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Examining urban and rural bicycling in the United States: Early findings from the 2017 National Household Travel Survey

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ABSTRACT

Introduction: Bicycling has personal and population health benefits. While bicycle research has focused primarily on the urban context, the rural context is equally important. There are documented disparities in health behaviors and health outcomes in rural areas compared to urban areas. It is unknown whether bicycling is one of these health behavior disparities.

Methods: This study addresses two questions: 1) what is the prevalence of bicycling behaviors by urbanicity (urban/rural and population density category), and 2) what are the characteristics that best categorize individuals as cyclists versus non-cyclists, overall and for rural populations. We used the 2017 National Household Travel Survey, a nationally representative sample of the US non-institutionalized population (age ≥ 5 years). Bicycling was defined as any bicycling, bicycling for exercise, bicycle commuting, and bike share program use. Analyses used complex survey procedures to estimate unadjusted and adjusted prevalence; and, random forest to rank characteristics that best categorize respondents as bicyclists.

Results: The unadjusted prevalence of any reported bicycling was higher in high-density urban areas ($\geq 10,000$ persons per square mile (ppsm)), 14.7% (95% CI: 13.4%–16.0%), than very low-density rural areas (< 500 ppsm), 11.8% (10.4%–13.2%). However, when adjusting for covariates, the prevalence was comparable: high-density urban: 14.4% (12.9%–16.0%); very low-density rural: 12.2% (10.8%–13.7%). Unadjusted prevalence of bicycling for exercise were also similar (high-density urban: 8.2% (7.0%–9.3%); very low-density rural: 7.0% (6.1%–7.9%)). We also found that characteristics that best categorize bicyclists from the overall sample were different from the rural only sample.

Conclusions: This research suggests that bicycling prevalence overall and for exercise are similar between urban and rural areas across population densities. It also suggests that characteristics that were important for rural bicyclists were different from urban bicyclists. Urban-focused bicycle research may need modification to fit the rural context to promote bicycling and physical activity.

1. Introduction

Bicycling is an uncommon travel behavior in the United States, yet it has personal and population health benefits (Krizec, 2007;

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Matthews et al., 2007; Dill, 2009; Brown et al., 2016a,b; Celis-Morales et al., 2017). There have been large increases in bicycling use since 2001 through 2016, although overall rates remain low at 0.6% of US commuters (Pucher et al., 2011; Alliance for Biking & Walking 2016). There has been considerable investment in the provision of bicycling infrastructure, such as bicycle lanes and bike share programs, which provide safe and convenient environments to encourage more bicycling (Dill, 2009; Faghih-Imani et al., 2014; Brown et al., 2016a,b; Hirsch et al., 2017). However, most planning and improvements to bicycling infrastructure are concentrated in urban areas and less is known about bicycling prevalence or supportive environments in rural or lower population density contexts (Aytur et al., 2011; McAndrews et al., 2017). This study estimates bicycling prevalence by urbanicity, a range of population density categories in urban and rural contexts. This research also explores socio-demographic and environmental characteristics that best categorize individuals as cyclists versus non-cyclists, overall and for rural populations.

Bicycling in rural contexts is important, as rural environments are increasingly being viewed as places of health behavior and health outcome disparities, compared to urban areas (Blake et al., 2017; Wheeler and Davis, 2017). For example, residents in rural areas have higher risks of cancers associated with modifiable risks and cardiovascular disease, compared to urban residents (Dwyer-Lindgren et al., 2016; Zahnd et al., 2018). Additionally, there are also health behavior disparities in rural counties: lower rates of meeting aerobic physical activity guidelines (at least 150 min of moderate-intensity aerobic activity, 75 min of vigorous-intensity or an equivalent combination per week) and higher rates of smoking and drinking (Matthews et al., 2017). Bicycling is a form of moderate- to vigorous-intensity physical activity and may be one way to reduce the disparity in physical activity levels between rural and urban populations.

However, the first step is to determine the prevalence of rural and urban bicycling to assess whether this is a health behavior disparity. Previous research has examined individual-level characteristics of bicyclists in low density and rural settings (McAndrews et al., 2017), examined bicycle supportive infrastructure and mode share in rural areas (Loh et al., 2012), and summarized active living supports and research more broadly in rural areas (Hansen et al., 2015). The current bicycling prevalence across urbanicity categories is unknown. Furthermore, the use of new bicycle infrastructure, such as bike share programs, by rural residents is unknown. These two points are important for understanding bicycling behavior across urbanicity categories to potentially tailor policy and investments for supportive bicycling environments.

1.1. Research questions

This first research question is: what is the prevalence of bicycling behaviors (any, for exercise, for commuting, and bike share program use) by urban/rural area and population density category? The second research question is: what are the socio-demographic and environmental characteristics that best categorize individuals as cyclists versus non-cyclists, overall and for rural populations?

2. Methodology

2.1. Sample

We used the 2017 National Household Travel Survey (NHTS), which is sponsored by the Federal Highway Administration in the US Department of Transportation and data were collected under contract by Westat. The NHTS was a household survey of a nationally representative sample of the US non-institutionalized population (age ≥ 5 years) with sample design and data collection details available online (Federal Highway Administration, 2018). We used the combined national sample and state add-on samples, for a total of 264,234 persons. We excluded respondents who had medical conditions affecting travel for an analytic sample of 237,146 persons.

2.2. Measures

2.2.1. Bicycling

The main bicycling question, from the person file, asked how many times the respondent rode a bicycle, outside and for any purpose, in the past 7 days. If greater than zero, two follow-up questions were asked: 1) “How many of these rides were strictly for exercise?”; and 2) In the past 30 days, “how many times did you use a bike share program (e.g. Bikeshare, Zagster, or CycleHop)?” For these three questions, we recoded responses as binary variables for any versus no trips. The bicycle commuting variable was from the trip survey file and recorded detailed trip-level data for an assigned day of the week. Participants were coded as having any bicycle commuting if they had at least 1 bicycle trip between home and work.

2.2.2. Urbanicity

The urbanicity measure was based on the urban and rural classification variable for the respondent's residential address using the US Census Bureau's definition of urban areas: “densely developed territory, and encompass residential, commercial, and other non-residential urban land uses” of at least 2,500 people (US Census Bureau, 2016). Rural areas were not explicitly defined but were all non-urban areas. Additionally, we further segmented urban and rural areas based on population density of the Census block group of the respondent's residential address. This resulted in five urban categories: High-density ($\geq 10,000$ persons per square mile(ppsm)); urban (4,000–9,999ppsm); suburban (2,000–3,999ppsm); low-density suburban (500–1,999ppsm); and very low-density (< 500 ppsm). There are two rural categories: low-density suburban (500–1,999ppsm) and very low-density (< 500 ppsm).

2.2.3. Covariates

For the adjusted prevalence, we used age, sex, race/ethnicity (Hispanic; White, non-Hispanic; Black, non-Hispanic; Other or multiple races, non-Hispanic), highest education level (less than high school; high school graduate or GED; some college or associates degree; bachelor's degree; graduate or professional degree), nativity (born in US or not born in US), have children, able to drive, employment status (not employed; part time; full time; multiple jobs), household size, household number of vehicles, season survey was completed (fall; winter; spring; summer), and whether the trip survey day was on the weekend (only used for bicycle commuting model).

2.3. Statistical analysis

To estimate the unadjusted prevalence of bicycling behaviors by urbanicity, we used survey procedures (proc surveyfreq); for the adjusted analyses we used predicted margins in survey logistic regression models (proc rlogist). Both procedures included survey weights and jackknife variance estimates for 95% confidence intervals; weights were provided in the person weights file. We used SAS v9.4 (Cary, NC) and SAS-callable SUDAAN v11.0 (Research Triangle Institute).

To model the association between bicycling and covariates, we used the random forest machine learning algorithm. We implemented the random forest models with the randomForest v4.6-14 package in R v3.4.2 (R Foundation for Statistical Computing, Vienna, Austria). The key parameters to specify for the random forest model are: mtry, the number of variables to sample at each split point; ntree, the number of trees to grow; nodesize, the minimum size of the terminal nodes; and, sampsize, the size of the sample to draw. We set ntree = 100 and left the other parameters at their defaults (mtry = 7; nodesize = 1; sampsize = 62,921). We used mean decrease in accuracy for ranking variable importance, which is based on how random permutations to values of each variable affect the classification of the outcome variable (Breiman, 2001).

3. Results

3.1. Bicycling prevalence

The weighted, unadjusted and adjusted prevalence of any bicycling, bicycling for exercise only, any bicycle commuting, and any bike share program use by urbanicity are in Table 1. Overall, the unadjusted prevalence of any reported bicycling was higher in high-density urban areas ($\geq 10,000$ persons per square mile), 14.7% (95% CI: 13.4%–16.0%), than very low-density rural areas (< 500 persons per square mile), 11.8% (10.4%–13.2%). However, when adjusting for covariates, the prevalence was more comparable: high-density urban: 14.4% (12.9%–16.0%); very low-density rural: 12.2% (10.8%–13.7%). Unadjusted prevalence of bicycling for exercise were also similar (high-density urban: 8.2% (7.0%–9.3%); very low-density rural: 7.0% (6.1%–7.9%)). High-density urban areas have higher prevalence of bicycle commuting 1.3% (0.8%–1.7%) than low-density rural areas 0.04% (0.0%–0.08%). Finally, bike share program use was higher for residents of high-density urban areas 2.1% (1.8%–2.4%) than residents who lived in very low-density rural areas 0.4% (0.2%–0.7%).

3.2. Bicycling covariates

The ten most important variables for classifying persons as bicyclists versus non-bicyclists, based on mean decrease in model accuracy, were: 1) population density; 2) household count of different travel modes; 3) household income; 4) taxi use; 5) household count of vehicles; 6) household count of trips; 7) age; 8) household size; 9) smartphone; and, 10) employment density (Appendix, Fig. A1).

For rural residents, the ten most important variables for classifying persons as bicyclists versus non-bicyclists were: 1) age; 2) number of walking trips; 3) walking for exercise; 4) household count of trips; 5) household count of different modes; 6) distance to work or school (whichever was farther); 7) household size; 8) household family income; 9) employment density; and, 10) count of public transit usage (Appendix, Fig. A2).

4. Discussion

This research estimated the national prevalence bicycling and subtypes of bicycling for exercise, for commuting, and bike share program use by urbanicity. We found that urban and rural areas, across population densities, had similar prevalence of overall bicycling and bicycling for exercise. We also found that prevalence of bicycle commuting and bike share program use were non-zero in the rural context. Other research has found rates of bicycle commuting in non-urban, small town settings was comparable to some urban areas (Loh et al., 2012). This finding is at odds with some assumptions in the active living research field that in rural areas commuting by bicycle is an unrealistic expectation due to longer distances (Hansen et al., 2015). While bike share programs are mainly part of the urban bicycle infrastructure, these results suggest that these programs benefit users who do not live in urban areas, such as rural residents, in addition to visitors and tourists (O'Brien et al., 2014). More research is needed into when and where rural residents are using bike share programs and if such programs could be adapted to provide additional mobility options in the rural context.

The random forest analysis for categorizing respondents as bicyclists in the whole sample, both urban and rural residents, found that population density around the residence was the most important factor, confirming previous research (Saelens et al., 2003;

Table 1
Weighted, unadjusted and adjusted bicycling prevalence and 95% confidence intervals by urban/rural areas and population density, NHTS 2017.

	Unweighted n	Any bicycling ^a		Any bicycling for exercise ^b		Any bicycle commuting ^c		Any bike share program use ^d	
		Unadjusted	Adjusted ^e	Unadjusted	Adjusted ^e	Unadjusted	Adjusted ^e	Unadjusted	Adjusted ^e
Overall	237,146	13.2% (12.8%–13.6%)	-	8.0% (7.6%–8.4%)	-	0.4% (0.3%–0.5%)	-	0.8% (0.7%–0.9%)	-
Urban Areas ^f									
High-density urban (≥ 10,000 ppsm)	16,215	14.7% (13.4%–16.0%)	14.4% (12.9%–16.0%)	8.2% (7.0%–9.3%)	8.3% (7.1%–9.7%)	1.3% (0.8%–1.7%)	0.6% (0.5%–0.8%)	2.1% (1.8%–2.4%)	1.5% (1.3%–1.7%)
Urban (4,000–9,999 ppsm)	51,247	14.3% (13.6%–15.0%)	14.1% (13.5%–14.7%)	8.6% (7.9%–9.4%)	8.6% (7.8%–9.4%)	0.4% (0.2%–0.7%)	0.5% (0.3%–0.7%)	0.6% (0.4%–0.8%)	0.5% (0.4%–0.7%)
Suburban (2,000–3,999 ppsm)	44,275	12.7% (11.6%–13.7%)	12.7% (11.8%–13.7%)	7.9% (7.1%–8.8%)	7.9% (7.1%–8.6%)	0.2% (0.09%–0.4%)	0.3% (0.1%–0.6%)	0.7% (0.3%–1.0%)	0.7% (0.4%–1.1%)
Low-density suburban (500–1,999 ppsm)	50,903	12.9% (11.8%–14.0%)	13.0% (12.1%–14.0%)	8.2% (7.7%–8.6%)	8.1% (7.7%–8.6%)	0.1% (0.03%–0.2%)	0.2% (0.1%–0.4%)	0.7% (0.4%–0.9%)	0.7% (0.5%–1.1%)
Very low-density (< 500 ppsm)	19,803	12.9% (11.8%–14.0%)	12.7% (11.4%–14.2%)	8.0% (6.7%–9.3%)	7.9% (6.6%–9.5%)	0.1% (0.05%–0.2%)	0.2% (0.1%–0.3%)	0.4% (0.1%–0.6%)	0.4% (0.2%–0.8%)
Rural areas ^f									
Low-density suburban (500–1,999 ppsm)	3,445	11.5% (6.6%–16.4%)	11.3% (7.4%–16.7%)	7.4% (3.3%–11.4%)	7.2% (4.2%–11.9%)	0.2% (0.0%–0.5%)	0.3% (0.02%–5.4%)	0.2% (0.03%–0.3%)	0.2% (0.08%–0.5%)
Very low-density (< 500 ppsm)	51,258	11.8% (10.4%–13.2%)	12.2% (10.8%–13.7%)	7.0% (6.1%–7.9%)	7.1% (6.2%–8.2%)	0.04% (0.0%–0.08%)	0.07% (0.02%–0.2%)	0.4% (0.2%–0.7%)	0.6% (0.4%–1.1%)

ppsm: persons per square mile, based on Census block group of residential address.

^a Any reported bicycling in the past 7 days.

^b For those who reported any bicycling, reported bicycling with the purpose of getting exercise in the past 7 days.

^c Any reported bicycling to or from work on the surveyed travel day.

^d For those who reported any bicycling, any reported bike share program use in the past 30 days.

^e Adjusted for age, sex, race/ethnicity, education, nativity, have children, driver, employed, household size, household number of vehicles, season, and weekend day (only for any bicycle commuting).

^f Residential address inside Census designated urban areas of at least 2,500 people per square mile and/or urban land uses.

Moudon et al., 2005; Winters et al., 2010). While previous research found that factors such as higher income were associated with more overall trips (Ortúzar and Willumsen, 2001), we are not aware of previous research about household travel mode diversity as a significant predictor of bicycle use. The overall findings contrasted with the result for rural residents, where age was the most important variable and count of walking trips was second most important. These results support some previous research that found age associations with bicycling (Hunt and Abraham, 2007) and synergies with walking (Pucher et al., 2010). The contrast between overall predictors and rural-specific predictors for classifying persons as bicyclists warrants further investigation.

Some limitations of this study include how survey questions were framed and the limited data to explore regional variations. For example, only respondents who answered that they had bicycled in the past 7 days were asked about shared bicycle use for the past 30 days. This likely underestimates the prevalence of bike share program for occasional users. Additionally, the nationally representative nature of these data does not allow exploration of more nuanced definitions of urbanicity, such as variations in the prevalence of bicycling based population density in conjunction with income or region of the country. The sample size in lower-density areas and Census regions is too sparse, and bicycling is relatively uncommon to be able to examine these relationships.

5. Conclusion

This research used nationally representative data which suggests that rural areas have comparable prevalence of overall and exercise bicycling as urban areas, across population density categories. This suggests that bicycling likely does not contribute to the lower levels of meeting physical activity recommendations observed in rural areas. However, this research also suggests factors that are important for rural persons to bicycle are likely different from urban persons. This supports previous suggestions that the largely urban-focused bicycle research community may need to include rural populations’ bicycle needs to effectively promote physical activity in the rural context.

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Appendix

Table A1
Variable abbreviations and descriptions for random forest models.

Variable	Description	Variable	Description	Variable	Description	Variable	Description
HOMEOWN	Home ownership	hhtrips	household trips	carever	car use	mileyear	miles travelled per year
HHSIZE	Household size	HBRESND	housing unit density	walkever	walk use	workhome	ability to work from home
HHVEHCNT	Household vehicle count	mode count	modecount	busever	bus use	workft	full time work
PC	personal computer	active trips	active	taxiever	taxi use	walksafety	perception of safety for walking
SPHONE	smartphone	household active trips	hhactive	paraever	paratransit use	walkinfra	perception of infrastructure for walking
TAB	tablet	delivery	package deliveries	trainever	train use	female	female
popdensity	population density	carshare2	car share use	age	age	white	white, non-Hispanic
PTUSED2	any public transit	children	number of children	hispanic	Hispanic	walk4ex2	walk for exercise
PRMACT2	primary activity in previous week	HTEEMPDN2	employment density	BORNINUS_r	Nativity	NWALKTRP2	number of walking trips
PHYACT2	physical activity level	HHFAMINC2	household income	DELIVER_r	delivery of packages	driver_r	driving ability
OCCAT2	job category	health2	self-rated health	Distance	distance to work or school, whichever is greater	DRVRCNT_r	count of drivers in household
EDUC_r	education level	FLEXTIME_r	flexible work hours	TravDayHM	travel day start location	GT1JBLWK_r	more than one job

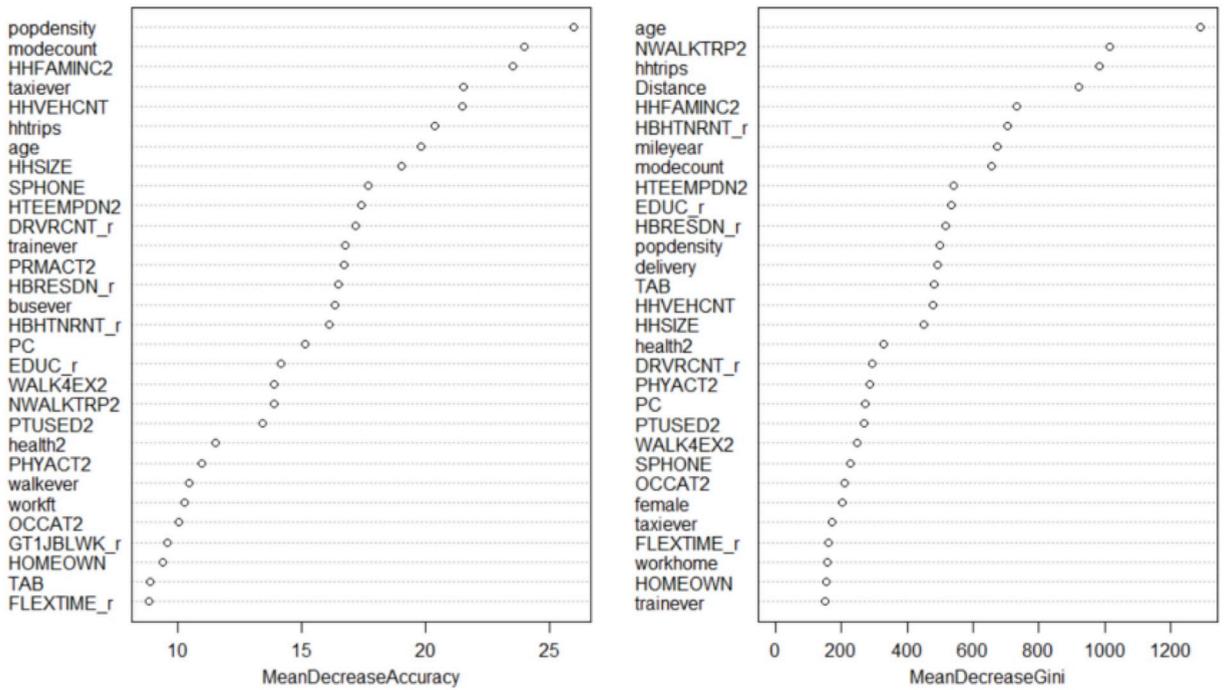


Fig. A1. Overall variable importance plots for categorizing bicyclists versus non-bicyclists: mean decrease in accuracy (left) and mean decrease in Gini coefficient (right).

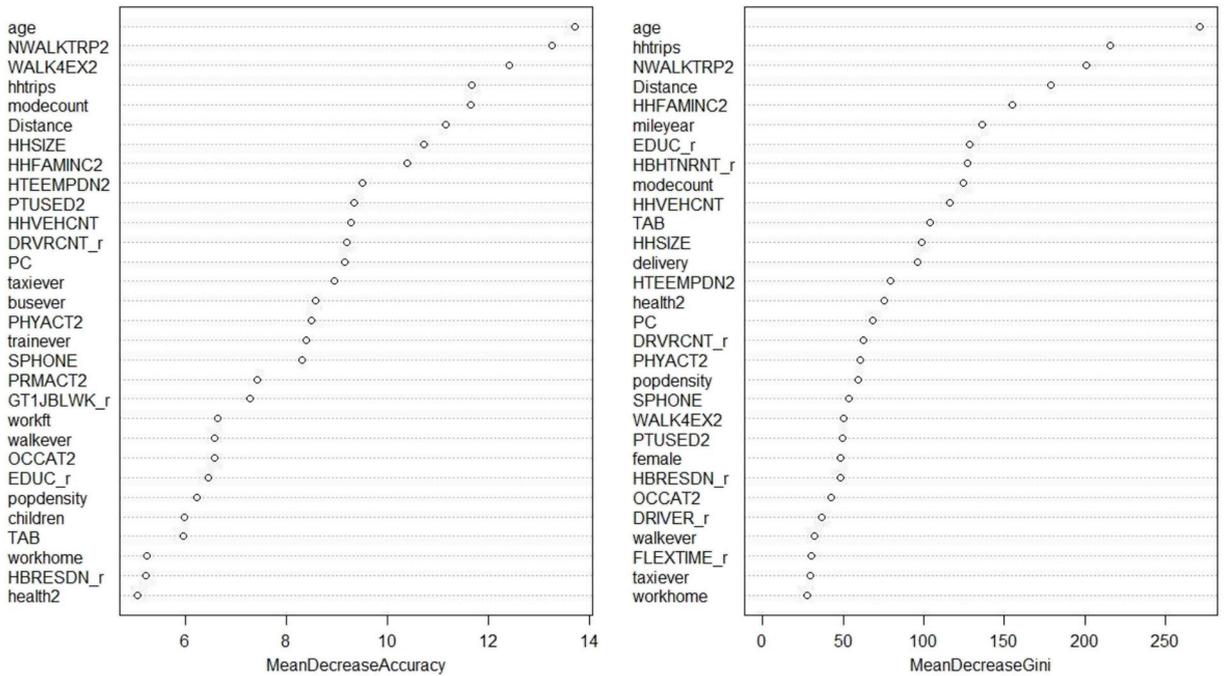


Fig. A2. Rural variable importance plots for categorizing bicyclists versus non-bicyclists: mean decrease in accuracy (left) and mean decrease in Gini coefficient (right).

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jth.2019.03.015>.

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