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Correlates of Walking for Transportation or Recreation Purposes

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Background: Walking is a popular recreational activity and a feasible travel mode. Associations exist between walking and the built environment, but knowledge is lacking about specific environmental conditions associated with different purposes of walking. *Methods:* This cross-sectional study used a survey of 438 adults and objective environmental measures. Multinomial logit models estimated the odds of walking for recreation or transportation purposes. *Results:* Utilitarian destinations were positively associated with transportation walking, but recreational destinations were not associated with any walking. Residential density was correlated with both purposes of walking, and sidewalks with recreation walking only. Hills were positively associated with recreation walking and negatively with transportation walking. *Conclusions:* Physical environment contributed significantly to explain the probability of walking. However, different attributes of environment were related to transportation versus recreation walking, suggesting the need for multiple and targeted interventions to effectively support walking.

Key Words: physical activity, environment

Walking has become an important subject in the fields of public health, transportation, and urban planning, because it is a popular physical activity[1-5] and a feasible travel option.[3, 6, 7] Past research shows that most walking occurs in neighborhood streets and other outdoor public spaces.[4, 5, 8, 9] The urban and transportation planning literature shows land use and transportation infrastructure conditions are associated with trip frequency, amount of driving, and transportation mode choice.[10] Literature from the public health field reports that access to recreational facilities, aesthetics, and safety of environments, are correlated with overall or recreational walking.[11, 12] A few recent studies have started examining the effect of the environment on different purposes of physical activity and walking.[13-15] Troped and colleagues found that after controlling for age and self-efficacy, perceived environmental variables were significantly associated with transportation-related physical activity, but not with recreational physical activity.[15] Another study showed perceived environmental attributes to be associated with different purposes of walking and with gender.[14] Still, knowledge is largely lacking about specific and objective environmental measures associated with particular purposes of walking and physical activity.

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The objective of this paper is to examine how recreation versus transportation walking is associated similarly or differently with specific environmental and socio-demographic variables, with a particular focus on objectively measured physical environmental variables. Recreation walking in this paper refers to walking for recreation or exercise.

Conceptual Frameworks

This research is based on a multi- or trans-disciplinary approach to active living research,[11, 16] to ensure all correlates of walking are considered comprehensively. The selection of variables is based on a comprehensive review of past research and theoretical frameworks in the fields of public health, transportation planning, and urban design and planning.[11, 17]

The social ecological model helps understand the multiple influences on behavior. Its emphasis on the dynamic interplay between personal, behavioral, and environmental factors provides a theoretical basis for this research.[18, 19] However, this model does not provide sufficient guidance toward conceptualizing physical environmental attributes. Physical environmental factors relevant to physical activity are numerous and subject to complex interactions, and require an additional theoretical framework.[20] The Behavioral Model of Environment or BME is used in this research.[11, 17] It identifies the generic parts of environments affecting outdoor physical activity, specifically walking and biking: Origins (O) and Destinations (D), Routes (R), and Areas (A). The Destination component is further subdivided into Transportation-related and Recreation-related Destinations for this study, TD and RD respectively.

Methods

Sampling

This cross-sectional study was based on a recently developed sampling method utilizing publicly available parcel-level geographic information systems (GIS) data. This strategy, called spatial sampling,[21] used parcels or lots as sampling units to select samples based on the geographic locations and the built environmental characteristics of areas around residences. It allowed for testing the environmental characteristics of the sample frame before drawing the samples to ensure proper variations and distributions of the key environmental variables.[21]

Data Collection

Survey. The socio-demographic data came from a telephone survey conducted as part of the Walkable and Bikable Communities (WBC) project. The survey was administered during the fall of 2002 by a professional survey company, Clearwater Research, using the Computer-Aided Telephone Interview (CATI) system. The instrument was developed using validated questions from existing surveys including the 1998 and 2001 Washington State Questionnaires for the Behavioral Risk Factor Surveillance System (BRFSS), 2000 National Health Interview Survey, Interna-

tional Physical Activity Questionnaire-Long (IPAQ-L), and a survey on physical activity in community developed by Brownson and his colleagues.[22] The instrument was then pilot-tested on 50 random samples drawn from the same sample frame. Interview protocols followed the methods used by the BRFSS, and no incentives were offered for participation. Eligibility criteria were: (a) age 18 y or older, (b) little or no difficulty walking three city blocks, (c) English-speaking, (d) living in the same address as in our database, and (e) living in a household with a telephone. The survey questions were grouped into nine sections including walking, biking, transit use, physical activity, neighborhood perception, attitude toward environment and transportation, household characteristics, demographics, and a short section for those initially refusing to respond. The short section included seven questions asking if they have difficulty in walking (5-point Likert scale), if they walk and bike in a usual week, if they own a bike, and basic demographic information including age, race and income ranges.

Advance letters on the University of Washington letterhead were sent to 3500 potential respondents one to several weeks prior to the phone contact. Full contact information was provided, and those who did not wish to participate could opt out by calling, e-mailing, or sending a letter. Over 31% (1098 households) of the 3500 were not contactable. Another 19.7% (688) were excluded because they did not meet the eligibility criteria. Response rate was estimated to be 31.54% and the cooperation rate was 34.32%.[23] Survey respondents were compared with those who initially refused to participate but completed the short section and with the BRFSS respondents, revealing no serious non-response bias.[24]

The final samples used for this study were a subset from the survey, consisting of 438 respondents living in the City of Seattle. The respondents were predominantly white (90%), with 54% female, and 16% age 65 y or more. About 43% were married, and 77% had no children under 18 y. About 76% were employed for wages or self-employed, and 54% had an annual household income of $50,000 or more. The majority reported very good or excellent health status. The mean body-mass index (BMI) was 25.2, and 195 (44.6%) had a BMI above 25, 41 (9.4%) of whom were considered obese (BMI above 30).

GIS Measures. Environmental variables captured fine-grained and disaggregated measures of individual respondents' residential environment, including distance to individual and agglomerations of destinations (e.g. grocery stores, restaurants, banks, post offices, retail stores, parks, trails, liquor stores, community gardens, gyms/fitness centers, etc.), intensity of land uses, pedestrian and other transportation infrastructure conditions (e.g., sidewalks, bike lanes, traffic volume, bus ridership, street trees, etc.), and topography. The raw data came from the county's parcel-level and building-level assessor's data, park layer, METRO bus ridership data, and the Puget Sound Regional Council's regional transportation network data (including trails).

Variables

Survey Variables. Survey variables were grouped into five classes (Table 1). The first four classes including Demographics, Behavior, Household Characteristics, and Attitude, captured various personal dimensions of the social ecological model,

Table 1 Survey Variables: Socio-demographic and Perceived Environmental Variables

Class	Name	Definition	Measurement and number of respondents for each category
Demographics	age	Age	18-24 y: 16, 25-34: 81, 35-44: 86, 45-54: 128, 55-64: 58, 65-74: 38, 75+: 31
	gender	Gender	Male: 202 [reference category], Female: 236
	race	Race	White: 394 [reference category], Non-White: 44
	marital	Marital status	Married or member of an unmarried couple: 225 Divorced, widowed or separated: 99 Never married: 114 [reference category]
Behavior	transit	Use transit	Yes: 166 [reference category], No: 272
	walkout	Walk outside the neighborhood	Yes: 240 [reference category], No: 198
	vmt	Vehicle miles traveled per month (VMT)	0 mile: 31 0.1-200 miles: 51 200.1-400 miles: 34 400.1-600 miles: 54 600.1-800 miles: 107 800.1-1000 miles: 91 1000.1-1500 miles: 44 1500.1+ miles: 26
	tranwalk	Frequency of walking for transportation purposes (only in Recreation Frequency Model)	0 times:124, 1-4 times: 195, 5+times: 119 [reference category]
	recwalk	Frequency of walking for recreation purposes (only in Transportation Frequency Model)	0 times:108, 1-4 times: 223, 5+times: 107 [reference category]
Household characteristics	car	Cars in the household	Fewer than 1 car per adult: 111 1car per adult: 273 More than 1 car per adult: 53 [reference category]
	dog	Dogs in the household	Yes: 223 [reference category], No: 215

Class	Name	Definition	Measurement and number of respondents for each category
Attitude	awareness	Awareness of the importance of physical activity (walking and biking) to keep healthy	<Factor Variable> Min: -8.54642, Max: 1.30636, Mean: 0, SD: 1
	walkbike	Agreement to the need to walk, bike, and use transit more to reduce congestion	<Factor Variable> Min: -4.19864, Max: 1.64859, Mean: 0, SD: 1
	congestion	Awareness of congestion and air problems and need to reduce auto use	<Factor Variable> Min: -5.48150, Max: 2.71268, Mean: 0, SD: 1
Neighborhood perception	neightype	Neighborhood type	Mixed or Commercial: 171 [reference category], Residential: 267
	visual	Interesting architecture to look at	Yes: 223 [reference category], No: 215
	social	People walk, bike, (and know each other) in the neighborhood	<Factor Variable> Min: -3.46617, Max: 1.63031, Mean: 0, SD: 1
	traffic	Neighborhood has traffic problem and air pollution from cars	<Factor Variable> Min: -2.34783, Max: 2.01372, Mean: 0, SD: 1

while the fifth class, Neighborhood Perception, captured the social and perceived environmental dimensions. All Attitude variables and two out of the four Neighborhood Perception variables were latent factor variables. Latent factors are known to capture the psychological dimensions better than the observed variables. Detailed methods used for the factor analysis are described elsewhere.[24]

Five open-ended survey questions were used to compute the dependent variables. These questions asked weekly frequencies of walking: (a) to work, (b) to school, (c) to grocery stores, (d) to other retail or service facilities, and (e) for recreation or exercise. An example of the actual questions is, "How many times during a usual week do you walk to grocery stores?" An introduction instructing the respondent to report walking in his or her home-based neighborhood preceded these questions. Answers from the first four questions were added up to create the frequency of transportation walking variable and the last question became the frequency of recreation walking variable. Income was excluded from this analysis due to its failure to show any statistical significance with the dependent variables and a relatively large number of missing values (46 respondents refused to answer or said don't know). Education, home ownership, property values, car ownership, and Vehicle Miles Traveled (VMT) were tested as potential proxies, and the latter two were selected for their significant bivariate association with the dependent variables.

GIS Variables. Environmental variables from the WBC project, were complemented with a number of additional land use and infrastructure measures for this study (e.g., liquor stores, greenbelts, community gardens, retirement communities, designated urban villages, beaches, sidewalks, street trees, property values, etc.). Environmental variables were measured using a custom-made GIS tool, called WBC Analyst, developed as part of the WBC project. *Buffer measures* included type and intensity of land uses and infrastructure conditions in a 1 km/0.6 mile buffer area around home. The buffer distance of 1 km was determined by the empirical evidence from this and previous surveys on the distance that people can and do walk. Comparisons of a series of matching perceived and objective variables confirmed that people generally perceive areas within 1 km from home to be part of their own neighborhood.[24] Therefore 1 km served as a behavior- and perception-derived limit of neighborhood for this research. The only exception was the bus ridership measure that was taken at a quarter-mile area from home, due to the previous research identifying a quarter mile as a distance threshold for bus uses.[25] *Proximity measures* searched up to 3 km from home, finding distances to 31 individual Destinations* identified based on both data availability and relevance to walking. Also included were 11 types of agglomerations of the Destinations, called Neighborhood Centers or NC. The NCs were spatially delineated by drawing the smallest polygon around all selected Destinations meeting the specifications—at least one of each Key Destinations† within 50 m/164 feet of each other. Street network-based measures were used for all variables included in this research.[26]

The specificity of measurement and lack of theories and previous research resulted in a large number of GIS variables. Both theoretical and empirical approaches were used for variable selection. First, factor and correlation analyses grouped highly correlated ($P > 0.7$) environmental variables together (32 groups total), and second, one variable was selected from each group based on their significance and magnitude of correlation with the dependent variables, and on the ease of measurement and interpretation. Third, the selected environmental variables were prioritized into VIP and Non-VIP variables. The VIP variables were those with strong theoretical support (having a consistent direction of association with walking shown by two or more empirical studies), and they were included in the model regardless of their statistical significance. The Non-VIP variables were those that had some empirical support but not meeting the criteria used for the VIP variables, and included in the model only if they retained statistical significance at the 0.05 level from the backward stepwise modeling process. A total of 13 VIP variables were identified,[2, 14, 15, 27-29] and 19 Non-VIP variables were considered in the stepwise process (Table 2).

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*The 31 Destinations were: grocery stores/markets, fast food restaurants, eating/drinking places, big box retail, banks, churches, neighborhood/community shopping centers, convenience stores, day care centers, fitness centers, medical/dental/hospital, libraries, mixed use, art gallery/museum, offices, post offices, regional shopping centers, retail stores, schools, sports facilities, movie theaters, trails, parks, beach, liquor store, greenbelt, community garden, community center, retirement center, and designated urban village.

†The Key Destinations used for the 11 NCs were: NC1 (grocery/market and retail), NC2 (grocery/market, restaurant and retail), and NC3 (grocery/market and restaurant), NC4 (convenience store, restaurant, and grocery/market), NC5 (office and mixed-use), NC6 (sports facility and school), NC7 (church and school), NC8 (office), NC9 (convenience store, fast food, and grocery/market), NC10 (office, fast food, and hospital), and NC11 (grocery/market, restaurant, retail, convenience store, bank and post office).

Table 2 GIS Variables: Objective Environmental Variables

Priority	Behavioral model of environment *	Variable name	Variable definition (measurement unit)	Mean	Standard deviation
VIP	TD	DistGro	Distance to the closest grocery store (feet)	2337.13 (0.443 mile)	1373.06
	TD	DistRes	Distance to the closest restaurant (log-feet)	7.37 (0.301 mile)	0.80
	RD, R	DistFit	Distance to the closest fitness center (categorical: < 1 mile: 111, 1-2 miles: 204, > 2 miles: 123 [reference category])		
	RD, R	DistPark	Distance to the closest park (feet)	2353 (0.446 mile)	1624.65
	RD	DistTrail	Distance to the closest trail (categorical: 11 = up to 0.25 mile, 12 = 0.25-0.5 mile, 13 = 0.5-0.75 mile, 14 = 0.75-1 mile, 15 = 1-1.5 mile, 16 = 1.5+mile, 17 = no trails within 3 km buffer)	12.03	0.73
	TD, A	Retail	Number of retail stores within 1 km buffer (log-count)	3.00	1.14
	R	Sidewalk	Total length of sidewalks within 1 km buffer (miles)	15.76	6.30
	R	TrafficVol	Mean traffic volume within 1 km buffer (cars)	10961.14	6951.96
	R	StTree	Total number of street trees within 1 km buffer (trees)	1348.58	802.27
	R, A	BlkSize	Mean block size within 1 km buffer (log-square feet)	12.24 (4.75 acres)	0.42
	R, A	BusRider	Total number of bus ridership (ons and offs) in 1 km buffer (log-count)	5.51 (247.15 passengers)	1.81
	A	AreaDen	Area-level density: Mean net residential density within 1 km buffer (log-residential units per square feet)	-7.87 (16.64 units/acre)	0.79
	A	Slope	Mean slope within 1 km buffer (%)	8.45	2.99

(continued)

Table 2 GIS Variables: Objective Environmental Variables *(continued)*

Priority	Behavioral model of environment *	Variable name	Variable definition (measurement unit)	Mean	Standard deviation
Non-VIP**	TD	DistBank	Distance to the closest bank (feet)	3500.01 (0.663 mile)	1872.77
	TD	Dist Daycare	Distance to the closest day care center (categories 11 = < 0.25 miles through 18 = 1.75+miles at a quarter mile increment)	14.53 (1.004 mile)	2.00
	TD	DistOffMix	Distance to the closest office+mixed use neighborhood center (log-feet)	6.92	1.20
	TD	RdirChurch	Ratio between airline and network distances to the closest church (%, airline distance in feet/network distance in feet *100)	76.58	16.30
	TD	RdirOffice	Ratio between airline and network distances to the closest office (categories: 11 = up to 50%, 12 = 51-60%, 13 = 61-70%, 14 = 71-80%, 15 = 81-90%, 16 = 91-99%, 17 = 100%)	14.2	1.78
	TD	DistConv	Distance to the closest convenience store (feet)	3012.36	1883.57
	TD	DistSchool	Distance to the closest school (feet)	2078.07	1158.64
	TD	DistPost	Distance to the closest post office (categories, 11 = up to 1 km/0.625 mile, every half km increments through 16 = 3+km/1.86+mile)	13.01	1.65
	A	ParcelDen	Parcel-level density: Number of residential units in the household parcel (log-residential units per square feet)	-0.17 (0.84 units)	1.135

* A, Area; R, Route; TD, Transportation Destination; RD, Recreational Destination

** Only the statistically significant ($P < 0.05$) Non-VIP variables from the Final Models are included in this table

Statistical Methods

Two types of models were estimated, Purpose Model and Frequency Model, based on the nature of the dependent variable. Ordinal categorical variables that had a simple linear relationship with the dependent variable were treated as continuous variables.

Purpose Model. The dependent variable included four categories: (a) *Both-Walker*, those who reported walking for both recreation and transportation purposes at least once in a usual week, (b) *Rec-Walker*, walking for recreation purposes only, (c) *Tran-Walker*, walking for transportation purposes only, and (d) *Non-Walker*, not walking at all (Table 3). A multinomial logit model was used to fit three binary logit models simultaneously, estimating the odds of walking for both purposes, for recreation purposes only, for transportation purposes only, all relative to not walking.

Table 3 Amount and Frequency of Walking by Purpose

	N	Avg. Weekly Min of Walking	Avg. Weekly Freq. of Walking	% Walking Frequently (5+trips/wk)	% Walking Moderately (1-4 trips/wk)
Both-Walkers	252	224	8.6	77%	23%
Rec-Walkers	79	131	3.8	33%	67%
Tran-Walkers	60	40	3.6	30%	70%
Non-Walkers	47	0	0	–	–
TOTAL	438	177	6.8	61%	39%

Frequency Models. Two frequency models were estimated based on the reported number of times that people walk during a usual week, one for transportation, and the other for recreation. Each dependent variable included three ordinal categories: zero times (*Non-Walker*), one to four times (*Moderate Walker*), and five or more times (*Frequent Walker*). The threshold of five times was based on a "regular" level of activity as recommended for maintaining good health.[30] For transportation, out of the 438 respondents, 119 (27.3%) were Frequent Walkers, 195 (44.5%) Moderate Walkers, and 124 (28.3%) Non-Walkers. For recreation, 107 (24.4%) were Frequent Walkers, 223 (50.9%) Moderate Walkers, and 108 (24.7%) Non-Walkers. Ordinal logit models were tested first as a common option when the dependent variables have ordinal categories. However, the results showed that the crucial equal slope assumption was violated.[31,32] A multinomial model was selected for this study since it handles categorical dependent variables without this strict assumption.

Analytical Process

Both Purpose and Frequency Models followed the same modeling process. The *Base Model* was developed first including only the survey variables which included

socio-demographic and perceived environmental variables. To estimate the *Final Models*, all VIP environmental variables were added to the Base Model and the statistical significance of the Non-VIP variables was tested using a backward stepwise process. Only those retaining a statistical significance at the 0.05 level were included in the Final Models. This paper focuses on the Final Model results, and statistically significant associations reported in the following sections are based on the *P*-value of less than 0.05 in the Final Models.

Results

Purpose Model

The pseudo *R*-square values of the overall model ranged up to 0.599 (Nagelkerke), a considerable improvement from 0.449 of the Base Model. To note is that the small odds ratios for several environmental variables shown in tables 5 and 7 are due to the small increments of their measurement units. For the case of several distance variables, the small effect of 100 feet on the dependent variable accumulates into a significant effect when multiple increments are considered.

Socio-Demographic and Perceived Environmental Correlates of Walking. The Both-Walker versus Non-Walker Model (seven variables significant at the 0.05 level) and the Tran-Walker versus Non-Walker Model (nine variables) captured more variations than the Rec-Walker versus Non-Walker Model (six variables) (Table 4). Of the five classes of survey variables, the Behavior class had the strongest and most consistent association with walking. All three variables, transit use (positive), walking outside the neighborhood (positive), and amount of driving (negative), had a statistically significant association with walking in all but the Rec-Walker versus Non-Walker Model. The Attitude class showed a positive association with all purposes of walking. Having a dog (positive) and architectural visual quality (positive) showed significant bivariate associations with walking, but neither showed a significance in the Final Model. The insignificance of race might be due to too few observations for the non-white category (44 respondents).

Objective Environmental Correlates of Walking. Distance to the closest office and mixed use NC (DistOffMix) and area-level residential density (AreaDen) were found significant in all models (Table 5). Parcel-level density showed a positive, and area-based density showed a negative association with the likelihood of walking for both purposes relative to not walking at all. Differences existed in the environmental variables that are significant in recreation versus transportation walking. For example, greater slope and shorter distance to daycare were associated with increased odds of walking for recreation purposes relative to not walking, while none of them were significant for transportation walking. These differences are further illustrated through the variations in the spatial distributions of walkability for transportation versus recreation (Figure 1). These maps confirm that areas highly supportive of recreational walking may not be as supportive of transportation walking, and vice versa. Description of the methods used for the maps can be found elsewhere.[33]

Table 4 Explaining Walking for Multiple Purposes with Socio-Demographic and Perceived Environmental Variables

	Both-Walker (vs. Non-Walker)			Rec-Walker (vs. Non-Walker)			Tran-Walker (vs. Non-Walker)		
		95% CI			95% CI			95% CI	
Variable name	Odds ratio	Lower bound	Upper bound	Odds ratio	Lower bound	Upper bound	Odds ratio	Lower bound	Upper bound
Demographics									
age	0.616**	0.438	0.866	0.929	0.651	1.327	0.574**	0.386	0.853
gender: female [male]	0.608	0.228	1.621	0.989	0.348	2.808	0.257*	0.083	0.793
race: nonwhite [white]	1.820	0.311	10.663	0.417	0.046	3.772	0.794	0.099	6.395
marital: married [never married]	1.607	0.458	5.630	0.596	0.155	2.294	1.919	0.456	8.088
marital: divorced [never married]	3.841	0.762	19.359	5.310*	1.040	27.103	8.153*	1.310	50.749
Behavior									
transit: no [yes]	0.049**	0.008	0.280	0.150*	0.025	0.914	0.057**	0.009	0.360
walkout: no [yes]	0.068**	0.022	0.210	0.171**	0.053	0.555	0.052**	0.015	0.184
vmt	0.705*	0.533	0.931	0.872	0.647	1.174	0.696*	0.510	0.951
Household characteristics									
car: < 1 car [> 1 car]	0.224	0.034	1.490	3.452	0.393	30.328	0.191	0.024	1.503
car: = 1 car [> 1 car]	0.323	0.072	1.447	2.465	0.405	15.009	0.118*	0.023	0.610
dog: no [yes]	0.527	0.158	1.755	0.448	0.131	1.528	1.635	0.357	7.501
Attitude									
awareness	1.505*	1.006	2.251	1.362	0.854	2.170	1.258	0.797	1.986
walkbike	2.084**	1.262	3.440	1.884*	1.109	3.199	2.571**	1.436	4.605
congestion	1.233	0.762	1.994	1.693*	1.002	2.861	1.668	0.939	2.963
Neighborhood perception									
neightype: residential [mixed/commercial]	0.097**	0.024	0.397	0.212*	0.046	0.985	0.144*	0.031	0.681
visual : no [yes]	0.637	0.233	1.743	0.576	0.196	1.690	1.568	0.482	5.095
social	1.478	0.885	2.470	0.732	0.427	1.255	1.207	0.674	2.160
traffic	1.661	0.917	3.007	1.195	0.644	2.217	1.517	0.779	2.951

Note: Reference category shown in brackets; see Table 1 for variable definitions and coding; ** $P < 0.01$, * $P < 0.05$

Table 5 Explaining Walking for Multiple Purposes with Objectively Measured Environmental Variables

	Both-Walker (vs. Non-Walker)			Rec-Walker (vs. Non-Walker)			Tran-Walker (vs. Non-Walker)		
		95% CI			95% CI			95% CI	
Variable name	Odds ratio	Lower bound	Upper bound	Odds ratio	Lower bound	Upper bound	Odds ratio	Lower bound	Upper bound
DistGro: 100 ft increments	0.971	0.932	1.012	0.981	0.941	1.024	0.961	0.915	1.009
DistRes	1.005	0.472	2.140	2.163	0.963	4.858	0.981	0.397	2.423
DistPark: 100 ft increments	1.996	0.967	1.027	0.993	0.961	1.026	1.005	0.971	1.040
DistFit: < 1 mile [> 2 miles]	0.699	0.124	3.939	0.234	0.039	1.392	0.395	0.058	2.705
DistFit: 1-2 miles [> 2 miles]	0.595	0.115	3.080	0.229	0.043	1.212	0.623	0.105	3.704
DistTrail	0.882	0.655	1.187	0.945	0.689	1.297	0.861	0.616	1.204
Retail	1.482	0.668	3.290	1.807	0.785	4.160	1.764	0.668	4.658
Sidewalk	1.119	0.953	1.315	1.049	0.891	1.234	1.049	0.875	1.258
TrafficVol: 1000 cars increments	1.012	0.919	1.113	1.007	0.912	1.111	1.008	0.908	1.119
StTree: 1000 trees increments	0.884	0.226	3.454	1.105	0.271	4.508	1.001	0.999	1.002
BlkSize	2.018	0.214	19.047	0.984	0.093	10.465	6.170	0.532	71.612
BusRider	0.703	0.468	1.057	0.763	0.505	1.152	0.625	0.389	1.004
AreaDen	0.135**	0.036	0.511	0.101*	0.024	0.421	0.186*	0.043	0.798
Slope	1.232	0.997	1.523	1.355**	1.090	1.685	1.134	0.892	1.441
DistBank: 100 ft increments	0.962*	0.931	0.995	0.974	0.939	1.010	0.955*	0.919	0.992
DistDaycare	0.650**	0.484	0.874	0.660**	0.486	0.895	0.954	0.680	1.337
DistOffMix	2.591**	1.463	4.587	2.233*	1.198	4.161	2.503**	1.314	4.768
RdirOffice	1.556**	1.133	2.136	1.560*	1.114	2.184	1.285	0.905	1.825
ParcelDen	2.740*	1.239	6.056	2.187	0.953	5.016	2.443	0.999	5.972

Note: See Table 2 for variable definitions and coding; ** $P < 0.01$, * $P < 0.05$

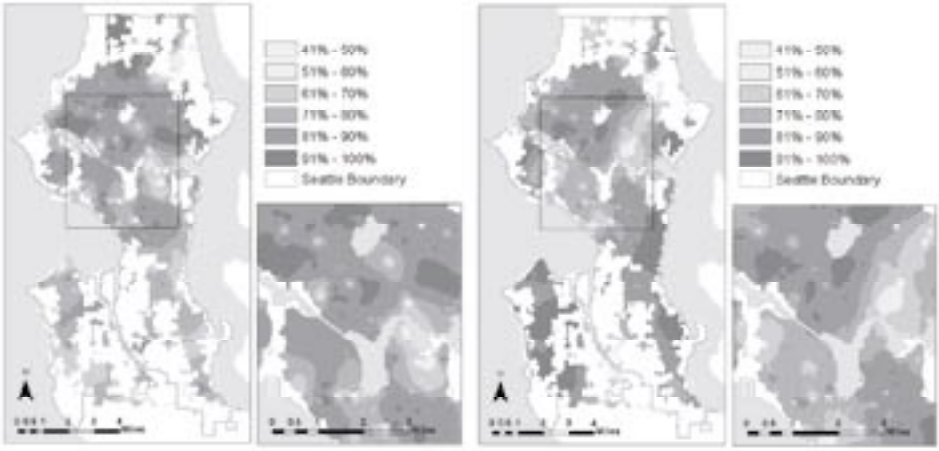

Figure 1—Transportation and Recreation Walkability Map

Note: Transportation Walkability Map is created by interpolating the predicted probabilities of walking for both purposes or recreation purposes only, for an average person. Recreation Walkability Map is created by interpolating the predicted probabilities of walking for both purposes or transportation purposes only, for an average person.

Specifications: Interpolation Method: Radial Basis Function; Kernel Function: Completely Regularized Spline Parameter/Power: 0.08871; Neighborhood Shape Type: Circular (no sectors); Number of sample points: 15; Minimum number of sample points: 10; Maximum neighborhood distance: 51,180 feet; Anisotropy Factor: 1; Output cell size: 10,000 square feet; Number of interpolation points (sample size): 438.

Frequency Models

The Transportation Frequency Model yielded a pseudo *R*-square value of 0.641 (Nagelkerke), a considerable improvement from the Base Model's (0.459). The pseudo *R*-square for the Recreation Frequency Model was much lower at 0.394 (Nagelkerke), which still demonstrated a significant increase from 0.195 of the Base Model. Although careful attention was given to select the independent variables that represent both purposes of walking equally, more variables were found correlated with transportation than with recreation walking.

Socio-Demographic and Perceived Environmental Correlates of Walking. Most socio-demographic variables held strong in explaining how many times people reported walking in a usual week, regardless of the purpose, with an expected direction of association. More variables were found significant for transportation than for recreation walking (Table 6).

Variables related to making more transportation walking trips in the neighborhood included: (a) younger age, (b) male, (c) married (vs. never married), (d) lower VMT, (e) transit user, (f) more cars per adult in the household, (g) walking outside the neighborhood (vs. no walking outside), (h) more walking for recreation purposes, (i) perceived neighborhood as a mix of residential and commercial, or commercial (vs. solely residential), and (j) higher social support. Variables associated with increased odds of walking frequently or moderately for recreation purposes included: (a) female, (b) more walking for transportation purposes, (c)

greater awareness of physical activity benefits and sources (awareness), (d) greater awareness of automobile problem (congestion), (e) having interesting architecture to look at, (f) having one car (vs. more than one car) per adult in the household, and (g) having a dog.

Objective Environmental Correlates of Walking. The differences in the objective environmental correlates of walking between the two models were substantial (Table 7); no single variable was found significant for both purposes of walking and had the same direction of association. Many VIP variables (Table 2) did not hold their statistical significance. For instance, most recreation destinations were found insignificant, even for recreation walking. More Non-VIP variables were related to transportation walking than to recreation walking. An interesting contrast is found for the slope variable, showing an opposite direction of associations with walking for the two different purposes.

Destinations were significantly associated with walking, especially with transportation walking. Five out of the seven variables significant for transportation walking were related to destinations, and two out of four were destination-related for recreation walking. The closer respondents were to a grocery store, a restaurant, a post office, or a bank, the more likely they were to walk for transportation purposes. This means that these destinations are associated with walking-supportive environments, not that people actually walked to them. Higher parcel-level density was positively associated with the odds of walking frequently for transportation, relative to not walking. Neither the parcel-level density nor the area-level density was significant for recreational walking. Route-related variables, such as block size, traffic volume, sidewalk and street trees, did not show a statistically significant association with transportation walking; but longer sidewalks was positively associated with recreation walking.

Discussion and Conclusions

The following nine points synthesize and discuss the results from all Final Models.

1. *Objectively measured environmental variables explained significant amounts of variance in estimating walking, above and beyond socio-demographic and perceived environmental variables.* The objective environmental variables captured up to 20% of the variation in the models, whereas the socio-demographic variables, including perceived environmental variables, captured about 10% to 40% of the variation depending on the model.

2. *Both socio-demographic and physical environmental variables had a stronger association with transportation walking than with recreation walking.* A notable example came from the Frequency Models, showing the fit of the recreation model (Pseudo R-square = 0.394) to be much poorer than that of the transportation model (Pseudo R-square = 0.641), consistent with the findings from the study of Troped et al.[15] However, a point to consider is the nature of dependent variables used in the Frequency Models. Number of walking trips per week may capture transportation walking more effectively than recreational walking. The amount (minutes) of walking variable could be more effective in capturing recreational walking.

Table 6 Explaining Frequencies of Walking for Transportation and Recreation Purposes with Socio-Demographic and Perceived Environmental Variables

	Transportation Walking					
	Moderate Walker vs. Non-Walker			Frequent Walker vs. Non-Walker		
		95% CI			95% CI	
Variable name	Odds ratio	Lower bound	Upper bound	Odds ratio	Lower bound	Upper bound
Demographic						
age	0.656**	0.516	0.832	0.618**	0.454	0.842
gender: female [male]	0.754	0.391	1.454	0.267**	0.115	0.619
race: nonwhite [white]	1.223	0.353	4.245	1.416	0.336	5.963
marital: married [never married]	4.384**	1.817	10.573	1.567	0.553	4.442
marital: divorced [never married]	1.485	0.536	4.113	0.500	0.138	1.815
Behavioral						
vmt	0.750**	0.628	0.895	0.852	0.683	1.063
transit: no [yes]	0.360*	0.165	0.786	0.186**	0.070	0.493
walkout: no [yes]	0.268**	0.141	0.510	0.242**	0.105	0.556
recwalk: 0time [5+times]	0.666	0.259	1.713	0.050**	0.014	0.177
recwalk: 1-4 times [5+times]	1.538	0.678	3.489	0.164**	0.059	0.453
Household characteristics						
car: < 1car [> 1 car]	0.107**	0.027	0.423	0.121*	0.024	0.623
car: = 1 car [> 1 car]	0.133**	0.042	0.423	0.081**	0.020	0.333
dog: no [yes]	1.006	0.472	2.142	1.400	0.492	3.985
Attitude						
awareness	1.032	0.737	1.445	1.026	0.660	1.594
walkbike	1.163	0.842	1.606	1.335	0.877	2.032
congestion	0.835	0.587	1.190	1.378	0.864	2.199
Neighborhood perception						
neightype: residential [mixed/commercial]	0.441*	0.200	0.972	0.380	0.143	1.013
visual : no [yes]	1.372	0.709	2.653	1.632	0.680	3.917
social	1.764**	1.247	2.494	2.652**	1.673	4.203
traffic	1.216	0.854	1.733	1.442	0.907	2.293

Note: See Table 1 for variable definitions and coding; ** $P < 0.01$, * $P < 0.05$

(continued)

Table 6 Explaining Frequencies of Walking for Transportation and Recreation Purposes with Socio-Demographic and Perceived Environmental Variables *(continued)*

	Recreation Walking					
	Moderate Walker vs. Non-Walker			Frequent Walker vs. Non-Walker		
		95% CI			95% CI	
Variable name	**Odds ratio**	**Lower bound**	**Upper bound**	**Odds ratio**	**Lower bound**	**Upper bound**
Demographic						
age	0.931	0.759	1.142	1.216	0.943	1.568
gender: female [male]	2.317**	1.294	4.149	3.352	1.621	6.935
race: nonwhite [white]	1.292	0.492	3.390	1.076	0.319	3.629
marital: married [never married]	0.842	0.411	1.723	0.687	0.279	1.694
marital: divorced [never married]	1.073	0.439	2.626	1.257	0.434	3.640
Behavioral						
vmt	0.971	0.836	1.127	1.076	0.892	1.299
transit: no [yes]	0.742	0.375	1.471	0.657	0.287	1.501
walkout: no [yes]	0.897	0.505	1.593	0.525	0.258	1.069
tranwalk: 0time [5+times]	0.244**	0.092	0.646	0.054**	0.017	0.175
tranwalk: 1-4 times [5+times]	0.574	0.251	1.314	0.105**	0.040	0.277
Household characteristics						
car: < 1car [> 1 car]	1.520	0.576	4.010	0.837	0.252	2.783
car: = 1 car [> 1 car]	2.962*	1.283	6.839	1.789	0.658	4.862
dog: no [yes]	0.547	0.256	1.172	0.218**	0.092	0.515
Attitude						
awareness	1.215	0.935	1.580	1.723**	1.173	2.530
walkbike	0.987	0.747	1.305	1.001	0.712	1.408
congestion	0.925	0.690	1.239	0.695*	0.490	0.984
Neighborhood perception						
neightype: residential [mixed/commercial]	0.660	0.330	1.317	0.698	0.291	1.670
visual : no [yes]	0.452**	0.249	0.822	0.473*	0.225	0.994
social	1.035	0.772	1.389	0.934	0.643	1.356
traffic	1.161	0.848	1.590	1.219	0.825	1.802

Note: See Table 1 for variable definitions and coding; ** $P < 0.01$, * $P < 0.05$

Table 7 Explaining Frequencies of Walking for Transportation and Recreation Purposes with Objectively Measured Environmental Variables

	Transportation Walking					
	Moderate Walker vs. Non-Walker			Frequent Walker vs. Non-Walker		
		95% CI			95% CI	
Variable name	Odds ratio	Lower bound	Upper bound	Odds ratio	Lower bound	Upper bound
BusRider	0.900	0.711	1.139	0.902	0.644	1.263
Sidewalk	1.037	0.945	1.138	0.972	0.856	1.105
StTree: 1000 trees increments	1.192	0.583	2.440	1.155	0.437	3.057
AreaDen	1.018	0.405	2.562	1.584	0.526	4.766
Slope	0.987	0.866	1.125	0.825*	0.688	0.989
BlkSize	2.181	0.432	11.009	2.855	0.346	23.547
TrafficVol: 1000 cars increments	1.015	0.960	1.074	1.021	0.952	1.094
DistGro: 100 feet increments	0.994	0.967	1.023	0.953*	0.916	0.990
Retail	0.743	0.439	1.257	0.629	0.314	1.259
DistRes	0.739	0.423	1.290	0.362**	0.181	0.725
DistPark: 100 feet increments	1.002	0.983	1.021	0.999	0.973	1.024
DistTrail	0.951	0.792	1.142	1.033	0.821	1.299
DistFit: < 1 mile [> 2 miles]	2.190	0.770	6.227	2.771	0.767	10.013
DistFit: 1-2 miles [> 2 miles]	2.150	0.819	5.646	1.766	0.527	5.916
DistDaycare	0.979	0.816	1.175	1.257	0.994	1.589
DistPost	1.152	0.915	1.451	0.704*	0.506	0.979
RdirChurch	1.027**	1.007	1.047	0.994	0.970	1.019
DistBank: 100 feet increments	0.976*	0.955	0.997	0.968*	0.940	0.996
DistConv: 100 feet increments	0.981	0.960	1.003	1.000	0.973	1.028
DistSchool: 100 feet increments	0.987	0.955	1.020	1.031	0.987	1.077
ParcelDen	1.518	0.925	2.494	2.110*	1.147	3.882

Note: See Table 2 for variable definitions and coding; ** $P < 0.01$, *$P < 0.05$

(continued)

Table 7 Explaining Frequencies of Walking for Transportation and Recreation Purposes with Objectively Measured Environmental Variables *(continued)*

	Recreation Walking					
	Moderate Walker vs. Non-Walker			Frequent Walker vs. Non-Walker		
		95% CI			95% CI	
Variable name	Odds ratio	Lower bound	Upper bound	Odds ratio	Lower bound	Upper bound
BusRider	1.084	0.866	1.356	0.953	0.727	1.250
Sidewalk	1.018	0.935	1.109	1.117*	1.001	1.245
StTree: 1000 trees increments	0.819	0.392	1.708	0.449	0.188	1.072
AreaDen	0.571	0.314	1.036	0.751	0.370	1.526
Slope	1.138*	1.011	1.280	1.158*	1.003	1.338
BlkSize	0.749	0.189	2.979	0.487	0.084	2.828
TrafficVol: 1000 cars increments	1.017	0.971	1.065	0.959	0.900	1.021
DistGro: 100 feet increments	1.008	0.985	1.032	1.006	0.977	1.036
Retail	1.017	0.638	1.621	0.843	0.481	1.477
DistRes	1.401	0.896	2.191	1.556	0.892	2.715
DistPark: 100 feet increments	0.994	0.978	1.011	0.992	0.971	1.013
DistTrail	0.988	0.841	1.162	0.905	0.742	1.103
DistFit: < 1 mile [> 2 miles]	0.824	0.336	2.023	0.822	0.263	2.565
DistFit: 1-2 miles [> 2 miles]	0.584	0.259	1.319	1.081	0.383	3.050
DistDaycare	0.704**	0.596	0.832	0.628**	0.509	0.774
DistPost	1.008	0.819	1.240	1.290	0.991	1.679
RdirOffice	1.270**	1.079	1.496	1.264	1.035	1.544

Note: See Table 2 for variable definitions and coding; ** $P < 0.01$, *$P < 0.05$

3. *Significant differences are found for the environmental variables associated with recreation versus transportation walking.* Hills, for example, showed a negative association with transportation walking, and a positive one with the recreation walking in the Frequency Models (Table 7).[34] The Purpose Model further supported the positive role of hills for recreation walking (Table 5). Recreational walkers may like the views and greater exercise opportunities that come with a hilly landform. In contrast, transportation trips are utilitarian activities and therefore even moderate slopes can become barriers. This was a good example of how the same environmental condition can be both a facilitator of and a barrier to walking, depending on the purpose of it. In addition, many environmental variables were found to be significantly associated with only one purpose of walking. For example, architectural visual quality and sidewalks were correlated with recreation walking only, while perceived social environment and distances to the closest grocery store, restaurant, post office and bank were correlated with transportation walking only. The finding on the social environment is similar to the study of Hoehner et al., reporting a positive association between transportation activity and objectively measured count of people engaging in physical activity in the neighborhood.[13]

4. *Utilitarian destinations, compared to recreational ones, showed stronger associations with both purposes of walking.* Park and trail variables did not show a statistical significance in any models, even in the Recreational Frequency Model. This finding was inconsistent with a couple of previous studies involving different populations, which reported their significance in increasing recreational walking among older women[35] and leisure activity among a diverse North Carolina population.[36] Utilitarian destinations emerged consistently as important indicators of a walkable environment.[34-39]

5. *Sidewalks were associated with frequency of recreation walking only.* Transportation walking has more to do with reaching a certain place along the shortest route rather than the quality of the route (e.g., having sidewalks), while recreational walking can be more flexible and people may choose certain routes based on route qualities. This finding suggests the need for collaboration at the interdepartmental level of governmental agencies, because most route-related variables are part of the transportation infrastructure, yet their roles expand to include the objectives of public health agencies.

6. *Differences existed between the objectively measured environmental variables associated with moderate versus frequent levels of walking.* Environmental factors tended to have a stronger contribution in explaining the odds of walking frequently than walking moderately, relative to not walking (Table 5), suggesting that supportive physical environment may be important for promoting health-sufficient levels of walking.

7. *Distance to destination measures were most effective in capturing walkability of neighborhood environment*. Among the different types of measurements considered for the objective environmental variables (e.g., count, size, route directness, distance, length, percent, etc.), "distance to destinations" served as consistently important measures for studying walking. These measures made the strongest contribution to the models. Four (three distance and one route directness variables) out of seven significant objectively measured environmental variables were destination-related in the Purpose Model, and seven (five distance and two

route directness variables) out of ten in the Frequency Models.

8. *Promoting walking for both purposes is more likely to yield health beneficial results.* Walking for both purposes seemed to be strongly associated with an increased likelihood of meeting the recommended level,[30] in both amount and frequency, of physical activity (Table 3). Different purposes of walking may appeal to different people at different times of the day and for different seasons and locations.

9. *Intervention strategies must be tailored to the socio-demographic profile of target communities.* For example, the gender and car ownership variables showed the directions of association change between the two Frequency Models (Table 6). Being a female was associated with increased odds of walking for recreation but with decreased odds of walking for transportation. Also, older age was negatively associated with transportation walking but not associated with recreation walking.

Some of the limitations for this research included its cross-sectional study design and predominantly white population, with over 90% of the respondents being white. Several commonly reported walking destinations such as drug store, cafes, and video stores, could not be included in this study due to lack of available data. While the use of detailed and disaggregated measures of environment is a strength of this research, the issues of spatial dependency among the GIS variables were still not fully addressed. Also, the walking variables came from self-reported measures, and objective measures of walking could have added validity to these variables. Future research is needed involving more detailed classifications of different types and purposes of walking. Differences will likely exist between exercise and recreational walking, and between commuting and shopping/service-related walking. Also needed are considerations of various minority groups along with the underpinning socio-economic and cultural factors, and of diverse geographic locations of communities, including urban, suburban, rural, and inner-city, to better understand the correlates of walking that may be unique to each group or community.

In sum, the strong role of routine daily destinations emphasizes the need for planning policies that encourage locating these land uses within proximate distance to residential areas. The importance of sidewalks for recreational walking, combined with previous research showing neighborhood streets to be the most popular places for physical activity,[4, 8, 11] suggests an expanded role for pedestrian infrastructure to include recreation and exercise venues.

Promoting both transportation and recreation walking will likely bring the highest sustainable results and health benefits. Yet, because environmental conditions may have no impact on, or even hinder one or another purpose of walking, future research and policy on walkable communities require targeted approaches that are tailored toward community-specific needs.

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