近隣ウォーカビリティと住民肥満レベルの関連性：
米国ユタ州ソルトレイクシティを例にして

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Neighborhood Walkability and Obesity: A Case Study in Salt Lake City, Utah, USA

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Abstract: アメリカでは肥満は過去数十年にわたり深刻な社会問題であり、個人の生活習慣改善に重点を置いた従来の政策的対応の限界が指摘されている。そこで研究・政策の両面で注目が高まっているのが、健康的な都市環境を提供することによる肥満の解消・予防に向けた取り組みである。本研究ではユタ州ソルトレイクシティを例に、GIS によるミクロな物理的環境指標と国勢調査による社会経済指標を組み合わせ、近隣ウォーカビリティが住民の肥満レベルに及ぼす影響を解析する。

Keywords: 近隣ウォーカビリティ (neighborhood walkability)、肥満 (obesity)、物理的環境指標 (measures of built environment)、社会人口統計指標 (measures of socio-demographic status)

1. Introduction

Globally, obesity is a growing and serious public health concern over the past few decades. The United States is one of the most obese countries, where an estimated 65% of adults are overweight or obese (Hedley et al. 2004). The rapid rise in obesity points to contextual causes operating at the population level and has promoted research in environmental factors that encourage physical activity and prevent obesity (Hill and Peters 1998). *Neighborhood walkability*, the physical supports for walking in the neighborhood, has been identified to relate to more walking and healthier weights in growing body of research (Ewing et al. 2003; Saelens and Handy 2008; Smith et al. 2008). Fundamental questions concerning the relationships between human health and walkability (or the role of the neighborhood built environment in general) remain unsolved, including what aspects of the neighborhood built environment to measure, how to operationalize them, and what geographic scales to use (O'Campo 2003; Forsyth et al. 2006; Messer 2007).

Population Density, pedestrian-friendly Design, and land use Diversity, are called *3Ds* and often used to conceptualize neighborhood walkability (Cervero and Kockelman 1997). Higher 3Ds together mean that many people and destinations are in close proximity via a well-connected street network, making walking an efficient, convenient, and potentially enjoyable transportation option. Density is generally measured by density of population, housing units, or jobs; pedestrian-friendly design is measured by street intersection density or sidewalk availability. However, diversity is operationalized in many different ways (Song and Rodriguez 2005; Brown et al. 2009), with little consensus or discussion on their suitability. Similarly, a range of geographic scales are used to define individuals' neighborhoods, but the appropriate scale is still an open question (Messer 2007; Weiss et al. 2007). Messer (2007) notes that data availability and quantitative considerations, rather than theoretical motivations, often determine operationalizations and geographic scales.

The authors of this report have been investigating potential relationships between neighborhood built as

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well as socio-demographic environments and obesity of residents from various perspectives. One of our latest studies focuses on the very issues of built environment measures and neighborhood scales; more specifically, it relates individual-level body mass index (BMI, defined as weight[kg]/height[m]^2) to four types of land use diversity measures obtained at three geographic scales of the neighborhood. The objective of this report is to discuss key findings from this study; a full report will be published in *The Professional Geographer* (Yamada et al. In press).

2. Data and Measures of Walkability

2.1 BMI data

BMI data used in this study are derived from a driver license database that contains all 453,927 license holders in Salt Lake County, Utah, in 2005. This database is a part of the Utah Population Database (UPDB), a health-related research database containing records from the Driver License Division (DLD) of the Utah Department of Public Safety. To protect confidentiality of license holders, all personal information from DLD was removed before the data were provided to the investigators on this research project. This project has been approved by the University of Utah Institutional Review Board and the Utah Resource for Genetic and Epidemiologic Research. As part of this process, the UPDB staff retained identifying address information, linked driver license data (height, weight, gender, and age) to census-block groups via UTM coordinates, and then provided the researchers with a data set without individual addresses.

This study uses a random subset of 4,960 individuals derived from the master database. Twenty individuals are randomly sampled from 248 census block groups that are also randomly selected from 549 block groups in the county; block groups with small population count and/or density have been excluded in advance. The sample also excludes young adults (<25 years old), elderly adults (≥65), and underweight individuals (BMI <18.5). Preliminary analyses find no significant difference between this sample and the countywide database with respect to gender-specific ages and BMIs.

2.2 Measures of walkability

This study examines three geographic scales that have often been used in the literature of neighborhood effects on health: census tract, census block group, and 1km street-network buffer. While predefined administrative boundaries such as tracts and block groups are easy to use (Krieger et al. 2003), they may mask potential heterogeneity within each unit and may not necessarily reflect residents' walking range in the neighborhood. Creating a buffer with a given distance around individuals' homes provides more individualized neighborhoods (Frank et al. 2006), but computation could be prohibitively intensive even with GIS, especially when the shortest-path network distance is used. Another challenge is to determine an appropriate buffer distance. Here we compare the three geographic scales to assess their relative utility.

Measures of land use diversity in the literature may be categorized into four: areas or proportions of walkable land uses, distances to specific destinations, census-based proxy scores, and statistical summary indices. This study focuses on the first three measures.

A simple approach is to examine areas of land uses that are considered to be walkable. Statistical summary indices of diversity can also be computed based on the areas (Frank et al. 2006), but Brown et al. (2009) demonstrate that original, uncombined areas of walkable land uses perform better than summary indices to explain individual-level BMI. Following Frank et al. (2006) and Brown et al. (2009), this study examines six land uses—single-family residential, multifamily residential, retail, office, education, and entertainment—as walkable uses.

Another approach is to assess the presence, density, or proximity to walkable destinations such as grocery and other retail stores, parks, offices, schools, and transportation services. We focus on three destinations—light rail stations, grocery stores, and the central business district (CBD)—for the following reasons. Past studies illustrate that residential proximity to light rail stations (Rundle et al. 2007) and grocery stores (Moudon et al. 2007) relate to more walking and healthier weight. The proximity to CBD is included in this study because of its close association with the proximity to light rail stations in Salt Lake County.

The third approach is to use proxy scores obtained from census or other existing data. We consider two proxies from the 2000 U.S. Census: housing age and proportion of residents who walk to work. Neighborhoods with older housing tend to have more mixed uses and the proportion of residents who walk to work is hypothesized to indicate the coexistence of residential and employment land uses within walking distance.

Measures based on areas of walkable land uses and census proxies are computed at the three geographic scales described above. Proximity measures are obtained as the shortest-path distance from individuals' residences to the closest destination. Street centerline data and parcel-level land use data are provided by the DIGIT Lab at the University of Utah. Information on light rail stations is obtained from Utah Transportation Authority. Dun and Bradstreet business data are used to retrieve information on grocery stores.

3. Methods

We use generalized estimating equations (GEE) to relate individual-level BMI to walkability features in the neighborhood. GEE is an extension of generalized linear models with the quasi-likelihood approach and is designed to analyze longitudinal and other correlated data (Zeger and Liang 1986). We control models for individual age and six neighborhood socio-demographic variables (neighborhood income, median age of residents, and proportions of African American, Hawaiian/Pacific Islander, Hispanic, and Asian) since the literature indicates that neighborhood socio-demographic status relates to residents' health including obesity independently of their own socio-demographic status (Krieger and Gordon 1999; Smith et al. 2008). Models consisting of the seven control variables only are used as baselines to assess the goodness-of-fit of other models.

We first create models separately for the three geographic scales to assess the utility of each scale. A total of thirty-seven models are created by adding other walkability measures to the baseline models. Model fit is measured by "corrected quasi-likelihood under the independence model criterion" (QICC), which penalizes models for their complexity (i.e., the number of explanatory variables included). Then, we modify and integrate the best scale-specific models to examine potential benefits of choosing geographic scales for individual walkability measures separately, rather than choosing one for the entire model.

4. Results

Essential findings from the GEE models explained above are summarized in this section.

(1) Population density and street intersection density improve model fit consistently for all gender-scale combinations. However, higher intersection density is unexpectedly associated with higher BMI, implying that intersection density is not a suitable measure of pedestrian-friendly design for this particular sample.

(2) Areas of the six walkable land uses considerably improve model fit for both males and females. In addition, gender differences are found in land uses that are significantly associated with BMI.

(3) While the proximity to light rail stations is found significant for all gender-scale combinations, adding the proximity to CBD into the models eliminates its significance only for male models. This implies that the proximity to CBD offers some benefit to both males and females in terms of their weight status, but the proximity to light rail stations is beneficial only for females.

(4) The proximity to grocery stores offers little improvement in model fit.

(5) The two census proxies improve model fit considerably, with older housing and a higher percentage of residents who walk to work both significantly associated with lower BMI.

(6) The combination of the proximity measure to light rail stations and that to CBD consistently performs best for females, while the housing age census proxy performs best for males.

(7) Among the three geographic scales examined in this study, the 1km street-network buffer generally achieves the best fit models.

(8) When different types of land use diversity measures are combined, the best model for males is achieved by the proximities to light rail stations and CBD, housing age, and areas of the six walkable land uses. The best model for females also includes proportion of residents who walk to work in addition to the same measures in the male model.

(9) The goodness-of-fit of those best models can further be improved by the use of different scales for individual walkability measures. Partial correlation between each measure and BMI is used as a criterion to choose an appropriate scale.

5. Summary

Despite the growing literature on neighborhood walkability and health, few guidelines exist for researchers to decide upon proper geographic scales and walkability measures. This study aimed at enhancing this literature by providing empirical and systematic comparisons of a wide variety of walkability measures and geographic scales. GEE models estimated for the individual-level BMI data for 4,960 adult individuals in Salt Lake County, Utah, demonstrated that optimal walkability measures differed by gender and geographic scale and that integrating walkability measures at different scales improved the overall performance of the models.

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