

Health Promoting Community Design

Environment and Active Living: The Roles of Health Risk and Economic Factors

Chanam Lee, PhD

Abstract

Purpose. This study examines the associations that a neighborhood's physical and social environments have with transportation and recreation physical activities, with an emphasis on the roles of health risk and economic factors.

Design. It is a cross-sectional study with a hypothesis-testing approach.

Setting. The study was conducted within the city of Seattle, Washington.

Subjects. The subjects included 438 able-bodied, randomly selected adults.

Measures. Physical activity and sociodemographic data came from a telephone survey (34% response rate). Environmental variables were measured subjectively as people's perceptions and objectively using the Geographic Information System. Bivariate analyses and the Structural Equation Model were used to test the overall theoretic framework and the relationships among latent and observed variables.

Results. Lower-income populations lived in areas with more routine destinations and higher densities and were more active for transportation than higher-income populations. People with higher health risks were less active for both transportation and recreation purposes. The social environment—perception of people walking and biking in the neighborhood—was more strongly associated with recreational physical activities, while the physical environment was more strongly associated with transportation physical activities.

Conclusion. Further investigation of different subpopulations and explicit distinction among different purposes of physical activities are needed in future research and interventions. This study is limited to urban areas and cross-sectional data. (*Am J Health Promot* 2007;21[4 Supplement]:293–304.)

Key Words: Motor Activity, Transportation, Recreation, Socioeconomic Factors, Prevention Research. Format: research; Research purpose: modeling/relationship testing; Study design: nonexperimental; Outcome measure: behavioral; Setting: local community; Health focus: fitness/physical activity; Strategy: built environment; Target population age: adults; Target population circumstances: education/income level

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INTRODUCTION

Physical activity is recognized as one of the most efficient and powerful tools for preventing many chronic diseases^{1–6} and for promoting health and well-

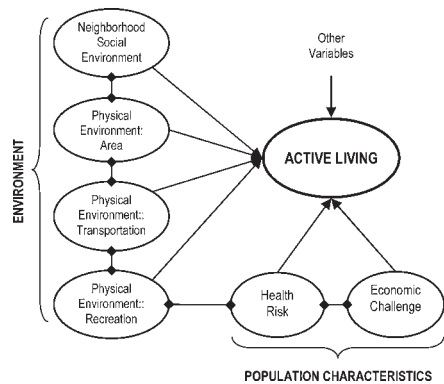
being of the entire population.^{7–10} In addition to personal factors, various social and physical environmental factors are associated with physical activity, including access to recreational facilities and shops, social support, and safety.^{11–18} Community-based environ-

mental approaches to promote physical activity are increasingly popular because of their potential to affect large population segments and for their promise in bringing about sustained results. However, knowledge of the specific environmental conditions associated with physical activity still lags behind that of personal determinants of physical activity.

Concerns are growing over the disproportionately high prevalence of health problems (e.g., obesity, overweight, and diabetes) among low-income and certain minority populations.^{12,19–27} Promoting physical activity among these most vulnerable segments of the population is regarded as one of the top public health priorities.²⁸ Existing empiric studies on neighborhood effects show that socioeconomic characteristics of the neighborhood, in addition to those of the individual, are related to levels of physical activity.^{29–32} Further, the levels of income inequality at the neighborhood level, often measured with Gini or concentration coefficients, have an independently significant association with various health outcomes.^{33–36} Differences exist in the accessibility to routine destinations and recreational facilities among the areas where different ethnic or income populations live.^{37–39} Fewer recreational facilities such as parks and trails are available in areas where low-income or minority populations live, while the demand for such free facilities may be greater.^{37,40} Poor neighborhoods often have fewer supermarkets than wealthy neighborhoods, and the poor sometimes pay more for their food.^{38,41,42} Studies show that limited access to supermarkets is associated with reduced fruit and vegetable consumption.^{43,44}

Figure 1

Conceptual Framework



Most previous studies relied on census geography to define the neighborhood and on crude and aggregated measures to capture the environmental variables. Empiric knowledge is limited in fully understanding how different subpopulations, such as specific minority and low-income groups, may require different approaches to promote physical activity.^{27,45} Also more explicit consideration is needed for the different purposes of physical activity such as recreational or utilitarian activities. While there has been a notable development in both theoretic conceptualizations and analytic techniques in recent years, the link between multiple levels of environmental factors and physical activity still remains elusive. This study's purpose is to address some of these gaps in the existing empiric knowledge by explicitly considering two different types of physical activity, transportation and recreational activities, and by focusing on two specific population characteristics, health risk and economic factors. This article also investigates how equitably or inequitably the environmental resources for active living are distributed in areas where different population groups live and points out the need for future policy and planning interventions to be more targeted and tailored to the specific needs for different subpopulations.

This study is based on a conceptual framework that identifies hypothesized relationships among active living, population characteristics, and environmental factors (Figure 1). It distin-

guishes physical activities between those done for transportation purposes (active living for transportation) and recreation purposes (active living for recreation). The framework is constructed by integrating the social-ecologic model⁴⁶ and the behavioral model of environment.⁴⁷ Social-ecologic approaches, underlying the recent popularity of community-based approaches to physical activity research and promotion, provide a useful framework for this research due to their recognition of the multilevel influences of health behaviors and attention to the importance of the physical environment. In addition to intrapersonal and interpersonal factors, the ecologic approach considers contextual factors that influence behaviors, including organizational, community, and policy factors.⁴⁶ This research captures the intrapersonal factors through the population characteristics variables, and the interpersonal variables through the neighborhood social environment variables (Figure 1). Because of this research's focus on the physical environmental factors and the limited availability and variability in the organizational and policy environments, the contextual factors are captured primarily through the community-level physical environmental factors. The behavioral model of environment is used to better conceptualize the characteristics of the physical environment important for understanding physical activities in neighborhoods. This model includes three spatial constructs, origin/destination, route, and area. The two conceptual models guide the empiric investigation of this study.

METHODS

Design

This was a cross-sectional study with a hypothesis test approach, and it was conducted in two phases. The first phase examined how the levels of transportation and recreation physical activities varied among different health risk and economic groups, and how the levels of support for active living differed in neighborhoods where these different population groups lived. The second phase dealt with a hypothesis test, examining the overall validity of

the proposed conceptual frameworks and further testing associations among physical activity, population characteristics, and the social and physical environmental variables.

Study Area

The study area covered about 50 square miles (60% of the total area of the city) within the city of Seattle, Washington, that have a wide range of net residential densities ranging from less than one to more than 700 units per acre of parcel and that have some retail or commercial activities available. The mean density of the study area was slightly higher than that of the city. The city is bounded by large water bodies including Puget Sound to the west and Lake Washington to the east. It has fairly well-connected street systems with grid-like patterns in many parts of the city. The majority of the streets within the study area are lined with sidewalks. Bike lanes are limited to a few major streets. The public bus system is available in all residential neighborhoods included in this study.

Sample

The sample consisted of 438 able-bodied adults, defined as having no or little difficulty walking three city blocks. The study used a sampling strategy called spatial sampling that allowed sampling respondents from a spatially delineated sample frame that was pretested to ensure sufficient or desirable variations in the environmental conditions to effectively assess their roles in physical activity.⁴⁸ The exclusion criteria for the survey were those who did not speak English, had difficulty communicating over the telephone, or lived in a household with no telephone, nonmatching addresses, no able-bodied adults, or no adult present at the time of contact.

Variables

Variables were selected based on the conceptual framework presented earlier (Figure 1). The theoretic constructs used in these frameworks, such as health risk, can be captured more effectively with latent factors than with individual observed variables. Therefore, this study used latent factors that corresponded to the constructs of the conceptual framework and that were extracted from a set of theoretically

relevant observed variables. The framework was further conceptualized into two separate models, the active living by transportation and the active living by recreation models. These two models had the same latent factors, but different sets of observed variables were used to capture physical activity to distinguish between transportation and recreational activities. The latent factors included transportation physical activity, recreation physical activity, health risk, economic challenge, social environment for walking and biking, and physical environment.

Selection of the observed variables was based on their theoretic relevance to the corresponding construct and the results from the exploratory cluster and factor analyses and bivariate analyses, including analysis of variance (ANOVA) and Pearson correlation analysis. Cluster analyses were used to explore the underlying patterns of groupings among the observed variables. A series of cluster analyses were performed, primarily using hierarchic, Ward's, square Euclidean distance, and Z-score standardization methods, which have been shown to work relatively well for physical environmental variables.⁴⁹ Cluster analyses also helped isolate variables with minimal or no contribution to the group variation. Two of the observed variables considered for capturing the active living latent factors, physical activity at work and hours spent in sedentary activities, were found to be insignificant from the cluster analyses. And the factor analysis and ANOVA results further confirmed their lack of statistically significant contribution to the model and therefore their exclusion from the study.

Factor analyses were used to ensure that each observed variable selected was related to the correct latent factor. All observed variables selected were loaded to the intended latent factor, but the four observed variables selected to capture the health risk construct were loaded to two different latent factors. Body mass index (BMI) and perceived health status were loaded to one latent factor, and the activity limitation and age variables were loaded to another factor, with all factor-loading values greater than 0.6. All but one variable, perceived neighborhood type (factor loading = 0.407), had

factor loadings greater than 0.5. Ideally, the selected set of observed variables is loaded to the single corresponding latent factor only. A few variables were related to two factors, both of which had theoretic relevance. Age and household income, for instance, were used as indicators for two factors, health risk and economic challenge.

For the social and physical environmental variables, additional bivariate analyses, including ANOVA and Pearson correlation analyses, were performed prior to the cluster and factor analyses to select those that had significant bivariate associations with physical activity from a larger pool of candidates.^{45,50} This data-driven approach was needed due to the relatively weaker theoretic foundation for the environmental variables compared with the personal variables, especially in selecting specific measurement types (e.g., selecting between net and gross density variables, and distance to and count of destinations variables). Distances to the closest parks and trails and mean slope within the buffer were used to capture the recreational physical environment factor. Distances to other recreational facilities, such as gym/fitness center and sports facility, were considered but excluded as they failed to show any statistically significant associations with physical activity. The mean slope variable was included because, in addition to its significant correlation with the park and trail variables, it showed a positive association with recreational walking in a previous study.⁴⁵ This study distinguished between area-based density and parcel-based density because preliminary analyses showed the unique and independently important roles of both density measures on walking and physical activity. The former measured dwelling units per acre for the entire neighborhood (1-km network buffer area from home); the latter measured dwelling units per acre for the single parcel in which the respondent's home was located and therefore was closely related to housing types but normalized by the size of parcel. Route-related transportation variables included the total length of sidewalks and the total number of street trees within the buffer area and were grouped together with the destination variables under the same latent factor.

The final list of variables shown in Table 1 also reflects a few modifications that occurred during the model respecification process of the structural equation model (SEM) development. For example, one of the observed variables considered for the social environment construct, assessing how well the respondent knew his/her neighbors, was excluded due to its lack of statistically significant contribution to the model. Note that several variables, such as vehicle miles traveled and distance to destination, were coded using a descending numeric or categorical order to have a consistent direction of association with the other observed variables loaded to the same latent variable.

Measures

Survey. Data on physical activity, population characteristics, and perceived environmental factors came from a telephone survey conducted as part of a larger project called Walkable and Bikable Communities.⁵¹ The survey instrument was developed using previously validated questions and was pilot-tested on 50 random samples drawn from the same population as the one used for the final interview. Examples of questions are "How many times during a usual week do you walk for recreation or exercise" and "When you walk for recreation or exercise, about how many minutes do you spend walking each time you walk" Responses were coded as the exact number reported by the respondent. Individual survey variables used to capture each theoretic construct and their coding schemes are included in Table 1. The survey followed the interview protocols used for the Behavioral Risk Factor Surveillance System by the Centers for Disease Control and Prevention.⁵² It was administered during the fall of 2002 by a professional survey company. Based on the recommended formula by the American Association for Public Opinion Research,⁵³ the response rate was estimated to be 31.54%, cooperation rate was 34.32%, and refusal rate was 40.45%. These rates were considered reasonable given the strict respondent selection criteria and the length of the survey, which was approximately 28 minutes on average.

Table 1
Descriptive Statistics of Observed Variables Used to Capture Latent Factors

Latent Variable	Observed Variable	Variable Coding and Descriptive Statistics
Transportation physical activity	Vehicle miles traveled per month*	11 = ≥ 1500 miles: 26 12 = 1000.001–1500 miles: 44 13 = 800.001–1000 miles: 91 14 = 600.001–800 miles: 107 15 = 400.001–600 miles: 54 16 = 200.001–400 miles: 34 17 = 0.001–200 miles: 51 18 = 0 miles: 31 Mean = 14.324, SD = 1.913
	Use transit	0 = no: 272 1 = yes: 166
	Frequency of walking for transportation in a usual week	11 = 0 trips: 124 12 = 1–4 trips: 195 13 = ≥ 5 trips: 119
Recreation physical activity	Amount of walking for recreation in a usual week	11 = 0 minutes: 111 1–149 minutes: 193 ≥ 150 minutes: 134
	Bike in a usual week	0 = do not bike: 338 1 = bike: 100
	Amount of moderate physical activity in a usual week Amount of vigorous physical activity in a usual week	Log-minutes: Mean = 2.212, SD = 1.265 11 = 0 minutes: 185 12 = 1–149 minutes: 122 13 = ≥ 150 minutes: 131
Health risk (health status)	BMI	BMI: Mean = 25.174, SD = 4.387
	Perceived health status*	11 = excellent: 115 12 = very good: 179 13 = good: 115 14 = fair: 27 15 = poor: 2 Mean = 12.137, SD = 0.892
	Activity limitation: difficulty walking three city blocks	0 = no: 403 1 = yes: 35
	Age†	11 = 18–24 years: 16 12 = 25–34 years: 81 13 = 35–44 years: 86 14 = 45–54 years: 128 15 = 55–64 years: 58 16 = 65–74 years: 38 17 = ≥ 75 years: 31 Mean = 13.842, SD = 1.537
	Yearly household income‡	11 = <\$25,000: 66 12 = \$25,001–\$35,000: 59 13 = \$35,001–\$50,000: 77 14 = \$50,001–\$75,000: 97 15 = ≥ \$75,001: 139 Mean = 13.420, SD = 1.434
Economic challenge (economic status)	Cars in the household	11 = <1 car per adult: 111 12 = 1 car per adult: 274 13 = >1 car per adult: 53
	Own or rent home	0 = rent: 156 1 = own: 282
	Gender	0 = female: 236 1 = male: 202
	Age†	See above
	Yearly household income‡	See above
	Number of residential units in the household parcel‡	Logged dwelling units per square foot: Mean = 2.961, SD = 1.135

Table 1
Continued.

Latent Variable	Observed Variable	Variable Coding and Descriptive Statistics
Social environment for walking and biking	Levels of agreement: many people walk in my neighborhood	5-point Likert scale: 1 = strongly disagree, 2 = somewhat disagree, 3 = neutral, 4 = somewhat agree, 5 = strongly agree Mean = 4.311, SD = 0.917
	Levels of agreement: many people bike in my neighborhood	5-point Likert scale: 1 = strongly disagree, 2 = somewhat disagree, 3 = neutral, 4 = somewhat agree, 5 = strongly agree Mean = 3.336, SD = 1.368
Physical environment: area	Perceived neighborhood type	0 = residential: 267 1 = mixed or commercial: 171
	Mean net residential density within 1-km buffer	Logged dwelling units per square foot: Mean = 7.872, SD = 0.788
	Number of residential units in the household parcel†	See above
Physical environment: transportation destinations and route	Total traffic volume within 1-km buffer	1000 cars: Mean = 10.961, SD = 6.952
	Total length of sidewalks within 1-km buffer	Mile: Mean = 15.76, SD = 6.30
	Total number of street trees within 1-km buffer	1000 trees: Mean = 1348.58, SD = 802.27
	Distance to the closest restaurant*	-Log-feet: Mean = -7.381, SD = 0.742
Physical environment: recreational destinations and slope	Distance to the closest bank*	-Mile: Mean = -0.080, SD = 0.043
	Distance to the closest grocery store*	-Mile: Mean = -0.054, SD = 0.032
	Mean slope within 1-km buffer	Percent: Mean = 8.45, SD = 2.99
	Distance to the closest park*	-Mile: Mean = -0.054, SD = 0.040
	Distance to the closest trail*	-11 = ≤0.25 mile -12 = 0.25–0.5 mile -13 = 0.5–0.75 mile -14 = 0.75–1 mile -15 = 1–1.5 miles -16 = >1.5 mile -17 = no trails within 3-km buffer Mean = -14.260, SD = 1.821

* Variables coded in a descending categoric/numeric order to be consistent in the direction of association with the corresponding latent factor, with the other observed variables included in the same group, exceptions for those variables loaded to multiple factors.

† Variables loaded to more than one latent variable.
BMI indicates body mass index.

Geographic Information System. Physical environmental variables were also objectively measured in Geographic Information System (GIS) using detailed and disaggregated measures taken around each survey respondent's home. The raw GIS databases came from a variety of sources, including the King County Assessor's Office, Puget Sound Regional Council (the metropolitan planning organization), and the city of Seattle. The city offered extensive GIS databases, including sidewalk, street trees, and detailed land uses that complemented the county data.

All physical environmental variables, except the perceived neighborhood type variable, were captured in GIS (Table 1). They were measured as distance and buffer measures, based on actual street networks. Distance

measures included distances to the closest utilitarian and recreational destinations from home. A 1-km radial buffer area was selected as an optimal extent to capture neighborhood walkability, based on a review of previous surveys on commonly reported walking distances, on the average distances estimated from the minutes of individual walking trips that the participants of this study reported, and on the comparison between perceived and actual presence of neighborhood destinations showing 1 km to be a perceived limit of the neighborhood boundary by the study participants.⁵⁰ Buffer measures included mean net residential density, traffic volume and slope; and total sidewalk length and street trees. Further descriptions on the measurements of the variables can be found elsewhere.^{45,50}

Analysis

Descriptive statistics were used to examine each variable's distribution to make sure they were appropriate for bivariate analyses and the SEM. Factor and cluster analyses were then used to determine that the selected variables were valid and capable of capturing their latent factor. Factor and cluster analyses were also used to ensure that the measurement model in the SEM was specified correctly.

Bivariate analyses focused on the observed variables and included Pearson correlations, ANOVA, and independent sample t-test to account for the different types of measurement and coding used for each variable. Variables were also tested for their equality of variance across groups using the Levene statistics ($p = .05$ as a cutoff). Alternative tests, such as Cramer's V, were used

Table 2
Summary of Bivariate Associations Between the Population Characteristics Variables and the Active Living and Environment Variables

	Transportation Physical Activity		Recreation Physical Activity				Social Environment for Walking and Biking		Physical Environment: Area				Physical Environment: Transportation			Physical Environment: Recreation					
	More vehicle miles traveled†	Use transit	More transportation walking	More recreational walking	More biking	More moderate physical activity	More vigorous physical activity	More walkers in my neighborhood	More bikers in my neighborhood	Perceiving neighborhood as mixed or commercial	Higher area-level density	Higher parcel-level density	Greater traffic volume	Longer sidewalks	More street trees	Closer to restaurant	Closer to bank	Close to grocery store	Steeper slope	Closer to park	Closer to trail
Health Risk																					
Higher BMI					—*	—**	—*														—*
Higher health status†	+**					+**	+**			—*	—**										
Activity limitation	—**	—*	—*	—**	—*	—*		—**													
Both§																					
Older age		—**	—**		—**		—**			—*	—*	—**			—*						
Male	+**		+**		+**	—*				+**	+**									—**	
Economic Status																					
Higher income	+**	—**	—**		+	+	+			—**	—**	—**		—*	—**	—**	—**	—**	—**	+**	
Home owner	+**	—**	—**							—**	—**	—**	—*	—**	—**	—**	—**	—**	—**	+**	
More cars	+**	—**	—**	‡		+**	+**			—**	—**	—**	—*				—**				

Note: See Table 1 for the variable coding information; different bivariate analysis was used for each pair based on the type and distribution of variables, including Pearson correlation, analysis of variance F-test, Games-Howell test, t-test, and Cramer's V; + and — show directions of association.

* Significant at the 0.05 level.

** Significant at the 0.01 level.

† Originally coded in a descending categoric/numeric order to be consistent in the direction of association with the corresponding latent factor, with the other observed variables included in the same group but shown in this table as having an ascending order for easier interpretation.

‡ Nonlinear association with different categories of the physical activity variable.

§ Variables in this class considered for both health risk and economic status factors.

for those variables that did not pass this test.

SEM was selected as a powerful multivariate tool that links theory-based approaches with analytic approaches. The purpose of SEM was not only to examine the hypothesized associations among latent variables but also to examine how well the two theoretically drawn models, the active living by recreation and active living by transportation models, fit the data. Therefore, it allowed the investigation of how useful the social-ecologic model and the behavioral model of environment were in explaining environment-physical activity relations, with particular considerations of the specific population characteristics and different physical activity purposes. The SEM includes two major components:

factor/measurement models and a structural model. Factor models refer to the relationships between latent and observed variables, and the structural model refers to the relationships between the independent and dependent latent variables. Using LISREL software, the estimation of SEM followed the five-step process proposed by Schumacker and Lomax,⁵⁴ including model specification, identification, estimation, model fit test, and respecification.

RESULTS

Bivariate Analyses

Correlates of Health Risk. Those with higher health risks were less active for both recreation and transportation

purposes (Table 2). Moderate and vigorous physical activities were consistently associated with reduced health risks. Those who had activity limitations reported significantly less driving and walking and being less active for recreation purposes than their nonlimited counterparts. Engaging in moderate or vigorous physical activity was strongly related to higher perceived health status and lower BMI.

Among the physical environmental variables, higher densities were negatively associated with health status, and closer proximity to trails was negatively associated with BMI (Table 2). None of the other physical environmental variables showed a statistically significant correlation with any of the health risk variables.

Table 3
Summary of Bivariate Associations Between the Environment Variables and the Active Living Variables

	Social Environment for Walking and Biking		Physical Environment: Area				Physical Environment: Transportation			Physical Environment: Recreation				
	More walkers in my neighborhood	More bikers in my neighborhood	Perceiving neighborhood as mixed or commercial	Higher area-level density	Higher parcel-level density	Greater traffic volume	Longer sidewalks	More street trees	Closer to restaurant	Closer to bank	Close to grocery store	Steeper slope	Closer to park	Closer to trail
Transportation Physical Activity														
Vehicle miles traveled per month†				-**	-**		-**	-*			-*	+**	-*	
Use transit			+**	+**	+**	+**	+**	+**	+**	+**				+*
Frequency of walking for transportation in a usual week	+	+**	+**	+**	+**	+**	+**	+**	+**	+**	+**	-**		
Recreation Physical Activity														
Amount of walking for recreation in a usual week	+**													
Bike in a usual week		+**								-*				+**
Amount of moderate physical activity in a usual week	+**	+			-**	-*								
Amount of vigorous physical activity in a usual week													+*	

Note: See Table 1 for the variable coding information; different bivariate analysis was used for each pair based on the type and distribution of variables, including Pearson correlation, analysis of variance F-test, Games-Howell test, t-test, and Cramer's V; + and - show directions of association.

* Significant at the 0.05 level.

** Significant at the 0.01 level.

† Originally coded in a descending categoric/numeric order to be consistent in the direction of association with the corresponding latent factor, with the other observed variables included in the same group but shown in this table as having an ascending order for easier interpretation.

‡ Nonlinear association with different categories of the physical activity variable.

Correlates of Economic Status/Challenge. Higher-income respondents lived in areas with lower densities and fewer routine destinations such as restaurants and grocery stores. Lower-income groups were more active for transportation but less active for recreation purposes than their higher-income counterparts. Transportation physical activities appeared to have the strongest associations with the economic status of the respondents. Lower-income populations reported more walking and more transit use but less driving. Forty-five percent (n = 50) of those who walked frequently for transportation purposes, at least five times per week, owned less than one car per

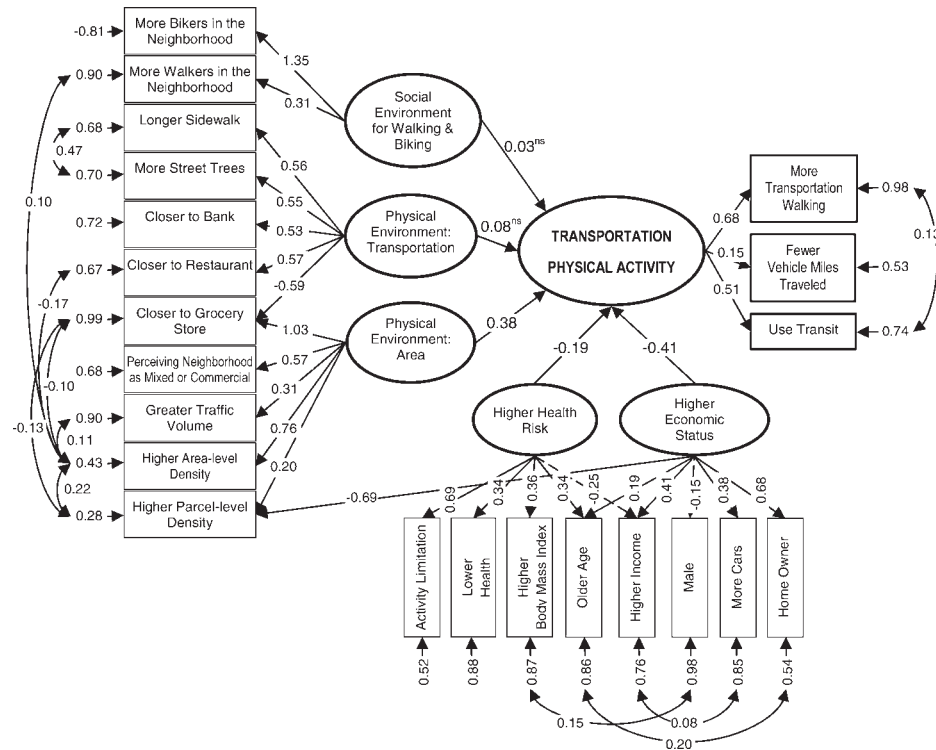
adult in the household, while less than 25% of those who owned one or more cars walked frequently. Perception of people walking and biking in the neighborhood was not associated with the respondent's economic status (Table 2). Many area and transportation physical environmental variables were significantly associated with the economic status/challenge variables. As expected, higher residential density had strong associations with lower household income, lower home ownership, and fewer cars. All transportation destination variables (distances to grocery stores, banks, and restaurants) were negatively associated with income and home ownership, but none of the

recreational destinations had a significant association with the economic status/challenge variables. Both route-related variables, number of street trees, and length of sidewalks were negatively associated with home ownership.

Environmental Correlates of Transportation Physical Activity. Only one variable, frequency of transportation walking, was related positively with perceiving people walking and biking in the neighborhood (Table 3). From the physical environmental variables, many area variables were strongly associated with transportation activities. Low residential densities were correlated with

Figure 2

Active Living by Transportation: Structural Equation Model Results Showing Latent and Observed Variables Associated with Transportation Physical Activity (Standardized Solutions)



more driving, more walking, and less transit use. Transportation-related physical environmental variables were consistently associated with all transportation activities as expected. Further, living in a hilly area was associated with more driving and less walking for transportation purposes.

Environmental Correlates of Recreation Physical Activity. The amount of moderate physical activity was associated positively with both social environmental variables—perception of people walking and biking in the neighborhood (Table 3). In contrast, vigorous physical activity showed no significant association with the social environmental variables. Parcel-level residential density and traffic volume showed negative associations with moderate physical activity. Transportation physical environmental variables showed limited associations with recreational physical activity, with only one significant association between proximate trails and more biking.

Structural Equation Model

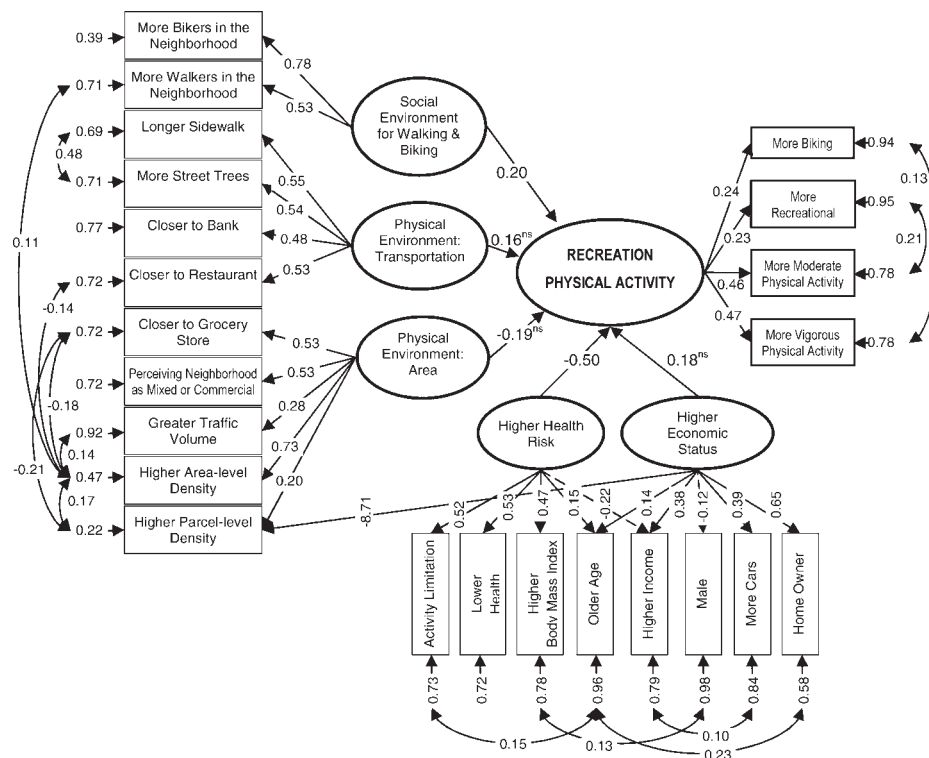
Overall Model Fit. Both conceptual models were shown to be valid and useful in framing environment-physical activity relationships that consider different subpopulation characteristics and physical activity purposes, demonstrated by the desirable levels of goodness of fit values (greater than 0.90).⁵⁵ Several commonly used fit indices are used, as no agreement exists as to which single global fit index works the best.⁵⁶ The degrees of freedom were 174 for the active living by transportation model and 194 for the active living by recreation model (Figures 2 and 3). The goodness of fit values for the active living by transportation and by recreation models were 0.93 and 0.94, respectively, adjusted goodness of fit indices of 0.90 and 0.91, and comparative fit indices of 0.95 and 0.96. The χ^2 values were 373.49 for the active living by transportation and 330.41 for the active living by recreation. A standardized root mean square residual, the difference between the observed and

the current covariance matrix, was 0.059 for the active living by transportation model and 0.051 for the active living by recreation model (values smaller than 0.1 generally suggest a good fit). Note that several relationships hypothesized to exist in the original conceptual framework (Figure 1) were not supported in the analysis. For example, distances to parks and trails and topography, all of which belonged to the recreational physical environment factor, were dropped during the model respecification process due to their statistically insignificant contribution to the overall model fit even for the active living by recreation model.

Measurement Models. The results from the SEM measurement models further confirmed that all variables were significantly loaded to the correct latent variable with an expected direction of association (Figures 2 and 3). The *t*-values of individual variables from the two models were generally comparable. The patterns of associations among the

Figure 3

Active Living by Recreation: Structural Equation Model Results Showing Latent and Observed Variables Associated with Recreation Physical Activity (Standardized Solutions)



observed variables were generally consistent with the findings from bivariate analyses reported earlier.

Higher BMI was associated with lower perceived health status. Having more cars was correlated with more driving and less transit use. Recreational walking was positively associated with moderate physical activity, and biking was positively associated with vigorous physical activity. Older age was related to increased activity limitation, as expected. Positive correlations in the environmental variables were found between area-level residential density and sidewalks, street trees and sidewalks, and parcel-level and area-level densities. An unexpected direction of association was also found: higher area-level density (mean logged dwelling units per acre within the 1-km buffer) was associated with longer distances to the closest grocery store and restaurant.

Structural Models. Both population characteristics latent factors, health risk

and economic status/challenge, were significantly associated with transportation physical activity, while only health risk was associated with recreational physical activity (Figures 2 and 3).

Higher health risk (lower health status) was positively and higher economic challenge (lower economic status) was negatively associated with transportation physical activity. Lower health risk was also related positively with recreational physical activity. Among the three environmental latent factors, only the area-related physical environmental factor was related to transportation physical activity (Figure 2). None of the other environmental latent variables were associated with recreational physical activity (Figure 3).

The health risk factor was negatively associated with both the transportation and recreation physical activity factors. The economic challenge/status factor, however, was positively associated with the transportation physical activity factor only. The SEM showed no significant associations between physical en-

vironments and health risk. However, the perceived presence of people walking and biking in the neighborhood was positively associated with recreational physical activity and negatively associated with health risk. Negative associations between economic status and physical environment found from the bivariate analyses were further confirmed. Note that the SEM tests associations between independent latent factors, such as the population characteristics and environmental variables, with correlational matrices only.

DISCUSSION

Physical Activity Levels Among Different Subpopulations

This research found that having high health risk was associated with less physical activity for both recreation and transportation purposes, while being economically challenged was associated with more physical activity for transportation purposes (Figures 2 and 3). It is likely that people with economic

challenges own fewer cars and are more dependent upon less expensive transportation modes such as walking and transit,⁵⁷ both of which are physically active modes of transportation.

Physical Environments for Different Subpopulations

Physical environment of the neighborhood was more strongly associated with the residents' economic status than with their health status (Table 2). However, seeing other people walking and biking in the neighborhood, captured as an indicator of the neighborhood's social environment, was marginally but significantly associated with the health risk of the residents. People with lower perceived health were also found to live in areas with higher residential densities. People with economic challenges tended to live in areas with higher residential densities and closer to destinations (e.g., grocery stores, banks, and restaurants), both of which were positively associated with higher levels of transportation physical activity. Lower levels of transportation physical activity among higher-income people can be partially explained by the fact that they are more likely to live in lower-density, single-family neighborhoods where limited transportation destinations and transit services exist.

Environmental Correlates of Physical Activity by Different Purposes

This study supports the argument that different purposes for physical activity are subject to different environmental correlates.⁵⁸ Also compared with recreation physical activities, transportation physical activities have stronger associations with the physical environment. This finding is consistent with previous studies and makes intuitive sense as transportation activities are heavily influenced and often driven by the locations of available destinations in the neighborhood.^{45,59} In general, supportive physical environments (e.g., utilitarian destinations near home) appear to be more important for transportation activities, and supportive social environments (e.g., having social models such as seeing other people walking and biking) to be more important for recreational physical activity (Table 3). Findings from the bivariate analyses showed that two transportation-related behav-

iors, frequency of walking for transportation and amount of transit use, had the strongest associations with all attributes of the physical environment including origin/destination, route, and area characteristics. Interestingly, even the recreational destinations and slope variables had stronger associations with transportation activities than with recreational activities (Table 3).

Support for the Conceptual Models

The proposed conceptual models, derived from the social-ecologic model and the behavioral model of environment, seem to be useful (Figures 1–3). Even though not all constructs were significant, the models helped frame the research and select variables to effectively capture the correlates of physical activity while considering the different purposes of physical activity and different subpopulations.

Limitations and Future Needs

This study relied on cross-sectional data, and therefore causal relationships among variables cannot be identified and are subject to self-selection bias. Several variables often used as proxies for self-selection, such as attitude, preference, neighborhood perception, reasons for moving, etc., were tested during the preliminary analyses of this study but dropped in the final analyses because none of them showed a statistically significant association with the dependent variables. Future research needs to include longitudinal studies to better understand the underpinning causal structure of the environment-physical activity relationships. Another limitation of this study is the urban setting of the study area, and therefore the findings of this study may not be relevant to rural or suburban communities. It is also likely that there are unobserved regional and cultural characteristics that are distinctive to the Seattle area. While this problem is difficult to address and found in most studies in this area of research, it does limit the external validity of the study. Future studies are needed to include diverse environmental settings and various other at-risk populations to further understand the mechanism through which different social and physical environmental factors interact with people with dif-

ferent health and socioeconomic conditions. The roles of mediating variables and interactions among observed variables could not be thoroughly addressed in this study due to the limited degrees of freedom.

In summary, the consideration of particular subgroups of people adds another layer of complexity to the already complicated interactions between environment and physical activity. This study indicates that explicit distinctions between different purposes or types of physical activity, and between different socioeconomic and health conditions of the study populations are essential in future research. Also due to the likely differences in the environmental supports needed to promote physical activity among different population groups, future policy and design interventions must be tailored toward the specific needs of the target populations.

Implications for Researchers

If this assertion holds true, further research on the physical activity-environment relationships will need to

SO WHAT? Implications for Practitioners and Researchers

This study appears to indicate that lower-income populations live in areas with more routine destinations and higher densities and are more likely to be physically active for transportation purposes than higher-income populations and that physical environment of the neighborhood is more strongly associated with the residents' economic factors than with their health risk factors. It also indicates that people with higher health risks are less active for both transportation and recreation purposes and tend to perceive their neighborhood to have less social support for walking and biking. Combined with other research, there seems to be moderate support for the assertion that the physical environment of the neighborhood and the economic status of its residents are associated more strongly with transportation physical activities than with recreational physical activities and that recreational activities are explained primarily by personal and social factors.

explicitly distinguish between different subpopulations and different purposes of physical activities.

Implications for Practitioners

If this assertion holds true and is substantiated with future studies, including different settings and populations, future physical environmental interventions can be more effective by targeting transportation physical activities and by tailoring toward the specific needs of the target populations due to the likely differences in the environmental supports needed to promote physical activity among different population groups.

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