THE REACH OF BICYCLING IN RURAL, SMALL, AND LOW-DENSITY PLACES

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ABSTRACT

Lessons derived from the urban experience of bicycling may not be broadly supportive of bicycling in what we call rural, small, and low-density (RSLD) places because of differences in built environment, social, and political contexts. In this study we investigated the hypothesis that bicycling is primarily an urban activity. We used binary logistic regression to compare the frequency of bicycling and the population characteristics of bicyclists across urban and RSLD places. We used multiple operational definitions of urban-rural continua to examine whether the results are sensitive to how RSLD places are defined. The data for bicycling are from the 2009 National Household Travel Survey (NHTS), which was designed to represent the population of the U.S. We found that bicycling is primarily—but not exclusively—an urban activity. Moreover, women and youth were more likely to bicycle in RSLD places compared to urban places. These findings suggest that an urban perspective on bicycling could limit the success of initiatives aiming to increase the diversity of populations that bicycle. Developing a base of empirical knowledge of bicycling in RSLD places is a necessary step toward developing more inclusive and effective multimodal transportation strategies.

INTRODUCTION

Key elements of bikeable places include supportive infrastructure, policy, education, encouragement, and enforcement programs. To be successful, these elements need to be sensitive to the local built environment, social, and political contexts. Yet, key aspects of the bikeability paradigm may not be context-sensitive. In practice this paradigm skews toward the experiences of urban places where the land use context is more supportive of the goal to increase bicycling for utilitarian purposes. For instance, strategies such as increasing bicycle commuting, adopting complete streets policies, and constructing on-street bicycle infrastructure networks have been derived from places with high-density activity centers that support utilitarian bicycling. In contrast, a different set of strategies such as paved highway shoulders and historic preservation programming might be needed to support bicycling in what we call rural, small, and low-density (RSLD) places where bicycling is more often considered a problem of tourism and recreation rather than a problem of transportation, if it is considered a problem at all.

Providing empirical evidence about the patterns of bicycling in RSLD places is a necessary step for developing more inclusive and effective transportation planning practices and policies for multimodal transportation. Research and practice that accounts for bicycling among RSLD populations is important because bicycling is a form of health-promoting physical activity, a potential mechanism of economic development, and an important mode of travel for people, especially youth, who do not have access to a vehicle.

In this study, we investigated the hypothesis that bicycling is primarily an urban activity. We used binary logistic regression to compare the frequency of bicycling and the population characteristics of bicyclists using two different definitions of urban-rural continua. The data for bicycling are from the 2009 National Household Travel Survey (NHTS), which was designed to represent the population of the U.S. We used two dependent variables that represent different levels of bicycling frequency: (1) bicycling only one or two times in the previous week; and (2) bicycling three or more times in the previous week. Although the NHTS was not developed as a survey of bicycling, it captures a wide range of RSLD environments in the U.S. as well as utilitarian and recreational bicycle trips.

We use the RSLD construct to refer to a diverse set of places that include remote and agricultural landscapes as well as low-density exurban and suburban settlements within urbanized areas. Despite the heterogeneity of these places, they tend to share a reliance on automobiles for their viability, and public transportation options are typically less developed than in traditional cities. Because the RSLD concept is expansive and heterogeneous, we used two different operational definitions of urban-rural continua to analyze the data: (1) Rural-Urban Commuting Areas that emphasize the economic characteristics of places; and (2) population density categories that represent the built environment context. In addition, we consider the influence of places with significant recreational economies and retirement communities because bicycling may be uniquely prevalent in these settings.

BACKGROUND AND LITERATURE

In the urban context, bicycling is usually framed as an alternative to motorized travel. This framing may be suited to places where motorized traffic is problematic, but outside of cities bicycling is not a clear substitute for car travel, and residents in RSLD places may have different motivations and resource needs for bicycling.

Rural places are characterized by spatial dispersion of economic, social, and cultural activities (*1*). With the exception of peak tourism periods, they generally do not have "urban" transportation problems such as congestion, scarce parking, and noise and air pollution (*2*). Prior studies about the concerns of rural transportation include questions of goods movement, heavy vehicle impacts on infrastructure, externalities of industrial traffic, and social isolation (*1-6*). In practice, mobility in rural places in the U.S. has been dominated by the automobile whereas urban places have presented opportunities for a diverse multi-modal system that relies on automobiles, transit, walking, bicycling and any variant of these modes (*2*).

In turn, prior research about bicycling has focused on bicycling for transportation and bicycle commuting in the context of cities (*7*). Very few studies have given attention to contemporary bicycling behaviors and attitudes among RSLD residents despite the fact that these settings are fully engaged in dialogue about creating bikeable communities (*8-9*). Certain national and statewide studies of bicycling have included variables representing rural and suburban places. Pucher et al. investigated bicycling trends in the U.S. using Census definitions of urban and rural places (*10*). This study found that the bike share of all trips was higher in urban places compared to rural places (1.12% versus 0.78%), that rural places have a higher percentage of recreational bike trips compared to urban places (61.5% versus 46.9%), and that the share of workers making commute trips by bike is about four times as high in urban places compared to rural places (0.60 versus 0.16).

Noland et al. conducted a survey-based study of bicycling for New Jersey, a state with a range of dense urban places, low-density suburbs, and agricultural areas (*11*). The survey included both recreational and utilitarian bicycle trips, and the majority of bicycle trips were for recreation. With respect to area-level characteristics, urban, rural, and suburban categories were not predictive of the propensity to bicycle, nor was the density of county roads. Consistent with other research, personal characteristics of survey respondents were stronger determinants of bicycling and bicycling frequency than environmental characteristics. Bicycling increased with population density when controlling for personal and household factors, but bicycling was still prevalent in low-density places.

Despite a lack of research focused on RSLD bicycling, examples from practice suggest that it can be a culturally and economically significant form of transport and recreation for RSLD residents. There are numerous examples of RSLD places making investments in bicycling, and these example offer insight into some of the opportunities that RSLD places present. The Cowboy Trail in northern Nebraska is among the longest rail trails in the country and is a recreation and tourism asset for the state. The Tour de Farm in western Georgia promotes the region's agriculture industry and local economies. In South Carolina, the Lower Savannah Council of Governments pursued a bicycle planning process and the resulting plan emphasized widening and paving shoulders on county roads. RSLD bicycling tends to emphasize off-street infrastructure, recreational bicycling, and bicycle programming and education strategies. Traditional issues of safety, education, enforcement, and design are present but they may be pursued with strategies that are distinct from those typically used in urban areas with higher population densities. More research is needed to understand the effectiveness of these strategies across the urban-rural continuum.

The Rails to Trails Conservancy, with financial support from bicycle advocacy groups, conducted a study of active transportation in rural places in the U.S. Comparing all-trip mode share and bicycle commute share across an urban-rural continuum, the authors found that bicycling is “far more prevalent in rural places than many would expect” (*9*). However, Loh et al. did not control for social and demographic factors (e.g., gender, age, and income) that are known to influence estimates of the propensity to bicycle (*9*). Therefore, the study’s estimates for rural places may not reflect the unique contributions of place on bicycling. In addition, the study may be sensitive to the operational definition of the urban-rural continuum. In the current analysis, we build on this previous approach by using multivariate regression analysis that enables us to examine the independent effect of urban-rural status on bicycling frequency. In addition, we used multiple operational definitions of urban-rural continua to examine whether the results are sensitive to how RSLD places are defined.

Physical Activity in RSLD Places

The physical activity literature from public health draws attention to emerging goals to promote bicycling in RSLD places. Research comparing overall levels of physical activity across urban and RSLD places has generally found that physical *inactivity* is highest in rural places, and that rural places are less likely to have specific resources and facilities, such as trails, that promote physical activity (*13-17*). However, other studies have found that sprawl, a characteristic of certain RSLD places, is not associated with physical inactivity (*18*).

A review study of physical activity and rural built environments found that research in this area is limited. Prior research has been cross-sectional, has neglected older adults, and has been limited in its geographic scope such that high-risk regions such as the Southeast and Midwest have received relatively less attention. Moreover, prior research on rural physical activity has used a mix of definitions to represent RSLD places, which makes it difficult to draw conclusions from the various studies (*14*).

The implication is that existing research and professional practices do not adequately understand bicycling outside of the urban context, which is a gap in knowledge that could limit the success of multimodal and active transportation initiatives in RSLD places. For example, a recent study about the effectiveness of the Safe Routes to School program found that “children in rural communities often miss out on the health and academic benefits that Safe Routes to School initiatives bring” (*19*).

Our study takes steps to address these gaps by using more fine-grained definitions of urban and rural places as well as nationally-representative data for children, youth, and adults (ages five and older). This empirical information can help bring RSLD bicycling into the mainstream of multimodal transportation planning and research.

DATA AND METHODS

We used the 2009 National Household Travel Survey for this analysis because it captures both utilitarian and recreational travel, is representative of the U.S. population (ages five and older), and includes the widest range of urban and RSLD places. Our sample included all responding individuals (N=285,634).

We note that an important limitation of this study is the likely underrepresentation of populations that are least likely to be included in the NHTS, such as non-white respondents and groups that are difficult to reach by telephone (*20*). We also note that the distinction between recreational and utilitarian bicycling is not always clear and a bicycle trip may be motivated by both reasons (*12*). The National Household Travel Survey distinguishes between four main types of trips: work, shopping, social/recreational, and other. Social/recreational trips include motivations such as leisure, exercising, relaxing, visiting friends, going out (e.g., entertainment, bar, event), and visiting public places such as libraries and parks.

We conducted analyses with two different dependent variables: (1) self-reported bicycling one or two times in the previous week (N=15,884); and (2) self-reported bicycling three or more times in the previous week (N=14,980). These trips include bicycling for any purpose. In addition to representing the likelihood of bicycling, these two outcome variables represent different levels of bicycling frequency and therefore potentially different populations of bicyclists.

Table 1 presents a descriptive summary of the variables included in the regression analysis. In addition to social and demographic factors, we hypothesized that urban-rural status predicts bicycling frequency and propensity. Therefore, we included information about the urban-rural status of each respondent based on their residential census tract.

Operational Definitions of RSLD Places

Because categories such as "urban" and "rural" do not have an intrinsic meaning, they must be translated into operational definitions for analysis (*21-23*). We used the following operational definitions of urban-rural continua to represent urban-rural status.

Rural-Urban Commuting Areas

Rural-Urban Commuting Area (RUCA) definitions reflect the intensity of commute flows between places and therefore this definition emphasizes economic relationships between places rather than urban form (*24*). For instance, a place may be located in an agricultural environment outside of a large metropolitan area, but if a significant proportion of its population commutes to work inside the metropolitan area, this place is considered more urban than rural.

The RUCA system includes 33 categories that can be aggregated into specialized urban-rural continua. We used the ten primary RUCA categories and did not aggregate them into a special definition. These ten categories are:

- Level 1: Metropolitan area core with primary commuting within an Urbanized Area (UA);
- Level 2: Metropolitan area high commuting, primary flow 30% or more to UA;
- Level 3: Metropolitan area low commuting, primary flow 10% to 30% to a UA;
- Level 4: Micropolitan area core, primary flow within an Urban Cluster (UC) of 10,000 to 49,999;
- Level 5: Micropolitan high commuting, primary flow 30% or more to a large UC;

- Level 6: Micropolitan low commuting, primary flow 10% to 30% to a large UC;
- Level 7: Small town core, primary flow within a UC of 2,500 to through 9,999;
- Level 8: Small town high commuting, primary flow 30% or more to a small UC;
- Level 9: Small town low commuting, primary flow 10% to 29% to a small UC; and
- Level 10: Rural areas, primary flow to a tract outside a UA or UC (including self).

We consider the Level 1 RUCA to be the “urban” category and all other levels to be RSLD categories.

Population Density Categories

The second urban-rural continuum definition we applied is based on population density. Population density represents the built environment characteristics relevant to bicycling behavior. For instance, towns and villages in rural areas may have relatively high population densities and an urban form that closely resembles older cities. Similarly, places considered part of Urbanized Areas according to the Census definition may have rural population densities and urban form. These are differences that matter for the propensity to bicycle, particularly for transportation. We used the 2010 US Census to calculate population density for each Census tract based on total population and land area.

We determined the cutoff points for each level in this continuum using the distribution of population densities for the state of Colorado as a reference as well as research about suburban sprawl (*25*). The categories include: rural (<200 persons per square mile), low-density suburban (200-1,200 persons per square mile), suburban (1,200-2,400 persons per square mile), urban (2,400-12,500 persons per square mile), and high-density urban (≥12,500 persons per square mile). For instance, urban places in Colorado are generally in the “urban” category, whereas cities such as Boston, Chicago, New York, and San Francisco tend to be “high-density urban” because they include more Census tracts with population densities greater than 12,500 persons per square mile. We consider the “rural,” “low-density suburban,” and “suburban” categories to be RSLD and the “urban” and “high-density urban” to be the urban categories.

Counties with Recreation-focused Economies and Retirement Communities

We hypothesized that counties with recreation-focused economies and large retirement communities could have a unique influence on bicycling behavior. Beale and Johnson developed a methodology to identify “recreational counties” in nonmetropolitan areas in order to develop research and policy to address the widespread population increases in these amenity-rich locations (*26*). The definition of recreational counties accounts for phenomena such as second homes and high levels of recreation-focused employment and income (*27*). Similarly, the category “retirement counties” have significant populations of retired persons and associated housing and services.

TABLE 1 Summary of Self-Reported Bicycling Frequency by Individual, Household, and Area Characteristics, 2009 National Household Travel Survey

		NHTS: Self-reported bicycling activity in the past week (%)			
Variable	**Cateogry**	**N**	**Zero trips**	**One or two trips**	**Three or more trips**
Sex					
	Male	133,211	86.2	6.8	7.0
	Female	152,423	91.8	4.5	3.7
Age					
	< 18	43,103	63.1	16.0	21.0
	18 or older	242,531	93.8	3.7	2.5
Household income					
	Under 100k	218,335	90.4	4.8	4.9
	Over 100k	67,299	85.4	8.2	6.4
Race of household respondent					
	White	245,238	89.1	5.6	5.3
	African American, Black	16,395	91.1	4.2	4.7
	Asian only	6,673	89.1	6.5	4.4
	American Indian, Alaskan Native	2,236	90.3	4.5	5.1
	Native Hawiian, other Pacific	884	87.3	7.5	5.2
	Multiracial	1,879	87.9	5.5	6.6
	Hispanic	9,125	87.3	6.6	6.1
	Other	3,204	89.8	5.4	4.8
Children in household (among respondents age 18+)					
	No	183,078	89.0	5.4	5.8
	Yes	59,453	91.0	6.2	3.0
Population density					
	High-density urban (>12,500)	77,055	91.6	4.2	4.2
	Urban (2400-12,500)	71,699	89.1	5.8	5.1
	Suburban (1200-2400)	40,926	88.7	5.9	5.4
	Low density suburban (200-1200)	87,770	88.6	5.9	5.4
	Rural (<200/mi2)	8,184	89.8	4.9	5.3
RUCA					
	Most urban 1	188,200	88.7	6.0	5.3
	Level 2	40,629	89.2	5.3	5.5
	Level 3	2,661	89.6	5.0	5.3
	Level 4	17,531	89.7	5.0	5.3
	Level 5	7,776	90.4	4.4	5.2
	Level 6	1,623	92.0	3.0	5.0
	Level 7	9,821	91.7	4.0	4.3
	Level 8	2,512	92.5	3.3	4.2
	Level 9	1,586	91.1	4.0	4.9
	Most rural	13,295	91.0	4.1	4.9
Recreation county					
	No	275,032	89.2	5.5	5.2
	Yes	10,602	88.0	6.0	6.0
Retirement county					
	No	231,281	89.6	5.4	5.0
	Yes	54,353	87.6	6.2	6.2

Notes: Categories defined as rural (<200 persons per square mile), low-density suburban (200-1,200 persons per square mile), suburban (1,200-2,400 persons per square mile), urban (2,400-12,500 persons per square mile), and high-density urban (≥12,500 persons per square mile). Sources: Ewing et al. 2003; U.S. Census, 2016.

Rural-Urban Commuting Area (RUCA) categories represent commute flows between population centers. Level 1: Metropolitan area core with primary commuting within an Urbanized Area (UA); Level 2: Metropolitan area high commuting, primary flow 30% or more to UA; Level 3: Metropolitan area low commuting, primary flow 10% to 30% to a UA; Level 4: Micropolitan area core, primary flow within an Urban Cluster (UC) of 10,000 to 49,999; Level 5: Micropolitan high commuting, primary flow 30% or more to a large UC; Level 6: Micropolitan low commuting, primary flow 10% to 30% to a large UC; Level 7: Small town core, primary flow within a UC of 2,500 to through 9,999; Level 8: Small town high commuting, primary flow 30% or more to a small UC; Level 9: Small town low commuting, primary flow 10% to 29% to a small UC; Level 10: Rural areas, primary flow to a tract outside a UA or UC (including self). Sources: Rural Health Research Center, 2016. U.S. Census, 2016.

Analytical Approach

We used binary logistic regression to estimate the likelihood of a respondent bicycling in the previous week, using two different dependent variables representing different frequencies of bicycling (i.e., one or two times, three times or more). The binary logistic regression model explains the relationship between the covariates and the binary outcome variable. The parameter coefficients in a logit regression model are expressed as log odds, which can be transformed into odds ratios. Odds ratios are defined as the probability that an event occurs divided by the probability that it does not occur. For example, a 0.5 probability of an event occurring has an odds ratio of 1.0. In the context of multivariate regression, the odds ratio represents the association of a covariate (*x*) on the outcome variable (*Y*) holding all other covariates constant.

The model form is given by the following equation,

$$\Pr(Y) = \frac{e^{(\beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n)}}{1 + e^{(\beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n)}}$$

where,

Y = survey respondent reported bicycling at the given level

x = covariate (reported in tables below)

β_0 = intercept parameter

β = parameter estimate

We specified the model using a purposeful approach based on theoretical relationships, prior empirical research, bivariate relationships between the dependent variables and potential covariates, and the Akaike Information Criterion (AIC) as a measure of model fit (*28*). We included interaction terms to examine the differential effects of age, gender, and income by urban-rural status. We also tested ordinal logistic models with a dependent variable representing the three different bicycling frequencies (i.e., zero times, one or two times, three or more times). The results were similar to those of the binary logistic models. We present only the results of the binary logistic models because of their relative clarity.

RESULTS AND DISCUSSION

Table 1 presents a descriptive summary of the frequency of bicycling by personal, household, and area-level factors. The majority of men and women in the sample reported not making any trips by bicycle in the previous week (86% and 92%, respectively). The proportion of respondents who reported bicycling one or two times in the previous week was 7% among men and 5% among women, and a similar proportion reported bicycling three or more times in the previous week (7% and 4%, respectively). People under age 18 reported the highest levels of bicycling activity; 16% bicycled one or two times in the previous week, and 21% reported bicycling at least three times.

Bicycling frequency estimates varied depending on which urban-rural continuum definition was used. Using the population density definition, urban, suburban and low-density suburban places had the highest proportion of respondents reporting bicycling one or two times in the previous week (all about 6%), and high-density urban places had the lowest proportion (4%). Pearson chi-square tests confirm that these differences are statistically significant ($p<.0001$). However, the Mantel-Haenszel test rejected a linear relationship between bicycling frequency and urban-rural status, as measured by population density category ($p=0.263$). Therefore, differences in these proportions should be interpreted cautiously. Descriptive results for bicycling three or more times in the previous week were similar, and both chi-square test statistics were significant for this variable.

The RUCA definition produced the opposite gradient. When places were stratified by RUCA, the most urban places (Levels 1, 2, 3 and 4) had the highest proportion of bicycling one or two times in the previous week (between 5% and 6%). Both chi-square test statistics were significant for the RUCA definition ($p<.0001$). Results for bicycling three or more times in the previous week were similar.

The differences between the two definitions of urban-rural continua may arise because the most urban RUCA (Level 1) includes a wide range of population densities. Places with very high population density, and that have relatively lower levels of bicycling, may be too few to lower the proportion estimated for RUCA Level 1.

Model Results

Tables 2 and 3 present adjusted odds ratios from the regression analyses. These figures control for individual, household, and area-level variables as well as the interaction effects of age, gender, and income by urban-rural status. The interaction effects for race and ethnicity were not significant and were not included in the model.

Urban-Rural Status

The model results suggest that bicycling is primarily—but not exclusively—an urban activity, which is consistent with the findings of Loh et al. (*9*). Residents of certain types of RSLD places were as likely to bicycle as their urban counterparts. This pattern was true for different bicycling frequencies and different definitions of urban-rural continua. Moreover, according to the population density definition, residents of the highest-density urban places were less likely to bicycle one or two times in the previous week compared to residents living in the urban category [odds ratio (OR)=0.69 (0.55, 0.85)].

For the RUCA definition, respondents who reside outside of the most urban category had lower odds of bicycling one or two times the past week than their urban counterparts, all else equal. However, not all of these differences were significant at the $\alpha=0.05$ level. Levels 3 and 9 were statistically equivalent to the most urban level [OR=1.00 (0.74, 1.37) and OR=0.75 (0.48, 1.17), respectively]. These categories represent metropolitan areas with low commuting to an Urbanized Area and small towns with low commuting to Urban Clusters, respectively. The results were similar for bicycling three days or more, but the patterns were slightly different. For more frequent bicycling, micropolitan areas with various degrees of commuting (Levels 4, 5, 6, and 9) were statistically equivalent to the most urban levels [OR=0.97 (0.84, 1.12), OR=0.87 (0.70, 1.08), OR=0.82 (0.50, 1.35), and OR=0.84 (0.53, 1.35), respectively].

TABLE 2 Logistic Regression Models for Bicycling Frequency by Rural-Urban Commuting Area, 2009 National Household Travel Survey

		Bicycling 1-2 times per week vs. 0 times			Bicycling 3 times per week or more vs. 0-2 times per week		
Variable	**Category**	**Odds ratio**	**95% confidence interval**	**Probability**	**Odds ratio**	**95% confidence interval**	**Probability**
Sex (ref=Female)	Male	1.62	(1.56, 1.69)	***	1.96	(1.86, 2.04)	***
Age (ref=18+)	Under eighteen	7.63	(7.30, 7.99)	***	9.73	(9.29, 10.20)	***
Race/ethnicity (ref=White)	African-American/Black	0.72	(0.66, 0.78)	***	0.84	(0.77, 0.91)	***
	Asian	0.82	(0.74, 0.91)	***	0.65	(0.58, 0.74)	***
	American Indian/Alaskan Native	0.73	(0.60, 0.90)	**	0.86	(0.70, 1.04)	
	Native Hawaiian/Other Pacific	0.97	(0.74, 1.26)		0.71	(0.52, 0.96)	*
	Multiracial	0.88	(0.72, 1.08)		1.09	(0.90, 1.33)	
	Hispanic	0.84	(0.77, 0.92)	***	0.78	(0.71, 0.86)	***
	Other	0.83	(0.70, 0.97)	*	0.78	(0.66, 0.92)	**
Children in hh (ref=No)	Yes	2.15	(2.06, 2.24)	***	1.33	(1.26, 1.41)	***
Hh income >$100,000 (ref=No)	Yes	1.42	(1.36, 1.48)	***	1.07	(1.02, 1.12)	**
RUCA categories	Level 2	0.86	(0.79, 0.94)	***	0.81	(0.73, 0.90)	***
(ref=Most urban level 1)	Level 3	1.00	(0.74, 1.37)		0.57	(0.38, 0.87)	**
	Level 4	0.86	(0.75, 0.98)	*	0.97	(0.84, 1.12)	
	Level 5	0.80	(0.66, 0.98)	*	0.87	(0.70, 1.08)	
	Level 6	0.55	(0.33, 0.92)	*	0.82	(0.50, 1.35)	
	Level 7	0.71	(0.59, 0.85)	***	0.68	(0.55, 0.84)	**
	Level 8	0.62	(0.42, 0.91)	*	0.55	(0.35, 0.87)	**
	Level 9	0.75	(0.48, 1.17)		0.84	(0.53, 1.35)	
	Level 10	0.75	(0.64, 0.87)	***	0.74	(0.62, 0.89)	***
Recreation county (ref=no)	Yes	1.42	(1.29, 1.55)	***	1.29	(1.17, 1.42)	***
Retirement county (ref=no)	Yes	1.22	(1.17, 1.27)	***	1.33	(1.27, 1.38)	***
Age * RUCA	Level 2	1.17	(1.06, 1.29)	**	1.66	(1.50, 1.85)	***
(ref=Most urban level 1)	Level 3	1.32	(0.91, 1.91)		1.98	(1.34, 2.93)	**
	Level 4	1.11	(0.95, 1.29)		1.17	(1.01, 1.35)	*
	Level 5	1.08	(0.85, 1.37)		1.84	(1.48, 2.30)	***
	Level 6	1.56	(0.87, 2.81)		2.61	(1.53, 4.39)	**
	Level 7	1.14	(0.92, 1.42)		1.55	(1.26, 1.92)	***
	Level 8	1.55	(0.98, 2.44)		2.80	(1.78, 4.41)	***
	Level 9	0.71	(0.40, 1.25)		1.84	(1.08, 2.93)	*
	Level 10	1.26	(1.05, 1.51)	*	1.71	(1.43, 2.04)	***
Male * RUCA	Level 2	0.89	(0.81, 0.98)	*	0.85	(0.77, 0.94)	**
(ref=Most urban level 1)	Level 3	0.72	(0.50, 1.03)		0.97	(0.66, 1.43)	
	Level 4	1.02	(0.88, 1.18)		1.00	(0.86, 1.16)	
	Level 5	0.84	(0.67, 1.06)		0.84	(0.68, 1.06)	
	Level 6	0.68	(0.38, 1.22)		0.57	(0.35, 0.92)	*
	Level 7	0.90	(0.73, 1.12)		0.95	(0.76, 1.18)	
	Level 8	0.67	(0.42, 1.05)		0.85	(0.55, 1.31)	
	Level 9	0.97	(0.58, 1.63)		0.66	(0.41, 1.08)	
	Level 10	0.79	(0.66, 0.95)	*	0.86	(0.72, 1.03)	
Hh income >$100,000 * RUCA	Level 2	0.99	(0.89, 1.09)		0.85	(0.76, 0.96)	**
(ref=Most urban level 1)	Level 3	0.55	(0.34, 0.89)	*	1.55	(1.02, 2.36)	*
	Level 4	1.01	(0.84, 1.21)		0.97	(0.79, 1.18)	
	Level 5	1.27	(0.97, 1.68)		0.68	(0.49, 0.95)	*
	Level 6	0.82	(0.37, 1.82)		0.45	(0.18, 1.09)	
	Level 7	1.10	(0.83, 1.46)		1.04	(0.76, 1.42)	
	Level 8	1.04	(0.56, 1.93)		0.38	(0.16, 0.92)	*
	Level 9	1.38	(0.73, 2.59)		1.24	(0.65, 2.38)	
	Level 10	0.90	(0.70, 1.17)		0.98	(0.75, 1.26)	
Summary statistics							
N_{total}		270,654			285,634		
$N_{bike\ one\ time = 1\ or\ bike\ three\ times = 1}$		15,884			14,980		
AIC - intercept only		120,898.10			117,484.21		
AIC - intercept and covariates		108,031.75			98,362.92		

Notes: Probability: * p<.05, ** p<.01, *** p< .001.

Rural-Urban Commuting Area (RUCA) categories represent commute flows between population centers. Level 1: Metropolitan area core with primary commuting within an Urbanized Area (UA); Level 2: Metropolitan area high commuting, primary flow 30% or more to UA; Level 3: Metropolitan area low commuting, primary flow 10% to 30% to a UA; Level 4: Micropolitan area core, primary flow within an Urban Cluster (UC) of 10,000 to 49,999; Level 5: Micropolitan high commuting, primary flow 30% or more to a large UC; Level 6: Micropolitan low commuting, primary flow 10% to 30% to a large UC; Level 7: Small town core, primary flow within a UC of 2,500 to through 9,999; Level 8: Small town high commuting, primary flow 30% or more to a small UC; Level 9: Small town low commuting, primary flow 10% to 29% to a small UC; Level 10: Rural areas, primary flow to a tract outside a UA or UC (including self). Source: Rural Health Research Center. 2016. http://depts.washington.edu/uwruca/ruca-codes.php. U.S. Department of Transportation. 2010. National Household Travel Survey.

Urban rural differences in bicycling were slightly attenuated for the population density definition. Respondents from low-density suburban and suburban places were as likely as urban residents to bike one or two times in the previous week, all else equal. In contrast, respondents in the most rural category and the high-density urban category were less likely than others to bicycle one or two times in the previous week. Respondents from rural and low-density places were also less likely to report bicycling three or more times in the previous week compared to their urban counterparts [OR=0.80 (0.73, 0.88) and OR=0.90 (0.82, 0.99), respectively].

For both dependent variables, and for both the population density and RUCA models, respondents residing in recreation counties and retirement counties were more likely than others to report bicycling in the previous week. The odds ratios across the different models and definitions of urban-rural continua were in the range of 1.21 to 1.40. This suggests that niche environments combining social, cultural, and built environment factors may attract bicyclists through self-selection, and that these niche factors may be more useful for understanding bicycling behavior than constructs representing urban-rural status.

Personal and Household Factors

Consistent with prior studies, men were more likely to bicycle than women, and more so when considering bicycling three or more times per week. For the RUCA definition, the odds ratios comparing male to female bicycling were OR=1.62 (1.56, 1.69) for bicycling one or two times in the past week and OR=1.96 (1.86, 2.04) for bicycling three or more times in the past week. The results were similar for the population density definition.

Children and youth under 18 years old had the highest odds of bicycling, with odds ratios of seven or more. Household composition also mattered: adults ages 18 and older with children in the household were more likely to bike than those in households without children, and the effect was stronger for bicycling only one or two times in the past week. For the RUCA definition the odds ratios were OR=2.15 (2.06, 2.24) for bicycling one or two times in the past week and OR=1.33 (1.26, 1.41) for bicycling three or more times per week.

Household income greater than $100,000 per year had a positive association with bicycling and its effect was also stronger for bicycling only one or two times in the past week. For the RUCA definition the odds ratios were OR=1.42 (1.36, 1.48) for bicycling one or two times in the past week and OR=1.07 (1.02, 1.12) for bicycling three or more times in the past week.

Respondents who identified as non-Hispanic white, Native Hawaiian/other Pacific, multiracial, and other were statistically equally like to report bicycling one or two times in the past week, whereas respondents of other races and ethnicities were less likely to bicycle. Respondents who identified as non-Hispanic white, American Indian/Alaskan Native, and multiracial were statistically equally likely to report bicycling three or more times in the past week, whereas respondents of other races and ethnicities were less likely to bicycle.

TABLE 3 Logistic Regression Models for Bicycling Frequency by Population Density, 2009 National Household Travel Survey

		Bicycling 1-2 times per week vs. 0 times			Bicycling 3 times per week or more vs. 0-2 times per week		
Variable	Category	Odds ratio	95% confidence interval	Probability	Odds ratio	95% confidence interval	Probability
Sex (ref=Female)	Male	1.71	(1.61, 1.81)	***	2.18	(2.04, 2.33)	***
Age (ref=18+)	Under eighteen	7.04	(6.61, 7.51)	***	7.90	(7.40, 8.44)	***
Race/ethnicity (ref=White)	African-American/Black	0.73	(0.67, 0.79)	***	0.84	(0.78, 0.91)	***
	Asian	0.85	(0.76, 0.94)	**	0.66	(0.58, 0.74)	***
	American Indian/Alaskan Native	0.73	(0.59, 0.90)	**	0.86	(0.70, 1.05)	
	Native Hawaiian/Other Pacific	1.00	(0.77, 1.30)		0.73	(0.53, 0.99)	*
	Multiracial	0.90	(0.73, 1.10)		1.10	(0.90, 1.33)	
	Hispanic	0.89	(0.81, 0.97)	**	0.82	(0.74, 0.90)	***
	Other	0.86	(0.74, 1.01)		0.80	(0.67, 0.95)	**
Children in hh (ref=No)	Yes	2.16	(2.06, 2.25)	***	1.34	(1.26, 1.41)	***
Hh income >$100,000 (ref=No)	Yes	1.52	(1.43, 1.61)	***	1.17	(1.09, 1.25)	***
Population density	Rural	0.86	(0.79, 0.93)	***	0.80	(0.73, 0.88)	***
(ref=Urban)	Low-density suburban	0.97	(0.89, 1.05)		0.90	(0.82, 0.99)	*
	Suburban	1.04	(0.95, 1.14)		0.99	(0.89, 1.10)	
	High-density urban	0.69	(0.55, 0.85)	***	0.99	(0.79, 1.25)	
Recreation county (ref=No)	Yes	1.30	(1.19, 1.42)	***	1.28	(1.17, 1.40)	***
Retirement county (ref=No)	Yes	1.21	(1.16, 1.26)	***	1.32	(1.27, 1.38)	***
Age * density level	Rural	1.28	(1.17, 1.40)	***	2.08	(1.89, 2.28)	***
(ref=Urban)	Low-density suburban	1.28	(1.17, 1.39)	***	1.73	(1.57, 1.90)	***
	Suburban	1.05	(0.94, 1.17)		1.37	(1.22, 1.53)	***
	High-density urban	0.81	(0.64, 1.03)		0.50	(0.40, 0.64)	***
Male * density level	Rural	0.82	(0.75, 0.90)	***	0.75	(0.68, 0.83)	***
(ref=Urban)	Low-density suburban	0.88	(0.81, 0.96)	**	0.79	(0.72, 0.87)	***
	Suburban	0.93	(0.84, 1.04)		0.88	(0.79, 0.99)	*
	High-density urban	1.32	(1.04, 1.67)		1.37	(1.07, 1.76)	*
Hh income >$100,000 * density lev	Rural	0.96	(0.87, 1.06)		0.91	(0.82, 1.01)	
(ref=Urban)	Low-density suburban	0.91	(0.87, 1.06)		0.79	(0.71, 0.87)	***
	Suburban	0.89	(0.80, 0.99)	*	0.85	(0.75, 0.96)	***
	High-density urban	0.89	(0.69, 1.17)		0.82	(0.61, 1.09)	
Summary statistics							
N_{total}		270,654			285,634		
$N_{bike\ one/two\ times\ =\ 1\ or\ bike\ three\ times\ =\ 1}$		15,884			14,980		
AIC - intercept only		120,898.10			117,484.21		
AIC - intercept and covariates		108,034.40			98,147.92		

Notes: Probability: * p<.05, ** p<.01, *** p< .001.

Population density categories defined as rural (<200 persons per square mile), low-density suburban (200-1,200 persons per square mile), suburban (1,200-2,400 persons per square mile), urban (2,400-12,500 persons per square mile), and high-density urban (≥12,500 persons per square mile).
Sources: Ewing et al. 2003; U.S. Census, 2016; U.S. Department of Transportation

Differential Effects of Age, Gender, and Income by Urban-Rural Status

This analysis extends prior understanding of bicycling in RSLD places by examining the interaction effects of age, gender, and income by urban-rural status. Compared to urban bicyclists, RSLD bicyclists are more likely to be women and youth, which are two groups at the center of efforts to expand the reach of bicycling beyond adult men.

Youth are more likely to bicycle in RSLD environments. Although bicycling frequency is highest in urban places according to both the RUCA and population density definitions of urban-rural status, the relationship between bicycling and urbanicity reversed when age (under 18 years old) was considered as an interaction term.

For the population density definition, younger people were more likely than adults to report bicycling one or two times in the previous week when they lived in rural or low-density suburban places [OR=1.28 (1.17, 1.40) and OR=1.28 (1.17, 1.39), respectively]. The differential effects of urban-rural status were stronger for bicycling three or more times in the previous week.

Youth in rural places had twice the odds of bicycling as adults in urban places [OR=2.08 (1.89, 2.28)]. In addition, youth who live in the high-density urban category were less likely to bicycle three or more times per week compared to adults in the urban category [OR=0.50 (0.40, 0.64).

The results were mixed for the RUCA definition: for each level of the urban-rural continuum, youth were increasingly likely to bicycle in more rural places when considering bicycling three or more times per week, but this relationship was true for only levels 2 and 10 when considering bicycling one or two times in the previous week.

Rural and suburban environments may be more amenable for women's bicycling. Men were more likely than women to report bicycling three times per week or more in the high-density urban places, but this outcome was less likely at every other level of the urban-rural continuum. The results were similar for bicycling one or two times per week, but the effect was significant only for rural and low-density suburban places. For both outcome variables, male respondents from high-density urban area were more likely to bike compared to the female respondents from urban area [OR=1.32 (1.04, 1.67), OR=1.37 (1.07, 1.76), respectively]. These results were weaker for the RUCA definition.

The interaction effects were mixed with respect to income. The interaction term with household income did not reach statistical significance for most categories of urban-rural status. Certain RSLD environments appeared to support bicycling among households with incomes lower than $100,000 per year, but the effect depended on the definition of the urban-rural continuum.

CONCLUSIONS

In this study we tested the hypothesis that bicycling is primarily an urban activity, and found that it is primarily, but not exclusively urban. In certain types of places, RSLD residents are as likely to bicycle as their urban counterparts. The most important finding, however, is that the population characteristics of urban and RSLD bicyclists are different.

First, young people had lower odds of bicycling in high-density urban places compared to other environments. This means that a paradigm of bikeable communities that replicates patterns urban bicycling that work well for adults may exclude youth and children. For example, a policy and programming emphasis that encourages employers to support bicycling for commuting (e.g., bike to work day) would not be widely relevant to people who do not have an employer. However, this is not to say that youth and children would not benefit from utilitarian bicycling options. Youth and children do not drive cars and therefore their relatively limited mobility may be expanded by bicycling. Useful models for youth-oriented bicylcle mobility could emerge from RSLD settings.

Second, based on a population density definition of RSLD places, women had lower odds of bicycling in high-density urban places compared to those with relatively lower population densities. Despite efforts from mainstream bicycle advocacy groups to increase women's cycling, an underlying urban bicycling paradigm may also be a mismatch holding back programs to create gender parity in bicycling. The reasons for this difference are unknown but may include different levels of comfort bicycling with heavy traffic, or perhaps different underlying activity patterns across settings.

We also found that for both dependent variables, and for both the population density and RUCA models, respondents residing in recreation counties and retirement counties had higher odds of reporting bicycling in the previous week. This suggests that niche environments combining social, cultural, and built environment factors may be more relevant to bicycling than constructs representing urban-rural status. In addition to offering amenities that support bicycling, these places may encourage bicycling for economic reasons. Research on rural economic development has found that economic growth, population growth, and land development in recreational places is accompanied with higher cost of living, particularly housing costs (*29*). Therefore, if bicycling is a lower-cost mode of transportation in expensive recreational settings, particularly rural recreational settings, bicycling may be used to offset higher housing costs. This example suggests a need to better understand the nature of bicycling in RSLD places. If bicycling for transportation purposes is more common among lower-socio economic groups, then considering the transportation/commute needs of RSLD residents is an important topic for future research and policy with respect to promoting bicycling in RSLD places.

Other results from this study are consistent with prior research, particularly the propensity to bicycle among groups with higher socio-economic status. For example, respondents with household incomes above $100,000 per year had higher odds of bicycling compared to those with incomes below $100,000. Additionally, respondents who identify as white had higher odds of bicycling compared to most other racial/ethnic groups. These findings may vary by trip purpose, which we did not control for, and which is a limitation of this study. A further limitation is the potential undercoverage of non-white travelers in the NHTS data, as well as other groups that may be hard to reach given the survey's methods. These respondents who are difficult to reach may include bicyclists across urban and RSLD places and the potential bias due to their missing data is unknown. Data collection and research designs that capture information about hard-to-reach populations are next steps for understanding the full reach of bicycling across places and populations.

Future research on bicycling in RSLD places should also investigate whether the cultural meaning of bicycling differs between urban and RSLD places in ways that important for how communities approach bicycle policy, planning, and design. For example, an urban model of bicycling that emphasizes an urban built environment and a car-free lifestyle may conflict with a smaller community's values, lifestyles, and physical environments. Specialized data collection and analysis comparing RSLD and urban places with respect to their motivation for bicycling and the strategies that they use to create a bikeable community are important next steps.

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