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Short Communication

Weather is not significantly correlated with destination-specific transport-related physical activity among adults: A large-scale temporally matched analysis

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ABSTRACT

Weather is an element of the natural environment that could have a significant effect on physical activity. Existing research, however, indicates only modest correlations between measures of weather and physical activity. This prior work has been limited by a failure to use time-matched weather and physical activity data, or has not adequately examined the different domains of physical activity (transport, leisure, occupational, etc.). Our objective was to identify the correlation between weather variables and destination-specific transport-related physical activity in adults. Data were sourced from the California Household Travel Survey, collected in 2012–3. Weather variables included: relative humidity, temperature, wind speed, and precipitation. Transport-related physical activity (walking) was sourced from participant-recorded travel diaries. Three-part hurdle models were used to analyze the data. Results indicate statistically or substantively insignificant correlations between the weather variables and transport-related physical activity for all destination types. These results provide the strongest evidence to date that transport-related physical activity may occur relatively independently of weather conditions. The knowledge that weather conditions do not seem to be a significant barrier to this domain of activity may potentially expand the universe of geographic locations that are amenable to environmental and programmatic interventions to increase transport-related walking.

1. Introduction

Researchers have recently focused on the potential effects of weather and climate on physical activity. Among prior studies with adults, precipitation has generally shown a negative correlation with physical activity, while temperature is positively correlated (Wolff & Fitzhugh, 2011; Sumukadas et al., 2009; Witham et al., 2014; Merrill et al., 2005; Klenk et al., 2012; Togo et al., 2005; Chan et al., 2006). The association of physical activity with other variables, such as wind speed, relative humidity, day length and hours of sunshine, is less consistent.(Wolff & Fitzhugh, 2011; Sumukadas et al., 2009; Witham et al., 2014; Klenk et al., 2012; Togo et al., 2005)

Two major limitations characterize most of this existing research. First, authors have not examined domain-specific physical activity, i.e. recreational/leisure, occupational, household, and transportation-related activity (Pettee Gabriel et al., 2012). Instead, many have examined only total activity from all sources. Second, there has been virtually no consideration of the fact that in terms of how weather affects transport-related physical activity, the particular destination an individual is traveling to may provide important contextual information. For example, active travel to transit (e.g. bus, subway) may be relatively weather-independent, especially if the purpose is to get to work or school, whereas active travel to leisure or entertainment destinations may be highly dependent on weather conditions. Consistent with the notion that weather may differentially affect active travel depending on destination, Goodman et al. referred to the possible "weather-resistance" of active commuting to school among children.(Goodman et al., 2012)

To provide a more thorough examination of this topic, we conducted a novel analysis of the association between weather and active travel, separated by destination type, in adults using travel diary data from the California Household Travel Survey (CHTS) and temporally matched weather data.

2. Methods

2.1. Data sources

Physical activity data was derived from the CHTS (Nustats, 2013). This survey was conducted from February 2012 to January 2013 with

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data collection occurring every day with no exceptions for this period, and enrolled over 42,000 households across California. Households were selected to participate using a geographically stratified address based sampling frame. All individuals within a recruited household were asked to complete an individual-level questionnaire and a one-day travel diary. Participants were asked to carry their travel diary with them on the assigned day and record their activities in real time. Surveys and travel diaries were retrieved via phone interview, online entry, or mail. If discrepancies or incomplete data were found, participants were re-contacted to complete or clarify their responses. One person per household also completed a household-level questionnaire. For this analysis, only data from adults 18 years of age and older are used. The complete CHTS dataset was downloaded from the Transportation Secure Data Center maintained by the National Renewable Energy Laboratory in September 2014. More details on the survey sampling plan and methodology of the CHTS are available elsewhere (Nustats, 2013).

Weather data were downloaded from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information Climate Data Online website (National Centers for Environmental Information, n.d.). Weather variables were recorded hourly at weather-reporting sites across California, most of which were located at airports, including commercial airports, general aviation facilities and military airfields. All hours for all days from February 2012 through January 2013 were downloaded. To match weather data to the CHTS file, zip code centroids of participating households were geocoded; zip codes are the most granular geographic identifiers provided with the public CHTS dataset. Using a nearest-neighbor matching procedure, the closest weather-reporting site using a crow-fly (Euclidian) distance was matched to each zip code. On the basis of this match, the weather data was merged into the CHTS file, while ensuring that the weather from the appropriate station was from the same day as the household completed the travel diary. Households for which the nearest matched weather station was in excess of 20 miles away were dropped on the assumption that this was not an accurate depiction of the weather they were subjected to on their reporting day. This resulted in a loss of 7.7% of the sample.

2.2. Variables

Our primary outcome of interest is time spent in active travel to seven different destination types (transit, shopping/errands, food/eating, social, work, school, and other personal reasons), computed by summing the recorded trip duration in minutes for all walk trips to a given destination type in the CHTS dataset. Trip duration was calculated by the survey research firm on the basis of the start and stop times of each trip recorded by participants in their travel diary.

The primary independent variables of interest were daily measures of mean hourly temperature (degrees Fahrenheit), relative humidity (%), wind speed (miles per hour) and total daily precipitation (inches; includes snow and rain). Variables entered as controls on the basis of their known associations with travel behavior and physical activity included household income, assessed via 10 categorical response options; number of individuals in the household; number of household vehicles; residence type (e.g. single family detached, small apartment building, large apartment building, etc.); month and day of week the household participated; age; sex; education level (coded in six categories); driver's license status; homeowner or renter; employed or not; disabled or not; foreign or U.S. born; and Hispanic or not. Total distance traveled in miles on the recorded day was used to account for the correlation between distance to destinations and travel behavior/mode selection.

2.3. Analysis

Time spent in in active travel to a destination can be thought of as the result of a multi-stage process. First, an individual must decide to travel to a destination, for example, a grocery store. If they decide to travel to the grocery store, they must then decide what mode to use. If they choose an active mode, time spent in active travel will depend on many factors, such as distance traveled and how fast an individual walks. In the econometric literature, these models are often referred to as "hurdle" models, meaning that an individual must pass a hurdle to possibly have a positive realization at the next step (Burke et al., 2015). Consistent with the conceptual model, we use a three part model in our analyses. The first is a probit model, with the dependent variable being whether someone goes to a particular destination or not. The second is also a probit model, with the dependent variable being whether someone uses an active mode (walking) or not to get to a particular destination, among those who go to the destination in the first place. The third part is a gamma regression model, with the dependent variable being minutes spent in active travel among those who actively travel to a particular destination. Models were estimated separately for each of the seven destination types.

Interpretation of the correlation between independent variables and the primary outcome of interest, minutes spent in active travel, requires a simultaneous consideration of all three model results. This is accomplished by "stacking" the estimates from all three models to compute marginal effects. All models include cluster robust standard errors to account for the fact that more than one individual per household could participate. Analyses were conducted in Stata V13.1 (StataCorp, LP, College Station, TX). Replication code is available at github.com/durandca

3. Results

Included in this analysis were 65,905 individuals. Survey-weighted participant characteristics are noted in Table 1. Average marginal effects for the destination-specific analyses of weather and transport-related physical activity are presented in Table 2. These estimates are interpreted in the usual way: the expected change in the dependent variable, on average, per unit change in the independent variable. Examining these estimates, it is clear that in general, the weather variables are not strongly correlated with time spent in transportation-related walking. Of the statistically significant correlations, the strongest appears to be the one between precipitation and walking to school, such that for each 1 in. increase in precipitation during the day the participant was recording their travel, total minutes spent walking to school decreased by 0.06 min, on average. Even extrapolating this result to an extreme rain event of 10 in. during the travel day, this would imply that time spent walking only decreases by just over half a minute, on average. Other marginal effects were similarly weak and/or non-significant.

4. Conclusions

This analysis represents, to our knowledge, the largest, most comprehensive assessment of the association between weather and transport-related physical activity in adults to date. Our results indicate that weather is only weakly correlated with walking to specific destinations. Contrary to the possibility we noted in the introduction that transport-related physical activity to some destinations may be more weather-resistant than to others, the correlations between transport-related physical activity and the four weather variables largely did not vary across destination types; all the marginal effects were either substantively or statistically insignificant. In this respect, the results are consistent with the literature indicating no association between weather and active travel to school by children (Helbich et al., 2016; Oliver et al., 2014; Mitra & Faulkner, 2012). The fact that we found similar results among adults to a wide variety of destinations suggests that weather simply is not an especially salient feature in terms of transport-related physical activity.

Perhaps the greatest value in analyses of weather and physical activity is in understanding if weather represents a "gatekeeping" characteristic, in the sense that unless meteorological conditions are favorable, an