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Article

Built environment and active commuting: Rural-urban differences in the U.S

Jessie X. Fan[a,*], Ming Wen[b], Neng Wan[c]

[a] Department of Family and Consumer Studies, University of Utah, 225 S 1400 E AEB 228, Salt Lake City, UT 84112-0080, United States
[b] Department of Sociology, University of Utah, 380 S 1530 E Rm 301, Salt Lake City, UT 84112-0250, United States
[c] Department of Geography, 332 S 1400 E, RM. 217, Salt Lake City, UT 84112-9155, United States

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ABSTRACT

The purpose of this research was to investigate rural-urban differences in participation rates in three modes of active commuting (AC) and their built environmental correlates. The 2010 Census supplemented with other datasets were used to analyze AC rates in percent of workers age 16+ walking, biking, or taking public transportation to work in 70,172 Census tracts, including 12,844 rural and 57,328 urban. Random-intercept factional logit regressions were used to account for zero-inflated data and for clustering of tracts within counties. We found that the average AC rates were 3.44% rural and 2.77% urban ($p < 0.01$) for walking to work, 0.40% rural and 0.58% urban ($p < 0.01$) for biking to work, and 0.59% rural and 5.86% urban ($p < 0.01$) for public transportation to work. Some environmental variables had similar relationships with AC in rural and urban tracts, such as a negative association between tract greenness and prevalence of walking to work. Others had opposite correlational directions for rural vs. urban, such as street connectivity for walking to work and population density for both walking to work and public transportation to work. We concluded that rurality is an important moderator in AC-environment relationships. In developing strategies to promote AC, attention needs to be paid to rural-urban differences to avoid unintended consequences.

1. Introduction

In the United States, rural areas have significantly higher prevalence of overweight and obesity, diabetes, coronary heart disease, hypertension, stroke, and cancers than urban areas (Befort, Nazir, & Perri, 2012; Bennett, Olatosi, & Probst, 2008; Jones, 2010). Research has suggested that disparities in physical activity (PA) between rural and urban residents may partially explain such rural-urban health disparity (Bennett et al., 2008; Martin et al., 2005; Patterson, Moore, Probst, & Shinogle, 2004; Weaver, Palmer, Lu, Case, & Geiger, 2013). However, evidence regarding rural-urban difference in PA is mixed depending on whether PA was subjectively or objectively measured, and what intensity threshold was used in objectively measured PA (Fan, Wen, & Kowaleski-Jones, 2014a). A study using both subjective and objective PA data from the National Health and Nutrition Examination Survey (NHANES) found that compared to urban residents, rural residents reported more PA but spent less time in higher-intensity PA. However, rural residents spent more time in lower-intensity PA, especially household PA, than urban residents (Fan et al., 2014b). Because different PA domains tend to have different levels of intensity, this finding likely implies that patterns of PA differ for rural and urban residents for different PA domains, which typically included leisure-time PA, occupational PA, household PA, and transportation PA. Yet, little is known regarding rural-urban differences in these more detailed PA domains. Such knowledge can be very important in helping us better understand factors contributing to health disparities between rural and urban areas, and to potentially inform community efforts and public health strategies to address such disparity (Bennett et al., 2008; Martin et al., 2005; Patterson et al., 2004; Weaver et al., 2013).

Active commuting (AC), an important part of transportation-related PA, offers an effective way of increasing PA by integrating activities into people's daily life (Bopp, Kaczynski, & Besenyi, 2012; Bopp, Kaczynski, & Campbell, 2013; Shephard, 2008). AC has many well-documented health benefits such as a reduced risk of obesity, diabetes, cardiovascular disease and risk factors, and all-cause mortality (Andersen, Schnohr, Schroll, & Hein, 2000; Hamer & Chida, 2008). AC also leads to a reduction of carbon dioxide emissions by reducing vehicle uses and traffic congestions, therefore generating indirect health benefits (Shephard, 2008). In addition, there are economic benefits through savings in vehicle operating and maintenance costs (Shephard, 2008).

However, when compared with other countries and with historical numbers in the U.S., the current AC rate in the U.S. is low despite these multiple benefits (Bassett, 2012; Kruger, Ham, Berrigan, & Ballard-

* Corresponding author.
E-mail addresses: fan@fcs.utah.edu (J.X. Fan), ming.wen@soc.utah.edu (M. Wen), neng.wan@geog.utah.edu (N. Wan).

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Barbash, 2008). Among the potential factors associated with PA in general and AC in particular, the built environment has received much attention because modifications in built environment features can potentially benefit large groups of people without being cost-prohibitive. Some studies have found that better street connectivity, better neighborhood aesthetics (e.g., more greenness), enhanced infrastructure factors (e.g., sidewalks), safer traffic conditions, higher population density, and mixed land-use patterns were positively associated with AC (Bassett, 2012; Bauman et al., 2012). However, other studies have found null or even opposite relationships (Panter & Jones, 2010). One potential contributor of these mixed results is the rural-urban status of the area as relationships between the built environment and PA may differ due to very different physical layouts in rural vs. urban settings (Frost et al., 2010).

In our previous research, we investigated environmental correlates of AC in rural settings using 2000 Census data (Fan, Wen, & Kowaleski-Jones, 2015). We also used a subset of the 2010 Census data that had the same tract codes as the 2000 Census, which is about half of all 2010 Census tracts, to investigate environmental correlates of PA in urban settings (Fan, Wen, & Kowaleski-Jones, 2014a). In this study, we aimed to utilize the full 2010 Census data in combination with several other national datasets to estimate participation rates in three modes of AC – walking, biking, or taking public transportation to work - in both rural and urban tracts, and to investigate if and how the relationship between built environment features and AC differ by rural-urban status. We were particularly interested in finding out if important built environmental features have the same relationship with AC participation rates in both rural and urban areas, or if certain built environmental features work differently in rural settings compared to urban settings in terms of effect size, or, more drastically, with opposite effect directions.

2. Methods

The 2010 Decennial Census (U.S. Bureau of the Census, 2010) and the 2007–2011 American Community Survey (U.S. Bureau of the Census, 2014a) were used as our primary datasets. The American Community Survey is an ongoing survey conducted annually by the US Census Bureau that captures changes in the socioeconomic, housing, and demographic characteristics of communities cross the US. We used census tract-level measures along with county-level measures to account for potential commuting across tract boundaries. Census tracts typically contain between 1200 and 8000 people, and are relatively permanent statistical subdivisions of a county. When first established, Census tracts are designed to be relatively homogeneous units with respect to economic status, population characteristics, and living conditions (U.S. Bureau of the Census, 2014b). Studies have found that tract-level indicators are more consistently related to residents' health than indicators at other geographic levels (Fan et al., 2014; Krieger, Chen, Waterman, Rehkopf, & Subramanian, 2003; Wan, Zhan, & Cai, 2011).

2.1. Rural-urban definition

Tract rural-urban status was defined using the U.S. Department of Agriculture (USDA) 2010 primary Rural-Urban Commuting Areas (RUCA) codes. The primary RUCA codes uses a flexible scheme to classify sub-county components into 10 detailed rural/urban categories (Environmental Systems Research Institute, 2010; U.S. Department of Agriculture, 2013). For this analysis, we followed the literature to define urban as all metro tracts (RUCA = 1–3, areas with a population of at least 50,000 people) and rural as all non-metro tracts (RUCA = 4–10, areas with a population of less than 50,000 people) (Befort et al., 2012; Martin et al., 2005). Based on RUCA codes, this study includes a total number of 70,172 tracts, including 12,844 rural and 57,328 urban tracts, encompassing all U.S. tracts in the 2010 Census where there was a population.

2.2. AC measures

In order to capture the multiple dimensions of AC, three tract-level aggregate AC measures were created: (1) *percent of workers age 16+ who walked to work (WTW)*, (2) *percent of workers age 16+ who biked to work (BTW),* and (3) *percent of workers age 16+ who utilized public transportation to work (PTTW)*. These were five-year averages generated from the 2007–2011 American Community Surveys based on the question "How did the person usually get to work last week?" If the respondent usually used more than one method of transportation during the trip then the method used for most of the distance was marked.

2.3. Built environment measures

Our main independent variables of interest were the built environmental variables indicating the 3D's of density, diversity, and design (Cervero & Kockelman, 1997), including population density, street connectivity, housing age, greenness, proximity to parks, and air quality. *Tract population density* measured the density aspect of the 3D's and was obtained from the 2010 U.S. Census. A tract-level street connectivity measure was used to capture the design aspect of the 3D's. The measure was defined as the number of intersections per square kilometer in the tract. Only roads with the speed limit of 25 miles/hour or lower were used in the connectivity analysis because roads with higher speed limits are considered highways or major roads that do not contribute to neighborhood walkability (Wang, Wen, & Xu, 2013). The census tract boundaries and road network data were derived from Environmental System Research Institute (ESRI) and the StreetMap USA file (Environmental Systems Research Institute, 2010). A greenness measure at a spatial resolution of 30 m was derived from the tree canopy dataset in the National Land Cover Database 2001 (Homer et al., 2007). Based on this dataset, a tree canopy density indicator was generated for each Census tract to describe the average percentages of tree canopy coverage of all pixels that fell in the Census tract. The park access variable at the tract level was constructed from the 2006 park layer in the ESRI GIS Data DVD (Environmental Systems Research Institute, 2010). Specifically, seven parks (Miller, 1956) closest to all 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 (Zhang, Lu, & Holt, 2011). Air quality was measured by a dummy variable indicating Environmental Protection Agency (EPA) air quality nonattainment status at the county level (U.S. Environmental Protection Agency, 2006). Finally, *Tract median housing age* was used to add information on aspects of neighborhood walkability not captured in our other measures (e.g., side walk availability), because older neighborhoods were built before car-dependency and are generally more walkable than newer neighborhoods (Berrigan & Troiano, 2002). This measure was obtained from the 2007–2011 American Community Surveys.

2.4. Control variables

Controls included additional factors that were likely associated with preferences and constraints related to AC decision making, including demographic factors such as age, race/ethnicity, nativity, and education level, economic factors such as income and homeownership, and other constraints such as commuting distance and neighborhood safety (Bauman et al., 2012; Bopp et al., 2012; Lemieux & Godin, 2009). These factors are important because they modify the costs and benefits associated with AC. For example, a neighborhood with poor walkability and/or a high crime rate is likely to discourage AC by increasing the total costs associated with walking/biking, while a neighborhood that is walkable, safe, and close to work destinations is likely to encourage AC by lowering the total costs associated with walking/biking. For this study, economic variables included tract-level *median housing value (in $10000), median household income (in $1000), percent of owner-occupied housing units, and tract Gini coefficient* (Kennedy, Kawachi, & Prothrow-Stith, 1996), a measure of tract income inequality calculated using the aggregate income data from the 2007–2011 American Community Surveys and applying a program developed in STATA (Whitehouse, 1995). Safety was measured by the county-level *number of crime per 1000 persons,* obtained from the 1998–2008 National Archive of Criminal Justice Data (National Archive of Criminal Justice Data, 1998-2008). Commuting distance was measured by tract *percent of workers age 16+ who had long commute of one or more hours to work per day,* also from the American Community Survey based on the question "How many minutes did it usually take this person to get from home to work last week?" Demographic variables included tract *residents' median age, tract percent of Asian Americans, non-Hispanic blacks, and Hispanics, percent of foreign-born population, percent of residents age 25+ with a college degree or higher, percent of people who lived in college dorms, and percent of people who lived in military quarters*. These variables, obtained or constructed from the 2010 Census, were included because people with different socio-demographic characteristics such as age, gender, culture, education, and occupation tend to have different preferences in their AC decision-making.

2.5. Analysis

In addition to descriptive analysis, regression analyses were conducted separately for the three dependent variables: prevalence of walking to work (WTW), biking to walk (BTW), and public transportation to work (PTTW). The regression analyses were conducted for all tracts first, then for urban tracts and rural tracts separately. In addition, full interaction models were estimated to test the statistical significance of urban-rural differences for each independent variable. Because the AC participation rates were clumped at zero, especially for BTW in both urban and rural tracts and PTTW for rural tracts, we employed fractional logit models to analyze such zero-inflated outcome data with values between 0 and 1, following the recommendation (Liu & Xin, 2014; Papke & Wooldridge, 1993). In addition, random-intercept fractional logit models were used to account for the geographic clustering of tracts within counties while single-level models were used for general model diagnosis such as multicollinearity tests. The random-intercept fractional logit models were estimated using Proc Glimmix and single-level diagnostic models were estimated using Proc Reg and Proc Surveyreg in SAS 9.4 (SAS Institute Inc., 2017). While statistical testing is conceptually not important given that we had the whole population, we present results for significance tests per convention.

3. Results

Table 1 presents basic descriptive information of our data. The estimates are presented first for all tracts, then for rural and urban tracts separately, with F-test p-values for testing rural-urban differences.

For the three AC variables, the average WTW percentage was 2.89% for all tracts, with rural tracts having a higher percentage (3.44%) than urban tracts (2.77%). The average BTW percent was 0.55% for all tracts, with urban tracts having a higher percentage (0.58%) than rural tracts (0.40%). The average PTTW percentage was 4.89% for all tracts, with urban tracts having a substantially higher rate (5.86%) than rural tracts (0.59%).

Average marginal effects from multivariate fractional logit regression estimates are presented in Tables 2–4. Rural and urban models are presented while the all-tract model results are available upon request. The collinearity analysis revealed no problematic multicollinearity issues, with Variance Inflation Factors (VIF) mostly within the range of 1 to 4. The highest VIF was 8.05 for tract median housing value, which is still considered acceptable (Hair, Black, Babin & Anderson, 2009). Model R^2s show that for urban areas, the PTTW model had the highest explanatory power, followed by the WTW model and then the BTW model. For rural areas, however, the WTW model had the highest explanatory power, followed by the BTW model, with PPTW model having the lowest explanatory power.

Out of the six environmental variables, significant urban-rural differences existed for their associations with the three AC measures. *Tract population density* was positively associated with urban WTW and

Table 1
Descriptive Statistics.

	All tracts (n=70,172)		Rural tracts (n=12,844)		Urban tracts (n=57,328)		Rural-urban *F*-test p-value[a]
Variables	Mean	STD	Mean	STD	Mean	STD	
Tract % workers walking to work (WTW)	2.89	4.95	3.44	4.49	2.77	5.04	< .001
Tract % workers biking to work (BTW)	0.55	1.54	0.40	1.18	0.58	1.61	< .001
Tract % workers taking public transportation to work (PTTW)	4.89	10.43	0.59	1.73	5.86	11.29	< .001
Tract pop. density (1000/sq mile)	4.61	8.94	0.53	1.10	5.53	9.64	< .001
Median housing age	39.40	17.13	39.67	13.44	39.34	17.86	0.044
Tract intersection density/sq mile	81.10	77.24	28.98	45.41	92.77	78.08	< .001
Tract % area green canopy	20.92	20.12	29.26	23.54	19.05	18.77	< .001
Average distance to 7 closest parks	7.09	10.44	18.00	14.85	4.65	7.17	< .001
EPA poor air quality status	0.58	0.49	0.14	0.35	0.68	0.47	< .001
Tract med. income (in $1000)	56.53	27.53	42.95	12.80	59.57	29.00	< .001
Tract Gini coefficient (%)	39.04	4.93	40.66	3.99	38.68	5.05	< .001
Tract med. housing value (in $10,000)	23.05	17.76	13.32	10.21	25.23	18.35	< .001
Tract % housing owner-occupied	0.65	0.21	0.71	0.14	0.64	0.23	< .001
County total crime/1000 people	39.31	20.37	25.18	16.52	42.47	19.80	< .001
Tract % 16+ commuting 1 h+	8.02	7.10	7.12	5.17	8.22	7.45	< .001
Tract % living in college dorms	0.62	4.81	0.71	4.58	0.60	4.86	0.019
Tract % living in military quarters	0.04	1.29	0.04	1.26	0.04	1.29	0.994
Tract median age	38.42	7.15	40.90	6.47	37.87	7.18	< .001
Tract % Asians	4.26	8.25	0.79	2.20	5.04	8.88	< .001
Tract % Blacks	13.28	21.99	7.57	15.85	14.56	22.95	< .001
Tact % Hispanics	15.01	20.67	8.09	14.53	16.55	21.51	< .001
Tract % foreign-born	11.93	13.56	4.00	6.00	13.70	14.13	< .001
Tract % 25+ college educated	27.11	18.12	17.83	10.05	29.19	18.86	< .001

[a] *F*-tests evaluated the significance of the difference between rural tracts and urban tracts.

Table 2
Random-intercept factional logit regression results on tract-level percentage workers walking to work (WTW).

Variables	Rural tracts Marginal effects	Rural tracts p-value	Urban tracts Marginal effects	Urban tracts p-value	t-test for difference[a] p-value
Tract pop. density (1000/sq mile)	-0.170	< .0001	0.008	< .0001	< .0001
Median housing age	0.063	< .0001	0.025	< .0001	< .0001
Tract intersection density/sq mile	-0.001	0.1236	0.003	< .0001	< .0001
Tract % area green canopy	-0.009	< .0001	-0.011	< .0001	0.301
Average distance to 7 closest parks	0.033	< .0001	0.023	< .0001	0.2684
EPA poor air quality status	0.204	0.0827	-0.173	0.0106	< .0001
Tract med. income (in $1000)	-0.030	< .0001	-0.012	< .0001	< .0001
Tract Gini coefficient (%)	-0.015	0.0387	0.050	< .0001	< .0001
Tract med. housing value (in $10,000)	0.048	< .0001	0.015	< .0001	0.4785
Tract % housing owner-occupied	-6.921	< .0001	-5.576	< .0001	< .0001
County total crime/1000 people	-0.013	< .0001	-0.016	< .0001	0.0285
Tract % 16+ commuting 1 hour+	-0.022	0.0002	-0.020	< .0001	0.8124
Tract % living in college dorms	0.131	< .0001	0.079	< .0001	< .0001
Tract % living in military quarters	0.097	< .0001	0.074	< .0001	0.8632
Tract median age	0.036	< .0001	-0.011	< .0001	< .0001
Tract % Asians	-0.027	0.0613	-0.002	0.3759	0.0947
Tract % Blacks	-0.019	< .0001	-0.014	< .0001	0.3489
Tact % Hispanics	-0.012	0.0003	-0.009	< .0001	0.4481
Tract % foreign-born	0.043	< .0001	0.001	0.5872	< .0001
Tract % 25+ college educated	0.036	< .0001	0.018	< .0001	0.0019
R^2	0.44		0.46		
R^2 environmental variables only	0.11		0.15		
R^2 non-environmental variables only	0.40		0.42		

Note: The random-intercept fractional logit models were estimated with WTW prevalence specified between 0 and 1. However, the marginal effects were multiplied by 100 for ease of presentation. As an example, a marginal effect of 0.025 for median housing age should be interpreted as: On average, a one year increase in tract median housing age was associated with a 0.025% increase in prevalence of WTW in urban tracts.

[a] *t*-tests evaluated the significance of the difference between rural tracts and urban tracts.

PTTW and rural BTW, and negatively associated with rural WTW and PTTW and urban BTW. *Tract median housing* age was positively associated with all three AC measures in both urban and rural tracts with the exception of an insignificant association for rural PTTW, with the largest marginal effect size found for rural WTW and urban PTTW. *Tract street intersection density* was positively associated with all three AC measures in urban tracts and PTTW in rural tracts, but was statistically insignificant for rural WTW and BTW. *Tract green canopy* was negatively associated with WTW and BTW in both urban and rural tracts and with PTTW in urban tracts, but was positively associated with PTTW in rural tracts. Longer *distance to parks* was positively associated with urban WTW, rural WTW, and rural PTTW, negatively

Table 3
Random-intercept factional logit regression results on tract-level percentage workers biking to work (BTW).

Variables	Rural tracts Marginal effects	Rural tracts p-value	Urban tracts Marginal effects	Urban tracts p-value	*t*-test for difference[a] p-value
Tract pop. density (1000/sq mile)	0.013	0.0331	-0.004	< .0001	0.1515
Median housing age	0.006	< .0001	0.015	< .0001	< .0001
Tract intersection density/sq mile	0.000	0.9855	0.001	< .0001	0.3411
Tract % area green canopy	-0.004	< .0001	-0.005	< .0001	0.8936
Average distance to 7 closest parks	0.001	0.1993	-0.004	0.0118	0.0412
EPA poor air quality status	0.026	0.3963	-0.204	< .0001	0.9964
Tract med. income (in $1000)	-0.003	0.0005	-0.005	< .0001	0.3285
Tract Gini coefficient (%)	0.000	0.9037	0.001	0.2667	< .0001
Tract med. housing value (in $10,000)	0.008	< .0001	0.002	< .0001	0.1578
Tract % housing owner-occupied	-0.770	< .0001	-0.883	< .0001	0.005
County total crime/1000 people	0.001	0.0662	0.003	0.0002	0.0088
Tract % 16+ commuting 1 hour+	-0.007	< .0001	-0.009	< .0001	0.2884
Tract % living in college dorms	-0.003	0.0007	-0.002	0.0029	0.127
Tract % living in military quarters	-0.002	0.6729	-0.008	0.0185	0.8277
Tract median age	-0.008	< .0001	-0.005	< .0001	0.0033
Tract % Asians	0.003	0.2665	-0.004	< .0001	0.2265
Tract % Blacks	-0.003	< .0001	-0.002	< .0001	0.0162
Tact % Hispanics	-0.001	0.4612	0.002	< .0001	0.0063
Tract % foreign-born	-0.002	0.1831	0.001	0.3207	0.0946
Tract % 25+ college educated	0.010	< .0001	0.014	< .0001	0.0359
R^2	0.15		0.18		
R^2 environmental variables only	0.05		0.07		
R^2 non-environmental variables only	0.13		0.16		

Note: The random-intercept fractional logit models were estimated with BTW prevalence specified between 0 and 1. However, the marginal effects were multiplied by 100 for ease of presentation. As an example, a marginal effect of -0.770 for tract percentage of owner-occupied housing should be interpreted as: On average, a one percent increase in tract percentage of owner-occupied housing was associated with a 0.770% decrease in prevalence of BTW in rural tracts.

[a] *t*-tests evaluated the significance of the difference between rural tracts and urban tracts.

Table 4
Random-intercept factional logit regression results on tract-level percentage workers taking public transportation to work (PTTW).

Variables	Rural tracts		Urban tracts		*t*-test for difference[a]
	Marginal effects	p-value	Marginal effects	p-value	p-value
Tract pop. density (1000/sq mile)	-0.032	0.0003	0.025	< .0001	0.0504
Median housing age	0.000	0.6238	0.066	< .0001	< .0001
Tract intersection density/sq mile	0.001	0.0003	0.002	< .0001	0.0966
Tract % area green canopy	0.002	0.0005	-0.007	< .0001	0.0013
Average distance to 7 closest parks	0.001	0.0934	-0.166	< .0001	< .0001
EPA poor air quality status	0.039	0.3541	1.277	< .0001	0.2481
Tract med. income (in $1000)	-0.003	0.0024	0.004	0.0127	0.0004
Tract Gini coefficient (%)	-0.009	< .0001	-0.012	0.002	0.0013
Tract med. housing value (in $10,000)	0.009	< .0001	0.001	0.5803	< .0001
Tract % housing owner-occupied	-1.346	< .0001	-7.841	< .0001	0.2741
County total crime/1000 people	-0.002	0.0272	0.011	0.0604	0.0258
Tract % 16 + commuting 1 hour +	0.020	< .0001	0.118	< .0001	0.007
Tract % living in college dorms	-0.010	< .0001	-0.020	< .0001	0.0065
Tract % living in military quarters	-0.008	0.0999	-0.044	0.002	0.8553
Tract median age	-0.009	< .0001	0.000	0.9521	0.1674
Tract % Asians	0.004	0.2138	0.045	< .0001	0.0067
Tract % Blacks	0.002	0.0048	0.056	< .0001	< .0001
Tact % Hispanics	-0.006	< .0001	0.038	< .0001	< .0001
Tract % foreign-born	0.017	< .0001	-0.008	< .0001	< .0001
Tract % 25 + college educated	0.004	0.0007	0.046	< .0001	0.5868
R^2	0.10		0.69		
R^2 environmental variables only	0.01		0.56		
R^2 non-environmental variables only	0.10		0.51		

Note: The random-intercept fractional logit models were estimated with PTTW prevalence specified between 0 and 1. However, the marginal effects were multiplied by 100 for ease of presentation. As an example, a marginal effect of 0.025 for tract population density should be interpreted as: On average, an increase of 1000 people/ sq miles in the tract was associated with a 0.025% increase in prevalence of PTTW in urban tracts.

[a] *t*-tests evaluated the significance of the difference between rural tracts and urban tracts.

associated with urban BTW and PTTW, and not associated with rural BTW. Finally, poor *county air quality* was negatively associated with urban WTW and BTW, positively associated with rural WTW and urban PTTW, and not associated with rural BTW and PTTW.

Control variables also showed significant urban-rural differences in many variables. For economic variables, *tract medium income* was negatively associated with all urban and rural AC measures with the exception of a positive association with urban PTTW. *Tract income inequality* was positively associated with urban WTW and negatively associated with urban PTTW and rural WTW and PTTW. *Tract median housing valu*e was positively associated with all AC measures with the exception of a negative association with urban PTTW. *Tract percent of owner-occupied housing* was negatively associated with all six AC measures. For safety variables, *county crime rate* was negatively associated with both WTW and rural PTTW but positively associated with both BTW and urban PTTW. *Percentage of workers having long commuting hours* was negatively associated with both urban and rural WTW and BTW but positively associated with both urban and rural PTTW. *Percentages of college dorm residents and military quarter residents* were positively associated with WTW and negatively associated with BTW and PTTW for both urban and rural tracts. Older *median residents' age* was positively associated with rural WTW, negatively associated with urban WTW, urban and rural BTW, and rural PTTW, but not associated with urban PTTW. With a few exceptions, higher *percentages of Asians, Blacks, and Hispanics* were generally negatively associated with WTW and BTW but positively associated with PTTW. Higher *percentages of foreign-born* was positively associated with rural WTW and PTTW but negatively associated with urban PTTW. Finally, higher *percentage of college educated residents* was positively associated with all three AC measures in both urban and rural tracts.

4. Discussion

In this analysis we investigated rural-urban differences in three AC modes: walking, biking, or taking public transportation to work, and examined the relationship between built environment features and AC participation. Several caveats need to be addressed before our discussion. First, our data were cross-sectional in nature, which limited our ability to infer causal relationships. With such data we were only able to confirm associations, although some of the environmental factors could be potential determinants for AC participation. Second, our variables were aggregate measures. As such, one should not extrapolate individual factors affecting AC decision from these results. Third, although we included many built-environmental variables, there were still additional relevant environmental variables we could not control, such as traffic volume, ease of access to sidewalks, or existence of bike lanes, which might be important correlates of AC. Fourth, our long commute variable measured time instead of distance, which might have led to some bias in our estimates because commuting time and AC decision are likely simultaneously determined at the individual level. Nevertheless, our study is innovative in several aspects. First, our study encompassed all 2010 urban and rural Census tracts in the U.S. with a non-zero population, which give this study broad generalizability, especially when compared to most previous AC studies covering smaller geographical areas. Second, we analyzed all three modes of AC, and in doing so, were able to evaluate the complexity of rural-urban differences in different AC modes and their correlates. As a result, our study adds to the current understanding of AC patterns and correlates with regard to rural-urban differences, filling in an important knowledge gap in the AC literature.

Our first important finding is that rural tracts had a higher rate of WTW but lower rates of BTW or PTTW, with the difference in prevalence of PTTW being substantial. This is likely a result of the general lack of public transportation options in rural areas as low population density renders the development of public transportation infrastructure cost-ineffective. Consistent with this explanation is the low explanatory power of the multivariate model for PTTW for rural tracts. These findings suggest that unless a more cost-effective method of public transportation is developed for low population density areas, the focus to promote AC in rural areas should be on walking and biking, while in urban areas, all three AC modes can be targeted.

Our second finding is that more than half (11 out of 18) of the environmental variable/AC associations examined were statistically different between rural and urban tracts. Four of these coefficients had the same direction but varied in effect size, but seven of these coefficients had effects in opposite directions. For example, tract intersection density, as an objective measure of street connectivity, is positively associated with AC in the majority of the current literature (Berrigan, Pickle, & Dill, 2010; Panter & Jones, 2010). While our urban results are consistent with this literature, the association is negative but statistically insignificant ($p = 0.128$) for rural tracts. This null relationship in rural tracts may be because, compared to urban settings, rural towns tend to be small with limited number of streets, and as such, whether these streets are well connected is not important for walking. Tract population density is another example. While higher population density is positively associated with neighborhood walkability and walking behavior in the literature (Ewing, Handy, Brownson, Clemente, & Winston, 2006; Frank et al., 2006), this relationship only holds for urban tracts. For rural tracts, population density is negatively associated with both WTW and PTTW, although it is not clear what the mechanism is behind such a negative association. The bottom line is, because the majority of Americans live in urban areas, research findings including both rural and urban areas are likely dominated by urban relationships. If these associations are utilized to provide information for policies and strategies to promote AC participation, attention needs to be given to rural-urban differences in order to prevent unintended negative consequences of "one-size fits all" type of approaches.

Third, sociodemographic factors explained a larger amount of variance than built environmental factors for all three AC modes in both rural and urban settings, with the exception of public transportation in urban tracts, for which built environmental factors explained more variances than sociodemographic factors. In addition, many of the sociodemographic variables had opposite directions for rural than for urban tracts. While the sociodemographic variables were not the focus of our study, future research should investigate these factors in more depth in order to further our understanding of these rural/urban differences in the environment-AC link.

Finally, while this study focused on rural-urban differences in AC, it is important to note that within urban and rural areas there may be substantial differences that warrant further investigation. For example, poor inner city urban areas may have very different AC patterns and AC correlates compared to economically better-off urban areas, while more remote rural areas may also have very different AC patterns and correlates compared to small towns and micropolitan areas. Future research should look into these within-urban and within-rural differences in order to gain better understanding of AC patterns and correlates to inform public health efforts.

Human subjects

This study was declared exempt by the University of Utah Institutional Review Board (IRB).

Conflict of interest

The authors declare no conflict of interest.

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