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## What moves us: Subjective and objective predictors of active transportation



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### ABSTRACT

**Background:** The majority of commuting trips in the United States are taken by motor vehicle. Yet, lack of regular physical activity has been identified as one of its most significant public health issues, and globally, risks due to physical inactivity are increasing. However, we believe current studies offer an unclear picture of the complex role of the environmental or psychological influences in active travel behavior across urbanicity classifications.

**Aims:** To (1) determine an association between objective or subjective measures of the built environment and active transportation, and (2) characterize the associations within both urban and non-urban contexts among a statewide sample of 862 adults residing in Wisconsin.

**Methods:** Multivariate logistic regression analysis of subjective data from the Survey of the Health of Wisconsin (SHOW) and data from the Wisconsin Assessment of the Social and Built Environment (WASABE), a direct observation audit tool, to test the impacts of subjective perceptions and objective built environment predictors on active transportation in both urban and rural contexts.

**Results:** Males, non-married, physically active individuals, those living in urban areas and with higher education levels had greater odds of using active transportation. Bicycle friendliness (aOR = 2.43; 95% CI: 1.4–4.2) and presence of non-residential destinations (aOR = 1.03; 95% CI: 1.01–1.05) were the strongest objective predictors of active transportation overall. Subjective measures were especially predictive of active transportation in non-urban areas, specifically for participants identifying presence of trails (adjusted odds = 3.71; 95% CI: 1.5–9.2) and non-residential destinations nearby (adjusted odds = 2.65; 95% CI: 0.99–7.06).

**Conclusions:** Active transportation is associated with built environment characteristics and perceived environmental factors, but the specific predictors and strength of associations vary by context. Results suggest perceived bicycle friendliness may be important in urban areas and access to trails for walking and biking may provide important opportunities to promote active transportation in more suburban or rural areas.

### 1. Introduction

In the United States, approximately 3.5 percent of commuting trips are taken by foot or bicycle, 5 percent by public transit, and the remaining 91.5 percent by private motor vehicles (Santos et al., 2011). Lack of regular physical activity has been identified as one of the most significant public health issues in the United States (Blair, 2009; Booth et al., 2012), and the global significance of physical inactivity is increasing as developing countries adopt more motorized modes of transportation. Physical inactivity is

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associated with increased risk of several adverse health outcomes including heart disease, type 2 diabetes, colon cancer, breast cancer, and mortality; yet, more research is showing the protective effects of physical activity against these outcomes, specifically in the form of active transportation (commuting by bicycling or walking) (Andersen et al., 2000; Colditz et al., 1997; Hamer and Chida, 2008; Kelley and Goodpaster, 2001; Kohl, 2001; Matthews et al., 2005; Riiser et al., 2018; Schauder and Foley, 2015; Verloop et al., 2000; Zheng et al., 2009). In fact, physical inactivity has been said to have caused 9% of the premature mortality (estimated at more than 5.3 million of the 57 million deaths), which occurred worldwide in 2008 (Lee et al., 2012). Active transportation might also provide one opportunity to meet physical activity recommendations and minimize adverse sedentary behaviors. Replacing motor vehicle trips with active trips has additional potential health co-benefits in the form of improved air quality and reduced greenhouse gas emissions that contribute to global climate change (Grabow et al., 2012; Maizlish et al., 2013; Mindell, 2018; Mueller et al., 2018; Rabl and De Nazelle, 2012; Rojas-Rueda et al., 2011; Woodcock et al., 2013, 2009). Risks to active travel do exist, mainly in the form of road crashes with motor vehicles and additional exposure to air pollution; however, the majority of research concludes that the benefits of active travel outweigh the costs (Grabow et al., 2012; Johan de Hartog et al., 2010; Mueller et al., 2015; Rojas-Rueda et al., 2011; Woodcock et al., 2013).

Physical activity levels appear to increase in the presence of specific attributes of the built environment (places where people live, work, and play) (Ewing et al., 2003; Frank and Engelke, 2005; Saelens BE, 2003; Sallis et al., 2012) particularly with respect to physical structures including presence of sidewalks, diversity of destinations, and street connectivity. Furthermore, the physical design of these places may also affect travel choices and how much commuters utilize active transportation methods (Ewing and Cervero, 2001; Frank, 2000; Sallis et al., 2004; Wang et al., 2016). Differing features of the built environment in urban, suburban, and rural areas have the potential to influence transportation methods, and thereby physical activity levels. Active transportation in more rural areas may be a greater challenge due to longer distances. However, additional environmental amenities for active transportation may have greater benefits, since historically fewer rural adults are meeting physical activity recommendations (Trivedi et al., 2015) and those living in rural areas are more likely to suffer from health disparities than their urban counterparts (Blake et al., 2017; Tribby and Tharp, 2019; Wheeler and Davis, 2017). To date, less is known about the levels and predictors of active transportation in non-urban areas in the United States (Aytur et al., 2011; McAndrews et al., 2017; Tribby and Tharp, 2019).

Consistent with the Cognitive Behavioral Theory, individual perceptions also influence associations between the built environment and physical activity (Blacksher and Lovasi, 2012; Duncan et al., 2005; Giles-Corti et al., 2005; Humpel et al., 2002; McCormack et al., 2004; O. Ferdinand et al., 2012; Sallis, 2009). The bulk of previous research has focused on recreational physical activity and neighborhood perceptions while few studies have specifically examined the relationship between neighborhood perceptions and active transportation, especially in non-urban contexts. Current evidence presents an unclear picture of which neighborhood elements (or perceptions thereof) predict active modes of transportation in urban and non-urban areas (Brownson et al., 2001; Grasser et al., 2012; O. Ferdinand et al., 2012). Using survey questionnaires and environmental audit data in Wisconsin, this study sought to examine both subjective and objective neighborhood characteristics associated with active transportation in order to determine significant predictors of active transportation among people living in different geographical contexts.

## 2. Material and methods

### 2.1. Study overview and design

Two primary data sources were utilized: (1) **Survey of the Health of Wisconsin (SHOW)** data based on in-person interviews, self-administered questionnaires, computer-assisted surveys, physical measurements, and laboratory tests of neighborhood residents (Nieto et al., 2010); and (2) **Wisconsin Assessment of the Social and Built Environment (WASABE)** data consisting of a neighborhood “built environment” audit to assess the objective physical and social environments (Malecki et al., 2014).

SHOW is a statewide population survey modeled after the National Health and Nutrition Examination Survey (NHANES) that annually gathers health-related data from a representative sample of Wisconsin residents. Details of this program have been previously published (Nieto et al., 2010). In brief, each adult study participant completes a questionnaire regarding physical and mental health history, demographics, and behavior, including diet and occupation, household, environment, and healthcare access and utilization. SHOW participants also receive a physical examination, including blood pressure, blood draw, urine collection, and height and weight measurements.

For this study, we used SHOW data on participants' demographic and health characteristics collected via personal interviews and participants' perceptions of their community environment recorded via self-administered questionnaires. Active transportation activity was assessed using a modified International Physical Activity Questionnaire (IPAQ) (Hagströmer et al., 2006), very similar to the questionnaire from the National Health and Nutrition Examination Survey (NHANES). Participants self-reported total time (in minutes or hours) and number of days over the past 30 days that they spent participating in active transportation, which was reported as the amount of time spent “walking or bicycling as part of getting to and from work, or school, or to do errands” over the past 30 days. Participants also reported total time and number of days engaged in specific moderate to vigorous physical activity during their leisure time. SHOW participant data for this study was collected during 2010.

Ancillary to SHOW, the Wisconsin Assessment of the Social and Built Environment (WASABE) study used a direct observation instrument developed and validated by SHOW investigators to assess neighborhood indicators of the physical and social environment surrounding participating households that may encourage or discourage physical activity. The WASABE instrument covers neighborhood characteristics, the transportation environment, land use and types of destinations, the social environment, and potential for street connectivity. More information regarding the reliability, construct validity, and methods of the WASABE tool can be found in

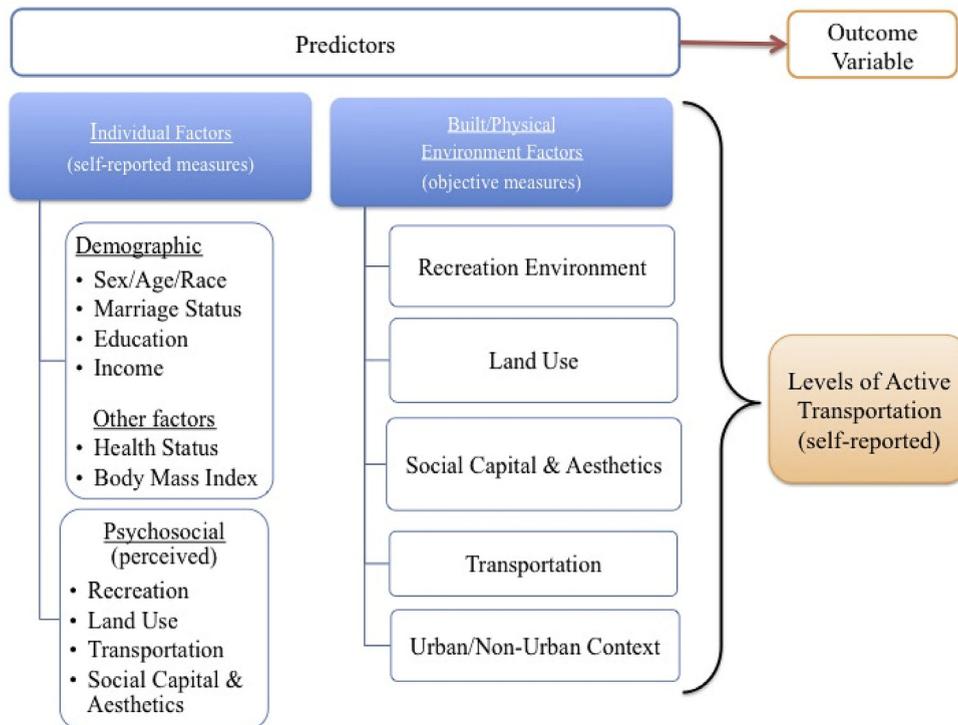


Fig. 1. Variable selection.

previous published work (Bailey et al., 2014; Malecki et al., 2014).

Using the WASABE instrument, neighborhood attributes were assessed by trained research assistants within a 400-m street-network buffer surrounding SHOW participants' home addresses, drawn using Street Network Analyst in Arc Map 9.3 (ESRI, Redlands, CA) (See sample map in Malecki et al., 2014). Distances from homes are often measured using the street network, as it reflects actual routes for walkers and bicyclists (Handy, 1996). Studies have commonly used 400 m as a perceived walkable distance for adults (about 5–10 min of walking) (Boehmer et al., 2007; Hoehner et al., 2007, 2005; Pikora et al., 2003; Smith et al., 2010). WASABE data used for this study were collected between 2010 and 2011.

An outline of variables used for this study can be found in Fig. 1 and illustrates the individual factors (subjective) and built environment measures (objective) that were assessed as predictors of active transportation in both urban and rural populations.

## 2.2. Outcome/dependent variable - active transportation measures

The dependent variable for this study is active transportation. Active transportation is defined as whether or not walking or cycling to work, for errands, or play was reported within the last 30 days; thus, a binary variable was used in the multivariate logistic regression.

## 2.3. Predictors

### 2.3.1. Self-report (subjective measures of the neighborhood environment)

The SHOW survey uses a self-administered questionnaire to obtain information about subjective/perceived neighborhood attributes, including questions about community environments. These items were modified from the Neighborhood Environment Walkability Scale (NEWS) study (Cerin et al., 2006). SHOW data were classified into four domains: recreational opportunities, land use, transportation, and social capital (see Table 1 for specific questions and response options). The first recreational opportunities question seeks a subjective evaluation of the options by asking respondents to rate the community as a place to be physically active. The second question concerns the proximity of trails to the participant's home and how much time it would take to walk or bicycle there (< 10 min was coded as proximity of the trail corresponding to presence of walking or biking trail in the objective assessment). The land-use question examines perspectives on the number and diversity of destinations within close proximity to the participant's home. The transportation question focuses on the perceived degree of safety from traffic for walking or bicycling in the community. Lastly, to examine the perceived visual attractiveness and upkeep of the community, the question on social capital/aesthetics asks participants to rate his or her degree of agreement with the notion that their community is "well-maintained." Due to the distribution of responses, all data except those on proximity of trails were combined into a three category Likert scale to ensure adequate power

**Table 1**  
SHOW neighborhood perception (subjective) questions and related objective measures.

Domain	SHOW Individual Neighborhood Perception (Subjective) Questions	WASABE Objective Audit Based Measures (within 400 m street network buffer)
Recreation	<p><b>Community Physical Activity Rating:</b> Rate your community as a place to be physically active (very pleasant, somewhat pleasant, not very pleasant, or not at all pleasant).</p> <p><b>Trail Nearby:</b> How many minutes it would take to walk from home to the nearest trail: 10 min or less, 11 to 20 min, 21 to 30 min, more than 30 min or don't know any trails within walking distance.</p>	<p><b>Indoor Recreation Facilities:</b> Presence of indoor recreational facilities including indoor fitness facilities; softball, soccer, or football fields; tennis courts, running tracks playgrounds golf courses; pools (YES/NO)</p> <p><b>Off-Road Recreation Trails:</b> Presence walking and cycling trails (YES/NO; on one side of the road, on both sides of the road, or crossing the road)</p>
Land Use	<p><b>Many Destinations:</b> There are many destinations within easy walking distance of my home (strongly agree, agree, disagree, or strongly disagree).</p>	<p><b>Total Destinations:</b> Count of total non-residential destinations including grocery stores, gas stations, pharmacies, restaurants, banks, and coffee shops</p>
Transportation	<p><b>Traffic Safety Rating:</b> How safe from traffic is the community for walking or riding a bike (very safe, somewhat safe, not very safe, and not at all safe).</p>	<p><b>Sidewalks:</b> % of streets in neighborhood having sidewalks;</p> <p><b>Bicycle Friendly Streets:</b> % of streets in neighborhood wide enough to support coexisting bicycles and cars</p>
Social Capital and Aesthetics	<p><b>Maintained Community:</b> My community is well maintained (strongly agree, agree, disagree, or strongly disagree).</p>	<p>% of neighborhood with: graffiti, public art, shade trees, litter, bike racks; % of neighborhood with positive role models – people walking or bicycling</p>

for statistical modeling (e.g., very safe, somewhat safe, and unsafe).

### 2.3.2. Objective environmental measures

Detailed methods regarding objective data collection using the WASABE tool have been previously published (Malecki et al., 2014). WASABE data were classified into the same four domains as the SHOW data (see Table 1). We assessed physical activity infrastructure in the community by counting the total number of recreational facilities in the neighborhood. These included indoor fitness facilities, fields for softball/soccer, tennis courts, running tracks, playgrounds, golf courses, and swimming pools. We assessed whether or not at least one of these facilities was present within the 400-m neighborhood buffer. Land use was determined by counting the total number of nonresidential destinations within each buffer, including grocery stores, gas stations, pharmacies, restaurants, banks, and coffee shops — in short, all places that would provide regular daily commercial activity and that were likely to generate walking or cycling trips (Vargo et al., 2012). The transportation environment was measured according to whether or not neighborhood buffers had segments containing sidewalks and/or bicycle lanes or roads were wide enough to support coexisting bicycles and cars. Social capital and aesthetics were measured by the percentage of various public features present within the segments inside the neighborhood buffer, both good and bad; for example, whether or not there was graffiti or attractive outdoor art, whether or not there were shade trees, the condition of buildings, and whether or not there were amenities such as benches, trash cans, and bicycle racks.

### 2.4. Covariates

Participants reported their age, gender, marital status, duration living at their current address, highest education attainment, household income, race, physical activity status, and self-reported health during in-person interviews. Participants were deemed physically active if they reported achieving the recommended 600 MET<sup>\*</sup>min per week of physical activity (U.S. Department of Health and Human Services, 2008), equivalent to 150 min of moderate or vigorous physical activity based on report of leisure time physical activity only, not including time reported in active transportation. Measurements for body mass index (height (cm) and weight (kg)) were obtained by clinical exam. Each survey participant's urbanicity, defined as urban or not urban, was based on the U.S. 2010 Census classifications of urbanized areas and urban clusters (U.S. Census Bureau, 2010). All SHOW participant addresses were geocoded using ArcGIS software addresses at the time of survey participation and were used to link participants to census blocks in order to classify participants' urbanicity. Addresses located in blocks within urbanized area or urban cluster were defined as urban; all other addresses were assigned to the 'not urban' category.

### 2.5. Statistical analysis

All statistical analyses were conducted using SAS, version 9.3 (SAS Institute Inc., Cary, NC). Descriptive characteristics of the study population can be found in Table 2. We performed chi-squared tests to assess the relationship between the demographic variables and the outcome variable, active transportation. To assess the relationship of demographic measures, objective measures, and perceptions with one another, we calculated Spearman correlation coefficients between all pairs of variables. These coefficients were also used to assess collinearity and to enable further regression analyses with active transportation as the outcome.

We employed multivariate logistic regression to test the impacts of subjective and objective built environment predictors on active transportation. The regression models were adjusted for demographic characteristics (age, race/ethnicity, gender, marital status, and education), economic factors (length of residence and household income), and other factors including body mass index (BMI), urbanicity classification, and physical activity levels. Age (21–74 years) and BMI (17–67) were included in the model as

**Table 2**  
Descriptive characteristics of study population, including active transportation (AT) levels.

Sample Characteristics	Total Sample	% of Sample	# using AT (n)	% of sample using AT <sup>a</sup>	AT Chi-Squared	% of Active Travelers <sup>b</sup>
<b>Study Population</b>	<b>N = 862</b>		<b>n = 259</b>			
<b>Gender</b>						
Male	388	45	134	15.5	< 0.01	51.7
Female	474	55	125	14.5		48.2
<b>Age</b>						
21-30	146	16.9	71	8.2	< .0001	27.4
31-40	141	16.4	37	4.3		14.3
41-50	185	21.5	50	5.8		19.3
51-60	214	24.8	53	6.1		20.4
61-75	176	20.4	48	5.6		18.5
<b>Race/Ethnicity</b>						
White	770	89.5	221	25.7	0.16	86.0
Non-White	90	10.5	36	10.5		14.0
<b>Marital Status</b>						
Married, lives with partner	281	32.6	116	13.4	< .0001	44.9
Not Married	580	67.4	142	16.4		55.0
<b>Education</b>						
High school graduate or less	213	24.7	48	5.6	0.26	18.5
Some college	364	42.3	115	13.4		44.4
College or beyond	284	33.0	96	11.1		37.1
<b>Family Income</b>						
> 100% Federal Poverty Level	744	88.3	202	24.0	< 0.001	80.2
< 100% Federal Poverty Level	98	11.6	50	5.9		19.8
<b>Length of Residency in Household</b>						
Less than 3 years	224	26.2	92	10.8	0.0028	36.1
3 or more years	629	73.7	163	19.1		63.9
<b>Body Mass Index</b>						
< 25	237	27.9	75	8.8	0.74	29.1
25 ≥ BMI < 35	446	52.5	138	16.3		53.4
> = 35	166	19.6	45	5.3		17.4
<b>General Health (self-report)</b>						
Fair/Poor	90	10.7	23	2.7	0.66	9.2
Very Good/Good/Excellent	749	89.3	226	26.9		90.7
<b>Physically Active</b>						
< 600 MET min/week	646	74.9	43	5.0	< .0001	16.6
≥ 600 MET min/week	216	25.1	216	25.1		83.4
<b>Urbanicity Classification</b>						
Urban	530	61.5	198	23.0	< .0001	76.4
Non-Urban	332	38.5	61	7.1		23.6

<sup>a</sup> The % of sample using AT is the number of people with the explanatory variable using AT out of the total sum of study participants (N).

<sup>b</sup> The % of Active Travelers is the number of people with the explanatory variable using AT out of the total sum of active travelers (n).

continuous variables. Gender, marital status (married or living with partner or unmarried), race/ethnicity (white or Hispanic + non-white), physical activity (MET minutes per week score of at least 600) and chronic disease status were considered binary variables. Education and household income were categorical variables. Urbanicity was also considered as a categorical variable (urban or non-urban).

Five phases of modeling produced a parsimonious multivariate model for the dependent variable, active transportation: (1) **demographic** variables only, (2) **demographic** variables and **subjective** predictors only, (3) **demographic** variables and **objective** predictors only (4) **demographic** variables plus both subjective and objective environmental predictors, and (5) **all variables** characterized based on **urban/non-urban status**. Using a manual backward elimination procedure and observance of model fit, environmental/subjective and objective predictors were removed if they were not statistically significant ( $p < 0.30$ ). Lastly, we ran the multivariate models containing demographic, subjective, and objective variables using the data as characterized by urban and not urban (model 5). Effects of individual parameters within models were considered statistically significant at an alpha level of  $p \leq 0.05$ .

### 3. Results

The final sample included 862 participants of which 259 reported using active transportation (about 30%). The average age for those using active transportation was just over 41 years old, with the average age for those not using active transportation being higher at just over 46 years old. The majority of the participants in this study identified as non-Hispanic white ethnicity; similarly, about 85% of those reporting active transportation were also non-Hispanic white. Over 81% of those using active transportation were living in urban areas, while just over half (51%) of those conducting active transportation were not married. About 3/4 of those actively commuting had a family income above 100% of the Federal Poverty Level during the years of SHOW data collection (2009–2010). The distribution of gender, race/ethnicity, age, educational attainment, self-reported health, physical activity status,

and income is provided for the total sample (Table 2).

Six objective and five subjective indicators from the four built environment domains — land use, recreational opportunities, transportation, and aesthetics — remained in the final multivariate model, for a total of 11 indicators. All objective predictors of the built environment were tested for interaction by urbanicity classification, and none were significant. There was also no significant interaction found between the subjective predictors and urbanicity classification or years of residency.

In the final adjusted multivariate model (Model 4), several factors predicted active transportation. Non-married people, those engaging in physical activity, and males had a greater likelihood of participating in active transportation aOR = 1.91 (95% CI: 1.30, 2.81;  $p = .002$ ), aOR = 2.63 (95% CI: 1.47, 4.69;  $p = 0.002$ ), and aOR = 1.65 (95% CI: 1.11, 2.43;  $p = 0.0014$ ), respectively. With every \$1,000 increase in income, study participants were slightly less likely to report using active transportation aOR = 0.98 (95% CI: 0.981–0.996;  $p = 0.004$ ). Those with at least a college education were more likely to use active transportation aOR = 1.946 (95% CI: 0.98–3.85;  $p = 0.056$ ), although the association was only marginally significant. After careful adjustment a number of explanatory variables including urbanicity classification, age, race/ethnicity, self-reported health, body mass index, and number of years residing in the current household were no longer associated with increased odds of active transportation.

### 3.1. Primary predictors

#### 3.1.1. Land use

In the minimally adjusted models accounting for demographics and neighborhood perceptions of positive attributes (Model 2), there was a significant, positive association between the self-reported observation that there were many destinations within 0–10 min walk, and there was a likelihood of active transportation aOR 2.92 (95%CI: 1.46–5.87,  $p$ -value =  $< 0.01$ ) (See Table 3).

Individuals reporting active transportation were more likely to agree that many destinations exist within proximity (close walking distance) of their community (Model 4) (aOR = 1.83, 95% CI: 0.90, 3.72;  $p = 0.092$ ). However, neighborhood perceptions of positive attributes thought to promote an active lifestyle were not statistically significant in the final adjusted model (Model 4).

Directly observed land use indicators such as the number of non-residential destinations in a 400-m residential buffer was significantly and positively associated with active transportation in all the models, with an aOR = 1.03 (95% CI: 1.01–1.05;  $p = < 0.01$ ) (Model 4).

#### 3.1.2. Transportation

Our findings suggest that having a higher percentage of bicycle-friendly roads is associated with more people using active transportation. This is true in all adjusted models, in the model with only objective variables (Model 3) aOR = 2.41 (95% CI: 1.47, 3.92;  $p = 0.0008$ ), and for the model that includes both subjective and objective variables (Model 4) aOR = 2.43, (95% CI: 1.41, 4.17,  $p = 0.0019$ ). The presence of sidewalks was not a strong predictor of active transportation; however, results of models adjusted for demographics suggests a potential positive association between audit-based measures and active transportation may exist, aOR = 1.62 (95% CI: 0.972–2.715;  $p = 0.06$ ) (Model 3) (See Table 4).

### 3.2. Physical activity/recreational opportunities

Presence of physical activity or recreational opportunities did not seem to play a significant role in affecting active transportation levels within this population (Models 3 and 4).

#### 3.2.1. Social capital and aesthetics

Without adjusting for objective environmental factors, (Model 2), the presence of a well-maintained community was inversely associated with active transportation, aOR = 0.40 (95%CI: 0.18–0.90;  $p$ -value = 0.03). However, in fully adjusted model (Model 4), associations between neighborhood perceptions of maintenance were no longer predictive of active transportation. It should be noted that no objective, neighborhood aesthetics features were left in the final multivariate models.

### 3.3. Urban vs. non-urban predictors

Wisconsin is a state that includes over one third of its population living in suburban or rural areas. Given the majority of research on built environmental and active transportation has occurred in primarily urban areas, this study also aimed to examine differences in predictors of active transport for populations living in both urban and non-urban areas. We again used multivariate logistic regression including all of the demographic, subjective and objective variables, based on urbanicity (urban or non-urban) (Model 5). In urban areas, males had greater odds of actively transporting than females (aOR = 1.77;  $p = 0.03$ ) and individuals were more likely to use active transportation if they were already meeting physical activity guidelines of greater than or equal to 600 MET minutes per week compared to those not meeting the guidelines (aOR = 2.39;  $p = 0.005$ ). The total number of nonresidential destinations present in a neighborhood also was associated with a slight increased odds of active transportation (aOR = 1.02;  $p = 0.02$ ); however, bicycle friendly streets increased odds of active transportation by 7 fold in urban areas (aOR = 7.1;  $p = 0.003$ ) (see Table 5).

In non-urban areas, a different set of predictors was identified in the regression analyses. Education was associated with active transportation and individuals who had at least some college had greater odds of using active transportation compared to those with an education of high school or less (aOR = 2.78;  $p = 0.03$ ). The likelihood of actively transporting was lower for those individuals who indicated that they live in a very well-maintained community (aOR = 0.14;  $p = 0.04$ ) compared to those living in a not very

**Table 3**

Logistic Regression Results: Four Models Testing Subjective and Objective Predictors and their Association with Active Transportation Behavior in Wisconsin (Models 1–2)<sup>a</sup>.

Variable	Model 1: Demographics Only			P-value	Model 2: Demographics & Subjective Variables			P-value
	aOR	95% CI LL	95% CI UL		aOR	95% CI LL	95% CI UL	
<b>Age (years)</b>	0.99	0.97	1.00	0.12	0.99	0.97	1.01	0.21
<b>Gender</b>								
Female	Ref				Ref			
Male	<b>1.64</b>	<b>1.19</b>	<b>2.27</b>	<b>&lt; 0.01</b>	<b>1.59</b>	<b>1.11</b>	<b>2.30</b>	<b>0.01</b>
<b>Race/Ethnicity</b>								
Non-Hispanic White	Ref				Ref			
Non-White or Hispanic	1.18	0.63	2.21	0.60	1.01	0.60	1.71	0.96
<b>Education</b>								
HS or less	Ref				Ref			
Some college	1.37	0.80	2.34	0.24	1.45	0.86	2.44	0.16
4 year degree or more	<b>2.05</b>	<b>1.04</b>	<b>4.04</b>	<b>0.04</b>	<b>1.94</b>	<b>1.00</b>	<b>3.76</b>	<b>0.05</b>
<b>Marital Status*</b>								
Married	Ref				Ref			
Not Married	<b>1.72</b>	<b>1.04</b>	<b>2.82</b>	<b>0.03</b>	1.42	0.86	2.34	0.17
<b>Urbanicity Classification</b>								
Urban	<b>2.11</b>	<b>1.26</b>	<b>3.55</b>	<b>0.01</b>	0.81	0.42	1.57	0.52
Non-Urban	Ref				Ref			
<b>Years of Residence</b>	1.01	0.99	1.03	0.40	1.01	0.99	1.03	0.39
<b>Household Income (\$1000)</b>	<b>0.99</b>	<b>0.99</b>	<b>1.00</b>	<b>0.04</b>	1.00	0.99	1.00	0.14
<b>General Health (self-report)</b>								
Excellent\V. Good\ Good	Ref				Ref			
Fair or Poor	1.02	0.49	2.11	0.97	1.12	0.54	2.32	0.76
<b>Physical Activity</b>								
< 600 MET min/week	Ref				Ref			
≥ 600 MET min/week	<b>2.21</b>	<b>1.39</b>	<b>3.50</b>	<b>&lt; 0.01</b>	<b>2.46</b>	<b>1.44</b>	<b>4.19</b>	<b>&lt; 0.01</b>
<b>Body Mass Index (Kg/m<sup>2</sup>)</b>	0.99	0.96	1.02	0.61	0.99	0.96	1.02	0.59
<b>Subjective</b>								
<b>Trail Nearby</b>								
0–10 min walk					1.25	0.72	2.18	0.42
11–20 min walk					0.93	0.37	2.30	0.86
> 20 min walk					Ref			
<b>Many Destinations</b>								
0–10 min walk					<b>2.92</b>	<b>1.46</b>	<b>5.87</b>	<b>&lt; 0.01</b>
11–20 min walk					1.31	0.71	2.42	0.39
> 20 min walk					Ref			
<b>Community PA Rating</b>								
Very Pleasant					1.14	0.40	3.26	0.80
Somewhat Pleasant					0.88	0.34	2.25	0.78
Not Very or Not At All Pleasant					Ref			
<b>Maintained Community</b>								
Very Pleasant					<b>0.40</b>	<b>0.18</b>	<b>0.90</b>	<b>0.03</b>
Somewhat Pleasant					0.59	0.33	1.06	0.08
Not Very or At All Pleasant					Ref			
<b>Traffic Safety Rating</b>								
Very Safe					1.30	0.69	2.45	0.42
Somewhat Safe					1.23	0.66	2.28	0.51
Not Very or Not At All Safe					Ref			

<sup>a</sup> Table only shows factors retained in the models.

well-maintained community. However, those reporting that they lived within an 11–20 min walk of a non-residential destination had a greater likelihood of actively transporting than those living greater than a 20 min walk from a non-residential destination (aOR = 2.65; p = 0.027). Lastly, individuals were more likely to use active transportation if they identified living near a recreational trail within 11–20 min of walking compared to living within more than 20 min of walking (aOR = 3.71; p = 0.002). None of the objective neighborhood and community environmental measures were significant predictors of active transportation for those living in non-urban areas.

#### 4. Discussion

We sought to determine which subjective and objective measures could predict active transportation behavior in a population-based sample of adults living throughout the state of Wisconsin, and more specifically, in both urban and non-urban areas. Wisconsin provides an interesting statewide sample from which to conduct active living research because it includes both large urban, suburban, and rural populations. In this analysis, suburban and rural participants were classified as non-urban residents. Another important

**Table 4**

Logistic Regression Results: Four Models Testing Subjective and Objective Predictors and their Association with Active Transportation Behavior in Wisconsin (Models 3 & 4)<sup>a</sup>.

Variable	Model 3: Demographics & Objective Variables				Model 4: Demographics, Subjective, & Objective Variables			
	aOR	95% CI LL	95% CI UL	P-value	aOR	95% CI LL	95% CI UL	P-value
<b>Age (years)</b>	0.99	0.97	1.01	0.20	0.99	0.97	1.01	0.29
<b>Gender</b>								
Female	Ref				Ref			
Male	<b>1.70</b>	<b>1.20</b>	<b>2.41</b>	<b>&lt; 0.01</b>	<b>1.64</b>	<b>1.11</b>	<b>2.41</b>	<b>0.01</b>
<b>Race/Ethnicity</b>								
Non-Hispanic White	Ref				Ref			
Non-White or Hispanic	1.19	0.64	2.19	0.58	1.07	0.61	1.86	0.81
<b>Education</b>								
HS or less	Ref				Ref			
Some college	1.29	0.76	2.21	0.34	1.41	0.82	2.41	0.20
4 year degree or more	<b>1.97</b>	<b>0.98</b>	<b>3.94</b>	<b>0.06</b>	<b>1.92</b>	<b>0.97</b>	<b>3.79</b>	<b>0.06</b>
<b>Marital Status*</b>								
Married	Ref				Ref			
Not Married	<b>1.68</b>	<b>0.99</b>	<b>2.83</b>	<b>0.05</b>	1.43	0.83	2.47	0.19
<b>Urbanicity Classification</b>								
Urban	1.45	0.85	2.48	0.17	0.68	0.35	1.33	0.25
Non-Urban	Ref				Ref			
<b>Residence Length (Years)</b>	1.01	0.99	1.02	0.59	1.01	0.99	1.02	0.56
<b>Household Income (\$1000)</b>	<b>0.99</b>	<b>0.99</b>	<b>1.00</b>	<b>0.06</b>	1	0.99	1	0.15
<b>General Health (self-report)</b>								
Excellent, V. Good, or Good	Ref				Ref			
Fair or Poor	1.22	0.53	2.82	0.64	1.29	0.58	2.87	0.53
<b>Physical Activity</b>								
< 600 MET min/week	Ref				Ref			
≥600 MET min/week	<b>2.31</b>	<b>1.37</b>	<b>3.91</b>	<b>&lt; 0.01</b>	<b>2.58</b>	<b>1.46</b>	<b>4.58</b>	<b>0</b>
<b>Body Mass Index (Kg/m<sup>2</sup>)</b>	0.99	0.96	1.03	0.64	0.99	0.96	1.02	0.55
<b>SUBJECTIVE</b>								
<b>Trail Nearby</b>								
0–10 min walk					1.28	0.73	2.24	0.39
11–20 min walk					1.1	0.43	2.84	0.84
> 20 min walk					Ref			
<b>Many Destinations</b>								
0–10 min walk					<b>1.83</b>	<b>0.9</b>	<b>3.73</b>	<b>0.09</b>
11–20 min walk					1	0.55	1.82	1
> 20 min walk					Ref			
<b>Community PA Rating</b>								
Very Pleasant					1.17	0.42	3.3	0.76
Somewhat Pleasant					0.92	0.37	2.29	0.85
Not Very or Not At All Pleasant					Ref			
<b>Maintained Community</b>								
Very Pleasant					0.55	0.24	1.27	0.16
Somewhat Pleasant					0.72	0.41	1.26	0.24
Not Very or At All Pleasant					Ref			
<b>Traffic Safety Rating</b>								
Very Safe					1.16	0.62	2.15	0.64
Somewhat Safe					1.02	0.55	1.88	0.95
Not Very or Not At All Safe					Ref			
<b>OBJECTIVE</b>								
<b>Total Destinations</b>	<b>1.03</b>	<b>1.01</b>	<b>1.05</b>	<b>&lt; 0.01</b>	<b>1.03</b>	<b>1.01</b>	<b>1.05</b>	<b>0</b>
<b>Sidewalks</b>								
No	Ref				Ref			
Yes	1.62	0.97	2.72	0.06	1.47	0.82	2.62	0.19
<b>Bicycle Friendly Streets</b>								
No	Ref				Ref			
Yes	<b>2.40</b>	<b>1.47</b>	<b>3.92</b>	<b>&lt; 0.01</b>	<b>2.43</b>	<b>1.41</b>	<b>4.17</b>	<b>0</b>
<b>Indoor Recreation Facilities</b>								
No	Ref				Ref			
Yes	0.71	0.33	1.50	0.36	0.77	0.37	1.57	0.46
<b>Off-Road Recreation Trails</b>								
No	Ref				Ref			
Yes	1.29	0.73	2.28	0.38	1.08	0.62	1.89	0.79

<sup>a</sup> Table only shows factors retained in the models.

**Table 5**  
Predictors of active transportation participants living in urban and non-urban areas (models 5).

Variable	Urban				Non-Urban			
	aOR	95% CI LL	95% CI UL	P-value	aOR	95% CI LL	95% CI UL	P-value
<b>Age (years)</b>	0.99	0.97	1.01	0.14	1.02	0.98	1.06	0.32
<b>Gender</b>								
Female	Ref				Ref			
Male	<b>1.77</b>	<b>1.05</b>	<b>3.00</b>	<b>0.03</b>	1.07	0.51	2.22	0.86
<b>Race/Ethnicity</b>								
Non-Hispanic White	Ref				Ref			
Non-White or Hispanic	1.14	0.58	2.23	0.71	0.27	0.04	1.71	0.16
<b>Education</b>								
HS or less	Ref				Ref			
Some college	0.96	0.52	1.78	0.90	<b>2.78</b>	<b>1.11</b>	<b>6.99</b>	<b>0.03</b>
4 year degree or more	1.36	0.60	3.08	0.45	<b>3.43</b>	<b>1.72</b>	<b>6.82</b>	<b>&lt; 0.01</b>
<b>Marital Status<sup>a</sup></b>								
Married	Ref				Ref			
Not Married	1.30	0.65	2.59	0.45	1.86	0.92	3.76	0.08
<b>Years of Residence</b>	1.02	0.99	1.04	0.20	0.98	0.95	1.01	0.16
<b>Household Income (\$1000)</b>	0.99	0.99	1.00	0.10	1.00	0.99	1.01	0.60
<b>General Health</b>								
Excellent/Very Good/Good	Ref				Ref			
Fair or Poor	1.52	0.50	4.63	0.45	0.50	0.11	2.32	0.36
<b>Physical Activity</b>								
< 600 MET min per week	Ref				Ref			
≥600 MET min per week	<b>2.39</b>	<b>1.33</b>	<b>4.32</b>	<b>0.01</b>	3.95	0.87	17.90	0.07
<b>Body Mass Index (Kg/m<sup>2</sup>)</b>	0.99	0.95	1.04	0.74	0.97	0.90	1.05	0.45
<b>Trail Nearby</b>								
0–10 min walk	1.51	0.70	3.25	0.06	0.90	0.31	2.64	0.12
11–20 min walk	0.49	0.14	1.67	0.11	<b>3.71</b>	<b>1.50</b>	<b>9.20</b>	<b>&lt; 0.01</b>
> 20 min walk	Ref				Ref			
<b>Many Destinations</b>								
0–10 min walk	1.62	0.67	3.91	0.06	0.70	0.11	4.23	0.30
11–20 min walk	0.80	0.34	1.79	0.10	<b>2.65</b>	<b>0.99</b>	<b>7.06</b>	<b>0.03</b>
> 20 min walk	Ref				Ref			
<b>Community PA Rating</b>								
Very Pleasant	3.72	0.84	16.5	0.08	0.61	0.14	2.78	0.80
Somewhat Pleasant	2.84	0.67	12.1	0.36	0.50	0.19	1.34	0.07
Not Very/Not Pleasant	Ref				Ref			
<b>Maintained Community</b>								
Very Pleasant	0.69	0.28	1.73	0.59	<b>0.14</b>	<b>0.02</b>	<b>1.05</b>	<b>0.04</b>
Somewhat Pleasant	0.70	0.34	1.44	0.49	0.68	0.22	2.10	0.16
Not Very/Not Pleasant	Ref				Ref			
<b>Traffic Safety Rating</b>								
Very Safe	0.96	0.45	2.02	0.69	1.08	0.29	4.07	0.50
Somewhat Safe	1.13	0.49	2.59	0.64	<b>0.57</b>	<b>0.24</b>	<b>1.36</b>	<b>0.05</b>
Not Very or Not At All Safe	Ref				Ref			
<b>Total Destinations</b>	<b>1.02</b>	<b>1.00</b>	<b>1.04</b>	<b>0.02</b>	0.84	0.65	1.10	0.20
<b>Sidewalks</b>								
No	Ref				Ref			
Yes	1.51	0.82	2.78	0.18	2.37	0.63	8.96	0.20
<b>Bicycle Friendly Streets</b>								
No	Ref				Ref			
Yes	<b>7.12</b>	<b>2.07</b>	<b>24.5</b>	<b>&lt; 0.01</b>	1.02	0.44	2.33	0.97
<b>Indoor Rec Facilities</b>								
No	Ref				Ref			
Yes	0.78	0.36	1.67	0.51	11.6	0.25	531	0.20
<b>Off-Road Recreation Trails</b>								
No	Ref				Ref			
Yes	0.88	0.50	1.55	0.66	1.60	0.35	7.30	0.54

<sup>a</sup> Table only shows factors retained in the models.

contextual factor to consider the implications of study results is Wisconsin's efforts in some urban areas to increase bicycle friendliness and in non-urban areas, as Wisconsin was the first state in the Nation to implement a rails to trails program to convert old railway lines to trails for walking and biking. These trails are present in many suburban and rural communities throughout the state.

Overall, in this sample of Wisconsin adults age 21–74, those participating in active transportation were more likely to be males, to be unmarried, to be physically active outside of active travel, to be living in more urban areas, or to have a greater education. Those

who have a propensity toward physical activity might also seek the benefits of that activity elsewhere, and in this case, through active transportation. Those with more education may have greater awareness or understanding of the health benefits of physical activity, in this case through active transportation. Other research and surveillance has seen this relationship between higher education and physical activity in and outside of the United States (Freeman et al., 2013; Whitfield et al., 2015; Wijk et al., 2017).

Consistent with previous built environment and active transportation research, we found increased proximity to non-residential destinations to be positively associated with active transportation, for both subjective measures (Models 2 and 4) and for objective measures (Models 3 and 4). These findings are consistent with other studies in the urban planning literature (Frank, 2000; Handy and Clifton, 2001; Hoehner et al., 2005; Saelens and Handy, 2008). Mixing land uses, and thereby decreasing the distances between destinations, is believed to be an important strategy for increasing active transportation (Frank et al., 2003). This also suggests policies that promote incorporation of mixed-use developments within residential areas may provide more opportunities for active transportation.

While numerous studies have identified the role of destinations in determining walking trips, both utilitarian and recreational (King et al., 2003; Lee and Moudon, 2006; Owen et al., 2004; Saelens and Handy, 2008; Sugiyama et al., 2012), fewer studies have look at this in the context of active transportation that may include multiple modes of transportation such as biking. In the present study, those individuals living in neighborhoods with streets that are supportive of bicycling, that is, that have either designated bicycle lanes or have a greater width to safely accommodate cyclists, were more apt to actively transport. This association was much greater in urban vs. non-urban areas. This is in accordance with other studies that documented an association between the presence of supportive bicycle facilities and physical activity levels, some in the form of active travel (Dill and Carr, 2003; Mertens et al., 2017; Nelson and Allen, 1997; Panter and Jones, 2010; Titze et al., 2008; Troped et al., 2001). One comparative analysis suggests that those countries with more cycling facilities have a higher percentage of trips taken by bicycle and have higher levels of bicycle safety (Pucher and Dijkstra, 2000). Results of other research suggest that urban planning and policies that transform streets to support bicycling, such as Complete Streets policies, are effective, and have been shown to increase walking and bicycling trips in other communities across the United States as well (Anderson et al., 2015).

Another important finding from this study was the significant association between access to trails and active transportation in rural but not urban areas. The evidence on presence of trails in rural areas having a relationship with physical activity is mixed, and not many studies have considered the role of distance to trails on physical activity (Boehmer et al., 2006; Brownson et al., 2000; Deshpande et al., 2005; Duncan et al., 2009; Parks et al., 2003; Wilson et al., 2004; Troped et al., 2001). A study by Deshpande et al. (2005) found that the use of trails was significantly associated with meeting physical activity recommendations in rural areas. Troped et al. also observed that for every quarter mile increase in distance from people's homes, the likelihood of using the trail decreased by forty-two percent. The increased odds of active travel in this study was only associated with participants who perceived a trail within a medium amount (11–20 min) of walking/cycling time compared to walking more than 20 min. Early studies by Brownson et al. (2000) did not find a significant association with access to trails and active travel in rural areas; however, another found that lack of trails within 10-min of walking from home in rural areas was correlated with obese/inactive individuals (Boehmer et al., 2006). Our non-urban population includes both suburban and rural areas and suggest trails may increase opportunities for using trails for utilitarian active transportation purposes.

Presence of bicycle-friendly streets was a predictor of active transportation in urban areas, but was not predictive in non-urban areas. According to a national sample of 1000 families, rural Americans value infrastructure investments to support walking and bicycling; almost 75% of rural Americans find bicycle lanes important and almost 95% of rural Americans find sidewalks important (Guarino and Weidman, 2011). In fact, these respondents ranked sidewalks as the “most important” of eight transportation-related facilities for livability, ranking sidewalks higher than having access to major roads, having reliable long-distance transportation, or having adequate parking. However, rural Americans are walking and bicycling at rates lower than in urban areas (Pucher et al., 2011). Thus, improvements to the built environment infrastructure to support active transportation and recreation are potentially just as important and necessary in non-urban areas.

An interesting story is presented in the non-urban areas, as we observed a significant, negative association between active transportation and rating of a well-maintained community. This could be reflected in the significant amount of suburban communities that are car dependent but have very pleasing aesthetics. These finding suggests that a well-maintained community may not be a prerequisite for active transportation in non-urban areas. Moreover, the research on the association between neighborhood aesthetics and physical activity is varied across urban and non-urban areas (Boehmer et al., 2006; Hoehner et al., 2005; Tilt et al., 2007; Titze et al., 2007; van Lenthe et al., 2005).

Other research examining physical activity behaviors in rural areas has not found strong relationships or any at all between a well-maintained community and physical activity (Boehmer et al., 2006; Deshpande et al., 2005). Yet, in contrast to our findings, one study found that rural obese and obese/inactive people were more likely to rate their community as not very or not at all pleasant (Boehmer et al., 2006) while another study found that enjoyable scenery was positively associated with leisure-time physical activity among rural women (Wilcox et al., 2000). Given inconsistencies across these studies, further research is warranted on how aesthetics may influence active travel in urban and non-urban areas.

While other studies have found a more robust role for perception of the built environment in determining physical activity, it is clear that the role of psychology in physical activity and active transportation behavior is complex (Gebel et al., 2009; Hoehner et al., 2005; McGinn et al., 2007). A recent systematic review has recognized that current evidence does not adequately identify whether or not objective or subjective variables more consistently predict physical activity, suggesting further research in this area (Orstad et al., 2016).

This study has certain limitations. It is cross-sectional and observational in nature; thus, we determine only correlations; we

cannot infer causality of relationships. In addition, the questions that comprise the SHOW data on perceptions of the built environment, while consistent with previous studies, do not fully align with the objective measures obtained from the WASABE tool (Malecki et al., 2014; Bailey et al., 2014). Participants were asked about their “community” rather than their “neighborhood,” while it is precisely the neighborhood that the WASABE instrument attempted to capture. Since the WASABE neighborhood is defined as a 400-m radius around each participant's home, this limitation has the potential to conceal the importance of destinations slightly farther away, even if within walkable distance. Moreover, the active transportation component of SHOW relied on self-reported recall of individual active transportation over the past 30 days, and so is subject to social-desirability bias and potential overestimation of transportation physical activity. It is also important to note that this self-reporting of active transportation did not differentiate between walking and bicycling. This may be misleading when associations between objective infrastructure supports of each mode of transportation are made. Use of an accelerometer, an objective measurement of active transportation, would reduce these limitations of self-reported physical activity.

Another limitation is the potential for “self-selection” of the residents, who may have intentionally chosen neighborhoods based on the existence of physical activity supports. In an attempt to control for this phenomenon, we used the length of residence in the home as a surrogate for self-selection. By controlling for length of residency, the chances decrease that the observed associations between the built environment and active transportation are explained by reverse causality.

It is worth noting that the SHOW data collection and the WASABE data collection were completed in subsequent years. The WASABE data collection was focused on objective features of the built environment that likely do not change rapidly in Wisconsin communities. While the possibility of misclassification of some features may be an issue, it is likely resulting in null findings as few of the objective built environment features were associated with active transportation relative to individual perceptions of destinations and bicycle friendly communities. Therefore, this is unlikely a large source of bias.

Our study methodically examined street-level environmental characteristics within a concentrated area surrounding participants' households in a statewide survey representing residents from across diverse urban and non-urban communities. The objective information gathered is at much finer resolution than that gathered by GIS techniques such as Google Streetview or other satellite images. Each utilitarian destination was meticulously counted, each sidewalk presence was methodically recorded, bicycle-supportive streets were systematically documented, visible walking and bicycling trails were carefully observed, and other aesthetic features were thoroughly logged by trained observers at each site. This level of scrutiny provides more up-to-date and objective information than all other methods regarding the environmental features that may play a significant role in predicting active transportation behavior. To add to its strengths, the study populations included many socio-economic groups and backgrounds. However, the sample lacks ethnic diversity; and as a representative sample of the state, the diversity reflects the overall makeup of the state population. Disparities in active transportation in more racially diverse communities warrants further study.

The study also includes both walking and bicycling as means of transportation, thus adds to the limited pool of research on this topic. Findings are largely generalizable to states in the central United States that are made up of communities with urban centers, surrounded by urban sprawl and rural fringe where little to no public transportation beyond busses are available. Most of the central United States has similar transportation infrastructures designed for cars. Thus, this study may support increased understanding of how these different contexts may shape opportunities for and uptake of active transportation.

## 5. Conclusions

Findings from this study expand on current understandings of subjective and objective indicators of physical activity, and specifically add to the limited literature that focuses particularly on active transportation in both urban and non-urban contexts. This research supports the notion that people will be more likely to engage in active transportation if they live in areas with (and perceive them to have) more non-residential destinations or if they have access to and perceive they have more bike friendly streets. Different strengths of association in urban and non-urban populations suggests that different strategies should be applied in different contexts. For example, perceptions of trails nearby, especially in non-urban areas, was associated with active travel. Wisconsin is one of the first states in the nation to convert many of its old railroad lines to trails and this may provide an important opportunity for community design considerations in other areas. Findings further suggest that having dedicated bicycle supportive streets may increase the likelihood of active travel, which supports potential future investments in bicycle and pedestrian infrastructure and multi-use community design planning in communities. Considering the increased health disparities of those living in non-urban areas, our work further supports prioritizing infrastructure that support active travel in both urban and non-urban areas. This research may aid in planning for mixed-use/smart growth communities, especially those in non-urban areas, to support health-promoting transportation designs and choices for all.

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