worth looking into for public policy purposes. A surprising finding in sociodemographic correlates of AC is the positive relationship between county-level crime rate and percentage of workers biking to work in town-micropolitan tracts, which is opposite to our findings for small rural tracts and contradictory to 2 previous studies that found a null relationship between perceived crime rate and biking to work in urban settings.[3,44] It is possible that town-micropolitan rural areas may have different social pathology that is not completely captured by our crime rate measure. Future research should look into more detailed measures of crime rate together with additional confounding factors such as traffic volume that may moderate the crime rate and biking to work relationship in town-micropolitan areas.

For physical environmental factors, our analyses support previous research that found significant correlations between physical environmental features and AC,[12] with new insights into the complex relationship for different AC modes in rural settings. Especially noteworthy is the mixed relationship between street connectivity and different modes of AC. Higher street connectivity was positively associated with percentage biking to work but negatively associated with percentage walking to work, a result contradictory to much of the existing literature in urban settings.[12,45] This suggests that the role of street connectivity may be different in rural areas compared to urban areas given that rural areas in general have much lower levels of street connectivity than urban areas. In addition, although pleasant neighborhood aesthetics (ie, more greenness) were typically hypothesized to be positively associated with active transportation, our results side with the few negative empirical findings showing a negative coefficient for tree canopy coverage and a positive coefficient for distance to parks when walking or biking was the dependent variable.[46] One possible explanation is that better tree canopy coverage and shorter distance to parks in rural areas may indicate the presence of large areas of natural land such as farm land, state parks, or national parks, which can increase the distance to work if commuters have to walk or bike around such areas. The finding that tree canopy coverage was positively associated with taking public transportation to work supports this explanation because the burden of long travel distance due to large natural land areas can be alleviated with public transportation.

Finally, significant differences existed between small rural tracts and town-micropolitan rural tracts, with small rural tracts having a higher rate of walking to work but lower rates of biking and public transportation to work. Because there were substantially more town-micropolitan tracts than small rural tracts in the United States, rural models using the nonmetropolitan rural definition would be dominated by relationships for town-micropolitan tracts. Our analyses identified quite a few variables that had opposite sign associations with AC in small rural tracts compared with town-micropolitan tracts. For example, tract median housing value was negatively associated with percentage walking to work for town-micropolitan rural tracts, but it was positively associated with percentage walking to work for small rural tracts. As such, it is important to note that in developing strategies to promote rural AC, special attention needs to be paid to small rural tracts to avoid unintended negative consequences of "one-size fits all" type of rural health promotion approaches.

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