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Assessing Seasonal and Climate-Related Variability in Rates of Walking and Physical Activity with Time Use Data

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Disclaimer

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Abstract

Background

Levels of walking as an activity that impacts health and quality of life is related to socioeconomic status and home location but the impacts of climate, season, and weather on walking have been largely understudied in both the transportation planning and public health professions.

Purpose

This paper assesses seasonal and climatic effects on walking related activities and demonstrates the utility of the ATUS for active transportation research as few such applications exist.

Methods

The American Time Use Survey (ATUS) is used to observe and analyze the seasonality of pedestrianism and general physical activity nation-wide by measuring the effect of month and climate region while controlling for sociodemographic characteristics of the respondents and their household using statistical regressions.

Results

Expected seasonal patterns for physical activity are found, but are paired with counter-intuitive results on the influence of climate regions suggesting both weather and culture influences levels of active transportation and recreation.

Conclusion

Differences in walking behavior between climatic regions offer one explanation of how respondents' surroundings impact their daily activities.

1. Introduction

Walking and related physical activities including non-motorized transportation such as bicycling, skateboarding, skiing, and skating play an important role in public health. Active transportation is considered a key factor in promoting healthy lifestyles that minimize obesity (Dunton et al., 2009) and other chronic illnesses (Centers for Disease Control and Prevention (CDC), 2012). Additionally, these activities offer quality of life, mobility and environmental benefits. Walking and related physical activities also provide mobility for those who cannot drive.

Active transportation and physical activity rates are related to environmental factors including infrastructure and design, perceived and observed aesthetics and safety, social context, and natural factors such as weather and topography (Bauman et al., 2012; Hoehner et al., 2005; Sallis et al., 2006). While climatic and weather differences are known to affect active transportation rates (Brandenburg et al., 2004), little is known about the regional differences in time spent walking and doing physical activity as a result. Data on physical activity linked to specific weather conditions offers the most precise opportunity to analyze variations, yet this data is not often available at local scales requiring more aggregate spatial scale consideration. By understanding contexts that facilitate active transportation at the regional level, policy measures can be directed toward overcoming potential barriers to promoting and increasing walking. While weather cannot be changed to increase levels of walking and physical activity, interventions can be targeted to promote more active healthy lifestyles. Moreover, results from regional analyses can provide insight for consideration of collecting disaggregate survey-based physical activity data with weather condition.

Time use data allows for a specific measure in how people spend their time, and offers the opportunity for regional comparison of these activities. Time use data are used here to build four models that aid in understanding variations in walking and physical activity rates across seasons and climatic regions while controlling for demographic characteristics. Seasonal and regional variation is shown and further study is needed to assess the impacts of more nuanced variations of weather impacts in order to promote active lifestyles.

2. Methods

2.1 American Time Use Survey and Current Population Survey

Introduced in 2003 by the Bureau of Labor and Statistics (BLS), the ATUS collects a 24-hour time diary for approximately 1100 respondents monthly on a rolling basis (total sample of over 12,000 per year) (U.S. Census Bureau, 2013). ATUS Recruitment is based on completion of the Current Population Survey (CPS), allowing linkage of variables for common observations (see Russell et al., 2007). Designed to be representative at the national level based on household characteristics, each household member over 15 years has an equal likelihood of being chosen. ATUS data are collected using a computer-assisted interview (CATI) with a maximum recall period of 24-hours—i.e., respondents are asked to recall activities from 4:00 a.m. on the previous day through 4:00 a.m. on the interview day. Detailed activities are recorded in sequence with start time and duration.

2.2 Climate Data Procedure

Climate regions were coded from the respondent's state of residence listed in the CPS, following regions for the continental US determined by Karl & Koss (1984), which are commonly used by federal agencies including the National Oceanic and Atmospheric Administration (NOAA) and are based on monthly, seasonal, and annual temperature weighted by area. For this study, Washington, D.C. was considered in the Northeast region, Alaska and Hawaii were each unique regions (Figure 1).

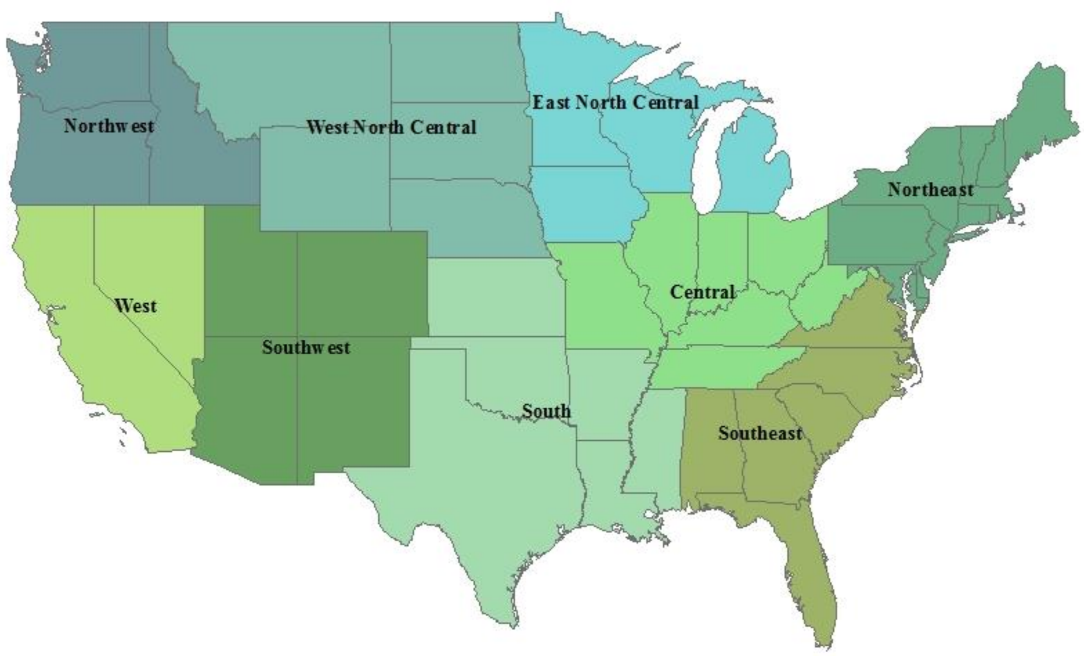

Figure 1. Climate Map of Continental US with Regions Determined by Karl and Koss (1984)

2.3 Data Treatment and Analysis

In this study, ATUS data from 2003 through 2012 offered the ability to observe walking activity by season. Time spent walking and participating in any type of physical activity was totaled for each respondent for a one-day period. Between 8.0% and 9.1% of data was collected during each month, giving the dataset a fairly uniform distribution throughout the year.

Time walking included total time spent in location type “walking,” and in the “sport exercise and recreation” categories of walking and hiking. This did not include standing, limited walking during other activities, or waiting time during transportation, which was distinctly coded.

Three outcome variables were used for this study: 1) whether or not a respondent walked or not during the 24-hour period (binary), 2) whether or not a respondent participated in some form of physical activity (walking or otherwise)(binary), and 3) the number of minutes a respondent walked or participated in related activities during the 24-hour period (continuous). Participation in one or more of the included activities for at least thirty minute caused participants to be flagged in the appropriate binary variable(s) (see Table 1).

Table 1. Composition of Outcome Variables

Walking 30+ Min. (binary) & Min. Walking (continuous)	Other Physical Activities Conducted for 30+ Min. (binary)		
Walking*	Bicycling*	Spelunking	Yoga
Hiking	Running	Caving	Volleyball
	Rollerblading	Dancing	Water sports
	Skiing	Equestrian sports	Weightlifting
	Ice-skating	Fencing	Strength training
	Snowboarding	Football	Other working out
	Playing sports with household children	Gymnastics	Wrestling
	Playing sports with non-household children	Playing hockey	Using cardiovascular equipment
	Sports and exercise as part of job	Martial arts	Other sports
	Aerobics	Racquet sports	Other exercise
	Baseball	Rugby	Other recreation
	Basketball	Soccer	
	Climbing	Softball	

Note: Walking and bicycling compiled from both ATUS location and activity field. All others come from the activity field only.

Socioeconomic predictor variables from the ATUS and CPS were linked using a common individual ID. Year and month of interview were extracted from the ATUS. Predictor variables from the CPS (see Table 2) were only considered if the level of missing observations did not reduce the overall sample by more than 10%. ATUS response month was binned into four seasons (spring denoting March through May, summer as June through August, fall as September through November, and winter as December through February).

Table 2. CPS Variables Considered in Models

Variable Name	Transformations and Notes
Day of week	Recoded as binary weekday/weekend
Holiday	As is, binary (yes/no)
Metropolitan status (1990 and 2000 definitions)	1990 & 2000 status combined as binary variable (metropolitan/other)
Family Income	Response rate too small to use
Type of housing unit	Recoded as series of (yes/no) binary variables: house/apartment, hotel, rooming house, mobile home/trailer, tent/trailer site, student quarters/dorm, and other
Total household members	As is (continuous)
Sex	Recoded as binary variable (male/female)
Race	Aggregated and recoded as binary variables (white only, black only, Asian only, Native American or Pacific Islander only, and more than one race)
Age	As is (continuous)
Birth country	Aggregated, recoded as binary (born in the US/born elsewhere)
Highest level of school or highest degree completed	Recoded as binary variables (did not complete high school, high school, college, advanced degree)
Number of own children < 18 years of age	Response rate too small to use
Married, widowed, divorced, separated, or never married	Recoded as binary variables (married/not married)
Spanish, Hispanic, or Latino	Recoded as binary variable (yes/no)
Does anyone in household have a business/farm?	Recoded as binary variable (yes/no)
Full time or part time work status	Recoded as binary variables (full-time, part-time, and unemployed/out of labor force)

3. Results

3.1 Descriptive Statistics

Time spent walking ranged from 0 minutes to 957 minutes, with a mean of 5.93 minutes. This mean is skewed toward zero, as 114,821 respondents (83.8% of the total) reported walking zero minutes during the 24-hour study period. 25% of ATUS participants reported some form of active transportation or recreation during the study period as shown in Table 3, which includes large variation between individuals.

Table 3. Percent of Respondents Reporting Participation in Active Transportation and Recreational Activities

Activity Category	Mean Number of Minutes	Standard Deviation	Percentage of Individuals with ≥30 Min.
Walking	5.92	22.48	7.7%
Other Physical Activity	10.07	37.92	10.3%
Total (all physical activity)	15.99	44.39	17.0%

Note: The percentage of observations for all physical activity does not equal the sum of the percentage that walked and those that participated in other physical activities because some participants were active in both categories.

The observations from each climatic region varied by relative population. Alaska and Hawaii had the smallest samples, each making up 0.3% of observations, while the Northeast region had the largest sample, with 18.2% of observations. The mean age of all ATUS respondents was 46 years old and the mean number of activities per person over the 24-hour study period was 20. The mean number of household members was 2.77. The mean time spent walking was low (ranging from 4.2 minutes in the Central region to 8.9 minutes in the West), largely because so few respondents reported walking at all (see Table 4). Percentages of those that walked at least thirty minutes within the subset of physically active respondents (at least thirty minutes) ranged from 39.1% in the West North Central region to 52.9% in the Northeast region.

Table 4. Walking and Physical Activity Rates by Climate Region

Region	% Walk ≥30 min.	% Any Physical Activity ≥30 min	Mean Time Spent Walking	% Walk ≥30 min. among Physically Active
Central	5.6%	14.0%	4.16	40.2%
East North Central	6.7%	16.3%	4.95	40.8%
Northeast	10.5%	19.8%	8.19	52.9%
Northwest	8.6%	19.0%	7.04	45.1%
South	5.5%	13.4%	4.17	41.0%
Southeast	6.3%	15.3%	4.70	40.9%
Southwest	7.7%	19.1%	6.31	40.1%
West	11.2%	22.5%	8.90	49.7%
West North Central	6.3%	16.1%	4.72	39.1%
Alaska	7.6%	18.8%	5.77	40.3%
Hawaii	7.5%	18.6%	7.00	40.4%
National (all regions)	7.7%	17.0%	5.92	45.0%

3.2 Models Estimating Predictors of Walking Behavior

Four models show the estimated effects of demographic, active transportation, region, season, and interacting independent variables on the dependent variables. These models estimated instances of walking at least thirty minutes among all observations (Model 1), at least thirty minutes of active recreation among all observations (Model 2), whether the subset of individuals who reported thirty or more minutes of active transportation or recreation during the day walked at least thirty minutes (Model 3), and the minutes walked among individuals that were active for at least thirty minutes, transformed with a natural log plus one (Model 4).

Binary logistic regression was used for Models 1, 2, and 3, as the minutes of participation in the studied activities were non-normally distributed. Models were fit to only contain significant independent variables and interactions. After initial model fitting, variables were removed if they had an odds ratio ranging from 0.95 to 1.05, as they were deemed to have too small of an effect to consider. Models were then re-estimated until all included variables were significant at the 95% confidence level and had an effect of more than a 5% deviation from the mean as indicated by odds ratios. Binary predictor variables for whether a respondent bicycled or used other active transportation forms during the 24-hour data-collection period were only considered in Model 1 and not used as predictors in other models because they were either included in the independent variable for the model (in Model 2), or artificially inflated the goodness of fit due to collinearity with the outcome variable (in Models 3 and 4).

General linear modeling (GLM) was used to model the minutes walked among active individuals, which was transformed with a natural log plus one (Model 4). This transformation made the data more normally distributed, but was not considered statistically normal at the 95% confidence level. Because of this, and so that interaction effects of select independent variables could be considered along with individual effects, GLM was used for this model.

Exploratory data analysis was conducted before modeling the data, using Chi-square testing for variable interactions, with significance assessed through Bonferroni-adjusted p-values. Relevant interactions of socioeconomic variables were included in the final models. ANOVA testing revealed that differences in the mean number of minutes spent bicycling, walking, doing other active transportation, and participating in other active lifestyle activities were present between seasons and climatic regions at the 99% confidence level. Chi-square testing shows significant interactions between walking and climate region, housing type and tenure, marital status, sex, race, education level, citizenship status, employment status, metropolitan or non-metropolitan residence, season, whether the time-use survey was conducted on a weekend versus weekday, and whether the respondent also participated in another active lifestyle or transportation activity. Low sample size in one or more regions prevented the inclusion of other variables including number of children and income level in these models. Interactions explored in the four final models included: sex and age, sex and season, sex and region, sex and race, age and season, age and region, and age and race. Goodness of fit results are presented in Table 5 and indicate the variables while significant do not account for a large portion of the variability.

Table 5. Goodness of Fit and Number of Observations for Binary Logistic Regression and GLM

	Walking at least 30 min. (all observations)	Active for at least 30 min. (all observations)	Walking at least 30 min. (subset of participants active for at least 30 min.)	ln (min. walking +1) (subset of participants active for at least 30 min.) (GLM)
Model N	136,118	135,991	34,034	34,034
Pseudo/Adjusted R^2	0.052	0.052	0.100	0.083

Note: Pseudo-R^2 is reported as a goodness of fit measure for binary logistic regression models (walking among all observations, any active recreation or transportation among all observations, and walking among active individuals). Adjusted R^2 is reported for the GLM model for the natural log plus one of minutes walking among active individuals.

3.3 Model Results

All four models showed effects from both seasonal and regional variables. Variables that were significant across all four final models were working part-time, being unemployed or out of the labor force, having no high school diploma, having a high school diploma (as the highest level of education), being married, renting a home, not owning or paying rent for a home, and having been born in the US (see Table 6). Of these variables, working part-time, being unemployed, renting a home, and not owning or paying rent for a home all have positive effects on walking and physical activity rates in all four models. These positive effects were expected, as these demographics tend to be correlated with lower incomes. Previous literature indicates that the working poor in the US tend to have much higher rates of commuting by walking and bicycling than other workers (Roberto, 2008). Conversely, being born in the US has negative impacts on walking and physical activity rates in all four models, which also follows expected patterns, as immigrants tend to have lower rates of vehicle ownership than those that are US-born (U.S. Federal Highway Administration, 2010). Having no high school diploma and having a high school diploma as the highest education level had negative effects in Models 1 and 2 and positive effects in Models 3 and 4, suggesting that less education lowers the propensity to walk overall, but raises this rate among those that are active. This does not follow expected trends, assuming that educational attainment is positively correlated with income level. Negative model effects from being married follow lower rates of walking and bicycling to school by children with married parents (Fulton et al., 2005).

Table 6. Final Binary Logistic Regression Models and GLM

		Model 1: Walking (all respondents) [Yes/No]		Model 2: Any Active Recreation (all respondents) [Yes/No]		Model 3: Walking (active respondents) [Yes/No]		Model 4: ln(min. walking) (active respondents)	
	Variable	**Sign**	**Odds Ratio**	**Sign**	**Odds Ratio**	**Sign**	**Odds Ratio**	**Sign**	**Coefficient**
Demographics	Working part-time	+	1.30	+	1.21	+	1.22	+	0.20
	Unemployed	+	1.47	+	1.28	+	1.44	+	0.40
	No high school diploma	-	0.68	-	0.64	+	1.19	+	0.09
	High school diploma	-	0.57	-	0.46	+	1.28	+	0.12
	College degree	-	0.74	-	0.69				
	White			-	0.92				
	Spanish/Hispanic/Latino	-	0.92			-	0.83	-	-0.20
	Black	+	1.25			+	1.43	+	0.30
	Owning business			-	0.92	+	1.10	+	0.12
	Married	-	0.84	-	0.81	+	1.20	+	0.18
	Female			-	0.79	+	1.49	+	0.34
	Housing unit hotel	+	2.15						
	Housing unit rooming house							+	1.04
	Housing unit house/apartment			-	0.54	-	0.68		
	Mobile home/trailer			-	0.43				
	Housing not rented or owned	+	1.55	+	1.16	+	2.17	+	0.41
	Housing rented	+	1.57	+	1.26	+	1.83	+	0.43
	Born in US	-	0.79	-	0.90	-	0.71	-	-0.40
	Metropolitan	+	1.13	+	1.24	-	0.87		
	Number of household members					-	0.89	-	-0.12
	Biked any minutes*	+	1.52						
Time	Weekday	+	1.27	+	1.31			-	-0.06
	Holiday	-	0.83	-	0.83				
Region	Central Region	-	0.69	-	0.69	-	0.85		
	East North Central Region	-	0.77	-	0.78	-	0.87		
	Northeast Region	+	1.12			+	1.39	+	0.48
	South Region	-	0.61	-	0.63	-	0.76		
	Southeast Region	-	0.71	-	0.73	-	0.82		
	Southwest Region	-	0.80	-	0.86	-	0.80		
	West North Central Region	-	0.80	-	0.85	-	0.82		
	Northwest			-	0.93				
Season	Fall			-	0.93				
	Summer			+	1.13	-	0.82	-	-0.13
	Winter	-	0.83	-	0.81				
Interactions	Female and white			+	1.14				
	Female and black	-	0.77	-	0.77	+	1.32		
	Female and Native American/Pacific Islander					+	1.63		
	Female and fall					+	1.10		
	Female and winter	-	0.94			-	0.83	-	-0.12
	Female and Central							-	-0.13
	Female and East North Central							-	-0.07
	Female and Northeast					-	0.84	-	-0.21
	Female and Southeast							-	-0.14
	Female and Southwest							-	-0.09
	Female and South							-	-0.17
	Constant	-	0.30			+	1.34	+	1.95

*Note: The independent variable for bicycling was only included in the model for walking among all observations (see Data section for further explanation).

The largest odds ratios were seen for uncommon factors such as living in a hotel, not renting or owning living quarters (among active participants), and being a female Native American or Pacific Islander. This type of pattern indicates that these factors, while not common among respondents (or the US population), may have major impacts on the active transportation and recreation habits of these minority groups.

Model 1 showed positive effects from living in the Northeast on instances of walking among all observations. Negative effects were seen from living in the Central, East North Central, South, Southeast, Southwest, and West North Central regions, as well as from winter and interactions between being female and winter. The influence from significant regional variables was largest in the South and Central regions. Winter (compared with spring) had a larger effect (odds ratio of 0.83) than the interaction between being female and winter (odds ratio of 0.93). Negative effects from winter were expected from previous literature, as weather conditions associated with this season have been shown to negatively impact walking and other forms of active transportation and recreation (Flynn et al., 2012; McMillan et al., 2006). The regional variation seen in this model (warmer and drier regions having negative effects, and the colder Northeast having a positive effect) was not expected from previous weather-related literature. This variation may be explained through cultural variability that could not be controlled for in this model.

Model 2 showed the same negative effects from region on any active recreation among all observations, with the addition of living in the Northwest as having a negative effect. No regions had a positive effect in this model. Fall and winter (compared with spring) both had negative effects, while summer had a positive effect. Negative effects were strongest in the South and Central regions. The strongest seasonal effects were winter. Seasonal variations occurred as expected from previous studies, as was the case in Model 1. Decreased physical activity in the identified regions did not seem to follow previous studies based on climate. No seasonal or climatic interactions were significant.

Model 3 showed the same effects of non-interacting regional variables as Model 1 on whether the subset of individuals who reported active transportation or recreation during the day walked. Summer (compared with spring) is the only significant seasonal parameter in this model, which has a somewhat unexpected negative effect. Interactions between being female and the fall season have a positive impact. Interactions between being female and winter, as well as being female and living in the Northeast, have significant negative impacts. The greatest effects from regional variables in this model were from the South and the Northeast. Significant seasonal and interacting variables had less than a 20% influence (odds ratios within 0.20 of 1). Negative effects of summer are less surprising in this model than they would be in Models 1 and 2 because Model 3 looks at the subset of active respondents. This suggests that activities other than walking may be more popular in the summer, which could be linked to weather. Significant interactions between being female with season and climate suggest gendered differences related specifically to changing conditions over space and (cyclical) time. Whether these interactions can be attributed to weather-related factors would need further research, as previous studies have found both a presence of gendered differences related to temperatures (Bergström & Magnusson, 2003; Saneinejad et al., 2012) and a lack of such differences in treatment and adaptation to inclement conditions (Sears et al., 2012; Spencer et al., 2013). Once again, regional variations do not follow expected climatic patterns.

Model 4 showed positive effects on the minutes walked among active individuals (transformed with a natural log plus one) from living in the Northeast. Interactions between being female and living in the Central, East North Central, Northeast South, Southeast, or Southwest region were negative, as was the interaction between being female and the winter season. The Northeast had a coefficient of 0.48, and the largest interaction coefficient resulted from being female and living in the Northeast. The interaction between being female and winter do not follow previous findings from a study in Maryland that found no significant difference in walking rates by gender due to extreme weather conditions (Clifton & Livi, 2005), but this does not rule out the possibility of nationwide differences. Summer (compared with spring) was the only significant non-interacting seasonal variable in this model, which had a negative effect. The negative effect of summer can be interpreted using similar logic to Model 3, in that those that are physically active seem to choose active recreation and transportation modes other than walking during the summer, or that it is too hot for recreational walking.

4. Discussion

Overall, individuals in the ATUS dataset reported very little walking and participation in physical activity. Three models showed negative effects for certain regions, while three models also indicated positive effects from living in the Northeast region. This division suggests that culture may play a role in the prevalence of active lifestyles more than seasonal or climatic variation. However, climate cannot be discounted as an influence on these active transportation and recreation rates.

Season also shows significant variation throughout the models. In two models, which include all observations (walkers and non-walkers), winter is seen to have a negative effect. Summer, while showing a positive effect on physical activity among all observations, shows a negative impact in two models which only predict whether active respondents have undertaken walking or other activities. While this may seem counter-intuitive, this may be related to increased prevalence and ease of other forms of physical activity during summer months, rather than an aversion to walking during this time. This is further demonstrated in Figure 3, as the number of minutes walked among active participants does not vary greatly by season.

4.1 Study Strengths and Limitations

ATUS data lends particular strength in its sample size, however, the explicit instances of walking used in our study are limited by the coding of the ATUS, which cannot always account for multitasking, despite listing primary and secondary activities (see Tudor-Locke & Ham (2008) for further discussion). Additionally, ATUS and CPS surveys do not inquire into land use or transit characteristics for respondents' areas of residence and work. Thus, these characteristics could not be included in our analysis, despite being known factors affecting active transportation rates (Saelens et al., 2003).

To better capture the influence of weather on walking and physical activities, more refined climatic regions are needed. If more disaggregate survey data, such that local home locations at the zip code or Census Block Group level were available with an exact survey date, local weather could be linked to allow analysis of specific influences of weather conditions across the US. Climate influences could also benefit from the addition of information on weather during the survey data days, as well as multi-day surveys including weather variation. Regional averages of precipitation and seasonal weather could also be included in follow-up models in place of seasonal indicators.

5. Conclusion

The predictable seasonal patterns found in this study, paired with the counter-intuitive findings on climate region, indicate that weather and climate may affect walking rates. Regional variations in walking and physical activity rates show that other factors such as culture and built environment play a role in walking rates. Regionally specific interventions to raise walking and physical activity rates may be needed in order to overcome seasonal barriers.

Analyzing walking behavior between climatic regions offers one explanation of how respondents' context and surroundings impact their daily activities. With this information, researchers can focus further on the identification and isolation of cultural variables, providing further understanding of influences raised in this study, including gender interactions with season and region. Results of the study suggest merit to the idea of adding climate and regional location measures to future activity data sources either through dedicated surveys or by finding a means to release geographic information within existing datasets while still protecting the identity of the participants.

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