

Exploring the association between WalkScore and Body Mass Index in Washington State.

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Abstract

Exploring the association between WalkScore and Body Mass Index in Washington State.

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Purpose:

Walking is the preferred form of exercise for most people in the United States, yet most people live too far from work, school or daily errands to be able to transport themselves by walking. Some denser areas facilitate walking for transportation. Incorporating walking into daily routines could be associated with a less sedentary lifestyle and less obesity. The purpose of this project was to explore the relationship between the ability to walk for running errands and obesity.

Methodology:

Walkability was measured using WalkScore.com, a website that gathers data on neighborhood walkability. A numerical WalkScore was obtained for each zip code in Washington state. Obesity was measured by BMI reported from the Behavioral Risk Factor Surveillance Survey published by the Centers for Disease Control and Prevention

from the years 2006-2010. This included The data were analyzed using logistic regression in Stata software.

Results:

An inverse association was observed between WalkScore and BMI. for every 10 point increase in WalkScore, BMI decreased by 0.077 points. This small association persisted, but with a smaller magnitude after controlling for income, race, education level, disability, age, sex, general health status, and physical activity, for every 1 point increase in WalkScore, BMI decreased by 0.0041. Other factors that influenced BMI significantly included income, education, sex and race.

Conclusions:

This project showed that there is a small part of obesity that could be explained by the walkability of the neighborhoods in which people live. WalkScore can be used as a measure of walkability in public health research. However, other social determinants like race, education, income and sex also have important associations with BMI. Further research with different methodology may help illuminate these relationships.

IRB Statement

The University of Washington Human Subjects Division (HSD) has determined that this research qualifies for exempt status in accordance with the federal regulations under 45 CFR 46.101/ 21 CFR 56.104.

Background

Obesity and Physical Activity in the United States

According to the World Health Organization (WHO) 1.4 billion adults worldwide are now overweight, with half a billion people being obese¹. As the global burden of disease shifts from infectious disease to non-communicable diseases, addressing obesity has become a major global health priority. Many low and middle-income countries are seeing the population of obese people rise, even while they continue to struggle with a burden of infectious disease. Overweight and obesity accounts for 44% of diabetes (Type 2) and 23% of ischemic heart disease globally².

In 2013, the obesity rate in the US is 35.7%³. The prevalence of obesity and overweight together is close to 69%⁴. The best news about the obesity rate is that it has reached a plateau since 2008⁵. Obesity is not uniformly distributed within the US, and significant health disparities exist within the US obesity picture. African-Americans have the highest age-adjusted rates of obesity (49.5%), followed by Mexican-Americans (40.4%), Hispanics and finally white Americans (30.3%)⁶. Disparities in obesity across income and education categories are also present, but appear to be different for men and women. Higher income and higher levels of educational attainment appear to be associated with lower obesity rates in women, while higher income is associated with greater obesity in African-American and Mexican-American men⁷. However, obesity affects all Americans at every income and education level.

One of the many causes of obesity and other problems related to sedentary lifestyle is a lack of physical activity. Less than half of American adults (48%) meet the physical activity guidelines set by the Centers for Disease Control and Prevention and 40 percent of adults have no leisure time physical activity at all⁸. This recommendation is not especially onerous: 150 minutes per week of moderate physical activity or 75 minutes per week of vigorous physical activity. This divides into roughly 22 minutes per day of

¹ World Health Organization Fact Sheet "10 Facts About Obesity" 2008

² World Health Organization Fact Sheet "10 Facts About Obesity" 2008

³ National Center for Health Statistics, Centers for Disease Control and Prevention "Prevalence of Obesity in the United States" NCHS Data Brief January 2012

⁴ NCHS Data Brief January 2012

⁵ NCHS Data Brief January 2012

⁶ Flegal KM, Carroll MD, Kit BK, Ogden CL. , Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999-2010 JAMA. 2012; 307(5):491-497

⁷ National Center for Health Statistics, Centers for Disease Control and Prevention "Obesity and Socioeconomic Status in Adults: United States 2005-2008" NCHS Data Brief December 2010

⁸ National Center for Health Statistics, Centers for Disease Control and Prevention "Facts about Physical Activity" 2013

moderate physical activity (at a pace where a person can talk, but not sing), and breaking this activity into 10-minute chunks is still acceptable. It is surprising that less than half of American adults meet even this low bar for physical activity.

Certainly income and education play a role in a person's ability to be physically active. Workplaces that provide gym access are typically well paying jobs, gym memberships are not free, and neighborhoods with access to parks and recreation facilities typically cost more to live in. Poverty and income inequality are also associated with lower physical activity among children and adolescents⁹. Racial disparities also exist, with more white American adults meeting physical activity than African-Americans or Hispanics¹⁰. Regional disparities are also present, possibly reflecting local trends in industry, weather and culture. People living in the Southeastern US are the least likely to meet recommendations on physical activity compared to other regions¹¹.

Physical activity can be any type of activity and can take place in any context. Researchers typically divide physical activity into leisure-time physical activity and utilitarian physical activity; the health benefits of physical activity are essentially the same, regardless of the purpose of that activity. This can be as simple as the difference between walking in the park and walking to work or the grocery store. While it would clearly be desirable for more Americans to choose to participate in more leisure time physical activity, there is plenty of room for improvement in utilitarian physical activity as well. 11.9 % of all trips in the US were taken on foot or by bicycle, and short trips are the most common type: trips less than 3 miles make up 50% of all trips¹². Of trips less than one mile, 60% are driven and 35% are walked or bicycled¹³.

Walking Behavior and Neighborhood Design

There is a complicated relationship between neighborhood design, walkability, physical activity and weight that various studies have attempted to address. This relationship can vary across age, race and income groups.

Starting at the most basic level, some neighborhood characteristics are associated with more physical activity. In general terms, these elements are known as the "3 D's" density, pedestrian friendly design, and diversity of destinations¹⁴. In a study of older adults enrolled in Group Health in King County, WA, Berke et al showed that neighborhood features such as: proximity of the nearest grocery store, residential density, smaller block sizes and proximity to retail destinations were all strong predictors of older adults

⁹ Singh GK, Kogan MD, Siahpush M, van Dyck PC

"Prevalence and correlates of state and regional disparities in vigorous physical activity levels among US children and adolescents" *Journal of Physical Activity and Health*. 2009 Jan;6(1):73-87

¹⁰ National Center for Health Statistics, Centers for Disease Control and Prevention "Facts about Physical Activity" 2013

¹¹ NCHS 2013

¹² National Household Travel Survey, 2009

¹³ NHTS 2009

¹⁴ Cervero, R., Kockelman, K., 1997. Travel demand and the 3Ds: density, diversity, and design. *Transportation Research Part D-Transport and Environment* 2 (3), 199–219.

walking within their neighborhood¹⁵. Other studies have also demonstrated this relationship for older adults: “across regions, time and neighborhood income, older adults living in more walkable neighborhoods had more transport activity and more moderate-to-vigorous physical activity ... relative to those in less walkable neighborhoods

Youth are more likely to be physically active when neighborhoods have high residential density, low traffic speed and volume, land-use mixing and access to recreational facilities¹⁶. Another study, one that used accelerometers to objectively measure physical activity, found that residential density, land use mix and street connectivity are all associated with objectively measured physical activity and more walking in Atlanta, GA¹⁷. These findings were replicated in New Zealand in a study of neighborhood design and physical activity measured by accelerometers¹⁸.

Several factors mediate the relationship between neighborhood features and walking behavior, such as vehicle ownership, personal preferences and resident perceptions of neighborhood walkability. Vehicle ownership can change the relationship between walkability and physical activity outcomes, in one study from Sweden, up to 25% of the association between neighborhood density and physical activity.

Personal preferences and perceptions also influence the relationship between neighborhood design and physical activity. In a qualitative study of Edmonton, Alberta residents, they stated preferences for walkable neighborhoods that correlated with the neighborhood features described above: traffic speed, proximity to retail destinations, sidewalk maintenance, green spaces, regional design and street connectivity¹⁹. But, participants also brought up some points not captured in other studies, such as the near impossibility of walking to the grocery store to buy groceries for a family of five, the challenges of navigating icy sidewalks and cold winters, and the disappearance of small, locally-owned retail stores²⁰.

Other studies have attempted to tease out what role neighborhood preference plays in changing the relationship between neighborhood design and physical activity. One study from Atlanta looked at people according to their neighborhood of preference, and found that for people with a preference for walking, neighborhood walkability encouraged

¹⁵ Berke, E. M., Koepsell, T. D., Moudon, A. V., Hoskins, R. E., & Larson, E. B. (2007). Association of the built environment with physical activity and obesity in older persons. *American journal of public health*, 97(3), 486–92.

¹⁶ Ding, D., Sallis, J. F., Kerr, J., Lee, S., & Rosenberg, D. E. (2011). Neighborhood environment and physical activity among youth a review. *American journal of preventive medicine*, 41(4), 442–55.

¹⁷ Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., & Saelens, B. E. (2005). Linking objectively measured physical activity with objectively measured urban form: findings from SMARTAQ. *American journal of preventive medicine*, 28(2 Suppl 2), 117–25.

¹⁸ Witten, K., Blakely, T., Bagheri, N., Badland, H., Ivory, V., Pearce, J., Mavoa, S., et al. (2012). Neighborhood built environment and transport and leisure physical activity: findings using objective exposure and outcome measures in New Zealand. *Environmental health perspectives*, 120(7), 971–7.

¹⁹ Montemurro, G. R., Berry, T. R., Spence, J. C., Nykiforuk, C., Blanchard, C., & Cutumisu, N. (2011). “Walkable by Willpower”: resident perceptions of neighbourhood environments. *Health & place*, 17(4), 895–901

²⁰ Montemurro, GR 2011

walking, but for people who preferred driving but lived in a walkable neighborhood, there was less association with physical activity²¹. Neighborhood preference for high-walkability neighborhoods also appears to influence the amount of utilitarian walking, but not the amount of leisure time physical activity²². A study in Salt Lake City, UT used youth as participants to correct for neighborhood selection and found no association with BMI or activity, but failed to account for high school sports participation²³. However, a different study of physical activity before and after residential relocation did show that changes in the built environment can influence walking behaviors, although this study relied on self-reported data²⁴. Given this conflicting set of conclusions, it is likely that neighborhood preference explains some, but not all of the association between neighborhood design and health.

Despite the issue of neighborhood preference, there is some relationship between neighborhood design and physical activity. Is the influence of neighborhood design enough to make significant impact on risk factors for disease, like blood pressure or obesity? One study linked neighborhood walkability in Dallas, TX with objective assessments of cardiorespiratory fitness measured by treadmill tests and found that neighborhood factors such as non-motorized commuting, density and older housing stock were all associated with better treadmill test scores²⁵.

In reviewing the evidence, it seems as though there are some neighborhood features that do improve the health of neighborhood residents, including proximity to parks, density, presence of retail within walking distance, and pedestrian safety features like traffic-calming measures or sidewalks. These are characteristics that could be changed by altering neighborhood design and zoning laws. However, there are also some factors that are more difficult to change, such as weather, resident perceptions of safety and ease of walking, and cultural trends.

Another objective measure of the impact of walking on overall health is Body Mass Index (BMI), since it is much easier to measure than cardiorespiratory fitness on a treadmill test. Using BMI as a measurement of the health impact of walkability does add an additional layer of complication, since both exercise and food determine the calorie

²¹ Frank, L. D., Saelens, B. E., Powell, K. E., & Chapman, J. E. (2007). Stepping towards causation: do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity? *Social science & medicine* 65(9), 1898–914

²² Norman, G. J., Carlson, J. A., Mara, S. O., Sallis, J. F., Patrick, K., Frank, L. D., & Godbole, S. V. (2013). Neighborhood Preference, Walkability and Walking in Overweight / Obese Men. *American Journal of Health Behavior*, 37(2), 277–282.

²³ Smith, K. R., Fan, J. X., & Yamada, I. (2012). Effects of Neighborhood Walkability on Healthy Weight: Assessing Selection and Causal Influences. *Social Science Research*, 40(5), 1445–1455.

²⁴ Giles-Corti, B., Bull, F., Knuiman, M., McCormack, G., Van Niel, K., Timperio, A., Christian, H., et al. (2013). The influence of urban design on neighbourhood walking following residential relocation: longitudinal results from the RESIDE study. *Social science & medicine*, 77, 20–30.

²⁵ Hoehner, C. M., Handy, S. L., Yan, Y., Blair, S. N., & Berrigan, D. (2011). Association between neighborhood walkability, cardiorespiratory fitness and body-mass index. *Social science & medicine*, 73(12), 1707–16.

balance that determines BMI. Despite this challenge, BMI is an important outcome to investigate, because of the poor health outcomes associated with obesity.

Increased physical activity from utilitarian walking does appear to have a relationship with BMI as well; adults living in high walkability neighborhoods appear to be more physically active and are less likely to be obese²⁶. In contrast to the study of Salt Lake City youth described above, other studies have shown that walkable neighborhoods decrease the odds of being overweight or obese in adolescents²⁷ and that high walkability and good nutritional environments decrease the likelihood that children will be obese²⁸.

Neighborhood features associated with lower BMI among residents include green spaces²⁹, land-use mix³⁰, residential density and street connectivity^{31 32}, retail destinations³³, proportion of residents walking to work and older housing stock³⁴. The relationship between BMI and these neighborhood design features varies considerably across race and class categories³⁵, with some studies showing a greater association in predominantly white neighborhoods³⁶, others showing a greater association in low-income neighborhoods³⁷.

In addition to neighborhood features, the food environment also plays a role in determining an individual's BMI. While the food environment is not the focus of this paper, it is worth noting that the work by Saelens in the Neighborhood Impact on Kids study showed that neighborhoods with access to healthy food options were associated with less obesity in children³⁸. Other studies have shown that grocery stores within

²⁶ Saelens, B. E., Sallis, J. F., Frank, L. D., Couch, S. C., Zhou, C., Colburn, T., Cain, K. L., et al. (2012). Obesogenic neighborhood environments, child and parent obesity: the Neighborhood Impact on Kids study. *American Journal of Preventive Medicine*, 42(5), e57–64.

²⁷ Slater, S. J., Nicholson, L., Chiqui, J., Barker, D. C., Chaloupka, F. J., & Johnston, L. D. (2013). Walkable communities and adolescent weight. *American Journal of Preventive Medicine*, 44(2), 164–8.

²⁸ Saelens, B.E. 2012

²⁹ Bell, J. F., Wilson, J. S., & Liu, G. C. (2008). Neighborhood greenness and 2-year changes in body mass index of children and youth. *American journal of preventive medicine*, 35(6), 547–53.

³⁰ Brown, B. B., Yamada, I., Smith, K. R., Zick, C. D., Kowaleski-Jones, L., & Fan, J. X. (2009). Mixed land use and walkability: Variations in land use measures and relationships with BMI, overweight, and obesity. *Health & Place*, 15(4), 1130–41

³¹ Frank, L 2008

³² Frank, L 2005

³³ Saelens 2008

³⁴ Smith, K. R., Brown, B. B., Yamada, I., Kowaleski-Jones, L., Zick, C. D., & Fan, J. X. (2008). Walkability and body mass index density, design, and new diversity measures. *American Journal of Preventive Medicine*, 35(3), 237–44.

³⁵ Frank, L 2005

³⁶ Casagrande, S. S., Gittelsohn, J., Zonderman, A. B., Evans, M. K., & Gary-Webb, T. L. (2011). Association of walkability with obesity in Baltimore City, Maryland. *American journal of public health*, 101 Suppl , S318–24.

³⁷ Manaugh, K., & El-geneidy, A. (2011). Validating walkability indices : How do different households respond to the walkability of their neighborhood ? *Transportation Research*, 16, 309–315.

³⁸ Saelens, B. 2012

walking distance are associated with less obesity in neighborhood residents³⁹. This association also varies by race, there appears to be a greater association between the proximity to supermarkets and the number of fruit and vegetable servings consumed among African-Americans than among whites, perhaps due to greater wealth and car ownership among whites⁴⁰. The food environment also varies by socio-economic status, one study showed that greater fast food restaurant density is associated with lower household income⁴¹.

While these studies looked at specific neighborhood features and their associations with BMI or obesity, other studies have examined the geographic, income and race variation in BMI. Block groups with lower socio-economic status and more minority populations appeared to have less access to physical activity facilities, and fewer facilities for physical activity appeared to be associated with more obesity in adolescents⁴². These income disparities also exist for adults: in King County, WA, the strongest predictor of obesity was found to be residential property values⁴³.

Measuring Walkability

Measuring walkability accurately is a key component of walkability research. There are multiple different methods available to measure walkability and walking behavior. Methods to measure walkability include telephone surveys, community audits and data derived from GIS sources. Methods for measuring walking behavior include using personal accelerometers and personal activity logs. Each of these methods have their own strengths and weaknesses.

Measuring walkability using perceived measures from individual telephone surveys gives information on perceptions of walkability and may incorporate additional information beyond that of objective measures. For example, physical activity is associated with perceived presence of recreational facilities, perceived presence of sidewalks, shops and services and perceived traffic safety⁴⁴. The most commonly used tool for assessing individual perceptions of neighborhood walkability is the Neighborhood Environment

³⁹ Zick, C., Smith, K. R., Fan, J. X., & Brown, B. B. (2009). Running to the Store? The Relationship between Neighborhood Environments and the Risk of Obesity. *Social science & Medicine*, 69(10),

⁴⁰ Morland, K., Wing, S., & Roux, A. D. (2002). The Contextual Effect of the Local Food Environment on Residents' Diets : The Atherosclerosis Risk in Communities Study. *American Journal of Public Health Research and Practice*, 92(11), 1761–1767.

⁴¹ Hurvitz, P. M., Moudon, A. V., Rehm, C. D., Streichert, L. C., & Drewnowski, A. (2009). Arterial roads and area socioeconomic status are predictors of fast food restaurant density in King County, WA. *The international journal of behavioral nutrition and physical activity*, 6, 46

⁴² Gordon-Larsen, P., Nelson, M. C., Page, P., & Popkin, B. M. (2006). Inequality in the built environment underlies key health disparities in physical activity and obesity. *Pediatrics*, 117(2), 417–24.

⁴³ Rehm, C. D., Moudon, A. V., Hurvitz, P. M., & Drewnowski, A. (2012). Residential property values are associated with obesity among women in King County, WA, USA. *Social science & medicine*, 75(3), 491–5

⁴⁴ Sallis, J. F., Brownson, R. C., Hoehner, C. M., Day, K., & Forsyth, A. (2010). Measuring the Built Environment for Physical Activity. *American Journal of Preventive Medicine*, 36.

Walkability Scale (NEWS)⁴⁵. These measures vary in reliability for questions that are less concrete, for example, for perception of crime there is considerable variation among users⁴⁶.

Observational measures and community audits are another way to gather information on walkability. These measures rely on in-person observation of a neighborhood or area and usually consist of a checklist or Likert scale of items that the user evaluates. Common observational measures include the Pedestrian Environment Data Scan, the Walking Suitability Assessment Form, the Environmental Assessment of Public Recreation Spaces and the Physical Activity Resource Assessment tool⁴⁷. These tools provide more objective information than telephone surveys but are also time-consuming to carry out, some tools can take up to 20 minutes per street segment to complete⁴⁸.

GIS-based measures offer the use of existing data sources to contribute to an assessment of the walkability of the area. Data sources commonly incorporated into GIS-based measures of walkability include population density, land use mix, retail stores, recreational facilities, street patterns, sidewalk coverage, vehicular traffic, crime, and other measures, like greenery or composites of the above measures⁴⁹. GIS-based measures are only as accurate as the data they rely on, and may be less accurate in rapidly-changing areas or in areas without significant data collection on the built environment. GIS measures also require significant time and trained personnel to use, and access to data sources can be costly.

Finally, a more personalized and objective measurement of walking behavior can be obtained from asking study participants to wear personal accelerometers or pedometers, devices which can measure their activity levels throughout the day. These devices offer data on how much a particular resident actually walks or uses active transportation. Several studies have used accelerometers to measure physical activity and have shown a relationship between walkability surveys⁵⁰ and GIS-based measures⁵¹.

One somewhat new (since 2007) measure that has gained some attention is the website WalkSore.com, which is described below:

WalkScore.com

⁴⁵ Leslie E, Saelens B, Frank L, et al. Residents' perceptions of walkability attributes in objectively different neighbourhoods: a pilot study. *Health Place* 2005;11(3):227–36.

⁴⁶ Sallis, J. F., Brownson, R. C., Hoehner, C. M., Day, K., & Forsyth, A. (2010). Measuring the Built Environment for Physical Activity. *American Journal of Preventive Medicine*, 36

⁴⁷ Sallis, I. F. 2010

⁴⁸ Brownson R, Hoehner C, Brennan L, Cook R, Elliott M, McMullen K. Reliability of two instruments for auditing the environment for physical activity. *J Phys Act Health* 2004;1:189–207

⁴⁹ Brownson R, Hoehner C, Brennan L, Cook R, Elliott M, McMullen K. 2004

⁵⁰ Saelens, B. E., Sallis, J. F., Black, J. B., & Chen, D. (2003). Neighborhood-Based Differences in Physical Activity : An Environment Scale Evaluation. *American Journal of Public Health Research and Practice*, 93(9), 1552–1558.

⁵¹ Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., & Saelens, B. E. (2005). Linking objectively measured physical activity with objectively measured urban form: findings from SMARTAQ. *American journal of preventive medicine*, 28(2 Suppl 2), 117–25.

WalkScore.com is a website that uses data from Google, Open Street Map, Education.com and Localeze to develop a numerical “WalkScore” for every address in the US, Australia and Canada, WalkScore also takes data inputted from its own users. WalkScores vary between 0 and 100, with 0 being the lowest walkability and 100 being the most walkable. WalkScore.com’s algorithm assigns points for destinations less than 0.25 miles, and does not assign points for destinations more than 1 mile away. WalkScore.com also rates some addresses for accessibility to transit, ease of bicycle commuting and is developing a new methodology to better account for surface street geography, known as the “Street Smart” WalkScore.

Although WalkScore is a relatively new methodology that uses data from some atypical sources for public health research, it has been validated as a way to assess walkability. A study of Rhode Island neighborhoods found that the WalkScore correlates with GIS-measured walkable destinations in neighborhoods⁵². In an analysis among youth in Boston, WalkScore was found to correlate strongly with GIS-measured walkability characteristics, particularly at larger spatial scales, of 800 meters and above⁵³. The same authors compared WalkScore validity across cities in regions across the United States, including the Pacific Northwest, East, Midwest and South, and found that WalkScore was valid in all regions, and was best at predicting walkability at the 1-mile radius⁵⁴.

The advantages of using WalkScore for the walkability measure in this study is that it is relatively easy to obtain WalkScores for a large number of areas and it is less costly to obtain than GIS-based methods, and it requires no special training to use.

While WalkScore has been used extensively in planning research, and has been corroborated with other measures of walkability, it is a relatively new measure in public health research⁵⁵. To date, only a handful of public health research studies have utilized WalkScore.com as a measure of walkability as it relates to health. One study of adolescent girls in Maryland in a masters thesis was unable to show an association between WalkScores and physical activity levels or BMI⁵⁶. However, another study in Boston did show an inverse relationship between diseases like obesity, diabetes and hypertension and WalkScore⁵⁷. These studies have focused on specific populations and urban areas, but not over a large geographic area. One study from King County

⁵² Carr, L. J., Dunsiger, S. I., & Marcus, B. H. (2011). Validation of Walk Score for estimating access to walkable amenities. *British journal of sports medicine*, 45(14), 1144–8.

⁵³ Duncan, D. T., Aldstadt, J., Whalen, J., & Melly, S. J. (2013). Validation of Walk Scores and Transit Scores for estimating neighborhood walkability and transit availability : a small-area analysis. *GeoJournal*, 78, 407–416.

⁵⁴ Duncan, D. T., Aldstadt, J., Whalen, J., Melly, S. J., & Gortmaker, S. L. (2011). Validation of walk score for estimating neighborhood walkability: an analysis of four US metropolitan areas. *International Journal of Environmental Research and Public Health*, 8(11), 4160–79.

⁵⁵ WalkScore.com <http://www.walkscore.com/professional/public-health-research.php>

⁵⁶ Jones, L.I. “Investigating Neighborhood Walkability and its Association with Physical Activity Levels and Body Composition of a Sample of Maryland Adolescent Girls” University of Maryland, Department of Epidemiology and Biostatistics 2010

⁵⁷ Mark Brewster, David Hurtado, Sara Olson, & Jessica Yen Walkscore.com: A New Methodology to Explore Associations Between Neighborhood Resources, Race, and Health. Harvard School of Public Health, Department of Society, Human Development and Health 2011

Washington has shown wide variations in obesity by zip code, and found that these variations are wider than disparities by race or by income⁵⁸.

Research Questions and Hypotheses:

1. What is the relationship between neighborhood walkability measured by WalkScore.com and BMI?
2. How does this relationship change when factors like income, education, race, age, sex, physical activity and disability are taken into account?
3. Is there a relationship between WalkScore and participation in physical activity of all types?

Hypothesis 1: There will be an inverse association between walkability and BMI.

Hypothesis 2: Factors like age, sex, race, income, disability, physical activity preference and education will explain some of the relationship between walkability and BMI, but the inverse association will persist even after controlling for these factors.

Hypothesis 3: People in more walkable neighborhoods will be more likely to participate in physical activity.

Methods:

Data collection and sources:

Obesity

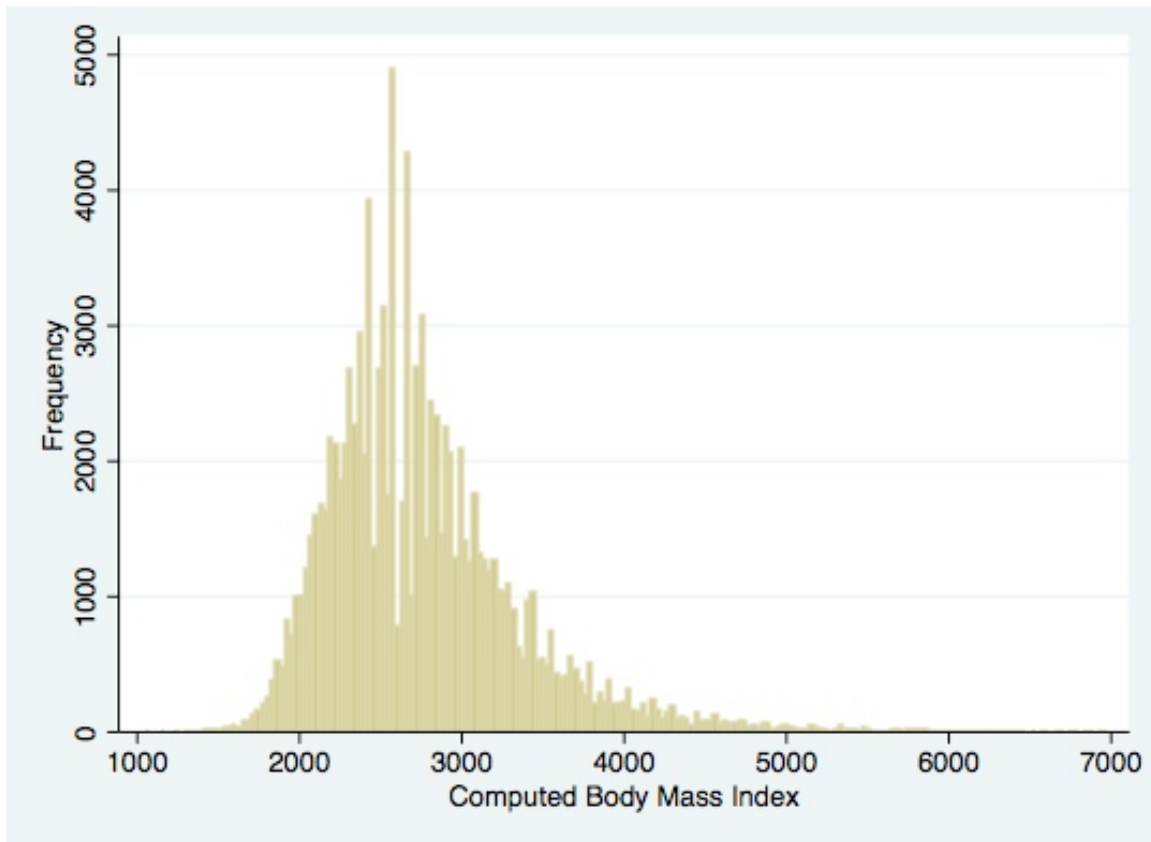
Obesity data were obtained from the Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is a nationwide land-line telephone survey administered by the Centers for Disease Control and Prevention. Since 1983, the CDC has administered the BRFSS yearly, using a core set of national questions as well as additional questionnaires that individual states add to the national survey. The BRFSS samples 430,000 people annually. The BRFSS uses post stratification weighting to adjust for nonresponse bias and to ensure that the individuals sampled represent the characteristics of each state. In 2011, the BRFSS began including mobile telephone numbers and changed their sampling method to iterative proportional fitting or “raking”⁵⁹. In Washington State, the BRFSS collects additional data on the individual’s zip code of residence, allowing for a finer geographic picture of the BRFSS data. The BRFSS samples approximately 19,000 households in Washington State each year. BRFSS yearly data were aggregated for the years 2006, 2007, 2008, 2009 and 2010 for Washington State to create a sample of 102,033 individual data points. BRFSS 2011 data, while available, were not included in

⁵⁸ Drewnowski, A., Rehm, C. D., & Solet, D. (2007). Disparities in obesity rates : Analysis by ZIP code area. *Social science & Medicine*, 65(12), 2458–2463.

⁵⁹ Centers for Disease Control and Prevention Fact Sheet on Improving Survey Methodology in the BRFSS 2013
http://www.cdc.gov/surveillancepractice/documents/DBS_BRFSS%20Improvements_12_232372_M_REM_5_25_2012.pdf

this study because the addition of the mobile telephone sampling and new sampling methods made it impossible to aggregate this data with the other years.

Figure 1: Distribution of BMIs in BRFSS in Washington State



Note: “Computed Body Mass Index” is a 4-digit number computed based on survey respondents reported height and weight. It is coded as a 4 digit number, instead of the usual 28.0 or similar. Thus, a BMI of 30.00 would be a Computed Body Mass index of 2800.

Computed Body Mass Index and Obesity:

< 1850 = underweight

1850-2490 = Normal

2500-3000 = Overweight

> 3000 = Obese

Walkability

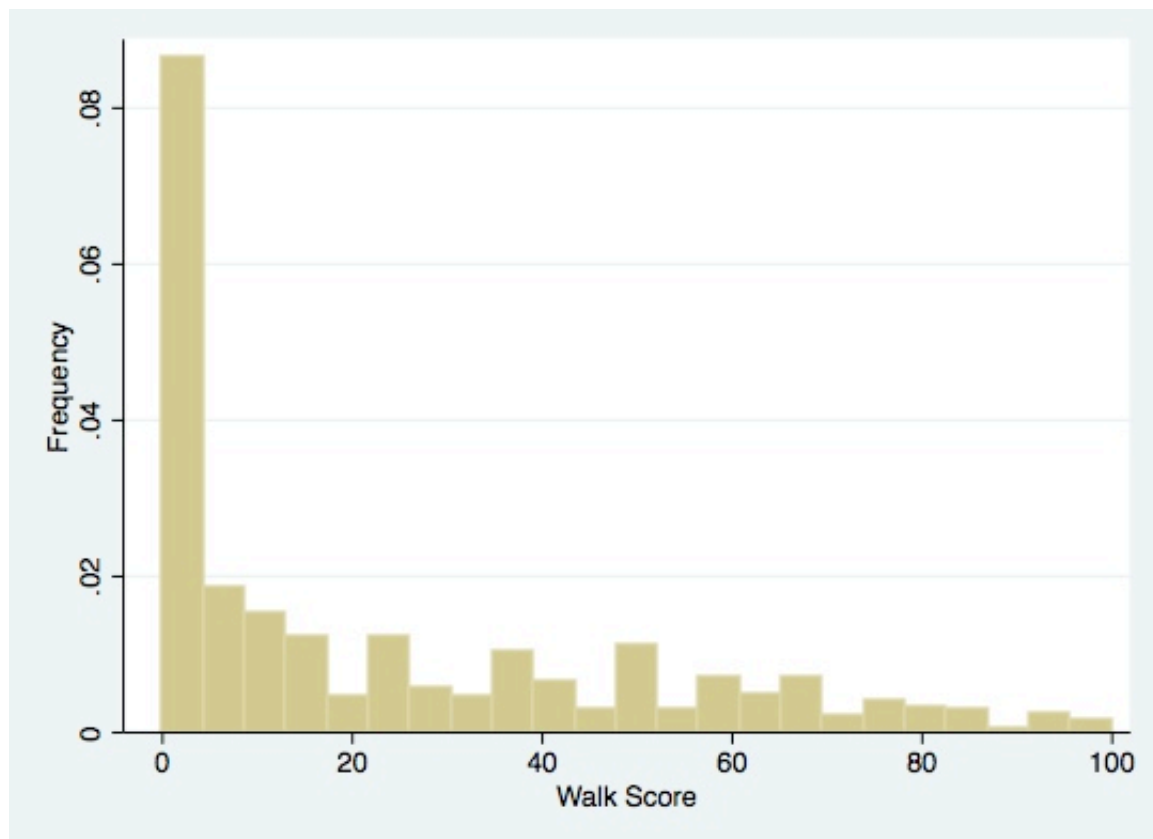
Walkability data were collected from WalkScore.com, a website that provides data on neighborhood walkability, public transit density and bicycle infrastructure for researchers, planners and real estate professionals. WalkScore.com’s algorithm awards points to addresses or specific latitudes & longitudes based on the number of amenities within one mile. Maximum points are awarded for facilities less than 0.25 miles and no

points are awarded for amenities greater than one mile⁶⁰. Facilities include retail, business, and school destinations. WalkScore.com uses data from Google, Open Street Map and Localeze. WalkScore users can also input data on destinations.

The WalkScore is assigned based on direct distances to amenities from a particular address. WalkScore.com is working to develop a “Street Smart WalkScore” which takes into account surface street walking routes to destinations by utilizing data on block lengths and destination addresses. Street Smart WalkScores were not available for all zip codes in Washington State, so these were not used in this study. WalkScores change relatively slowly over time, as facilities move into or out of a particular neighborhood, so the differences between Walkscores for 2006-2010 (when BRFSS data were obtained) and 2013 (current Walkscore) should be minimal.

Additionally, WalkScore.com breaks areas into four categories based on the numerical WalkScore. These categories are: Walker’s Paradise (90-100), Very Walkable (70-89), Somewhat Walkable (50-69) and Car-Dependent (0-49)⁶¹. The finest geographic information available for BRFSS data was the 5-digit zip code, so this was the variable chosen to approximate neighborhood.

Figure 2: Distribution of WalkScores In Washington State



⁶⁰ WalkScore.com WalkScore Methodology <http://www.walkscore.com/methodology.shtml>

⁶¹ WalkScore.com Why It Matters <http://www.walkscore.com/live-more/>

Some zip codes in Washington State are institutional zip codes (for universities or businesses, for example) had no residents associated with them, these 175 zip codes were not included in the analysis. Some rural zip codes in Washington State also have few residents associated with them, and thus even fewer BRFSS respondents. Zip codes with fewer than 10 BRFSS respondents were not included in the analysis, which resulted in dropping 5,529 surveys across the years of data. For each zip code, the geographic centroid latitude and longitude for the zip code was obtained from a free online database⁶². The centroid is the exact geographic center of the zip code. These latitudes and longitudes were used to generate a WalkScore associated with each zip code. In merging the BRFSS data with the WalkScores, there were a few zip codes that emerged with BRFSS respondents but no associated WalkScore. The majority of these zip codes had only one BRFSS respondent, and one zip code for which there was a Washington BRFSS respondent was actually located in Alaska. There were six zip codes with large numbers (from 223 to 1,109) of BRFSS respondents and no associated WalkScore. These zipcodes were manually entered into WalkScore's site and the calculated WalkScore was manually entered into an Excel file which was then imported into Stata.

As is clearly visible in the graph above, the distribution of WalkScores is not a normal distribution, it is instead heavily skewed towards the Car-Dependent category. Washington state has many, many zip codes that are very rural, and thus would be car-dependent in terms of distance between houses and necessities like schools and grocery stores.

Statistical Methods:

BRFSS data for the years 2006, 2007, 2008, 2009 and 2010 were merged. Missing data on zip code or BMI were dropped from the analysis. Linear regression was then used to calculate a raw regression coefficient for the relationship between WalkScore and BMI. Then, a new regression coefficient was calculated controlling for income, race, education level, disability, age, sex, general health status, and physical activity.

Then, logistic regression was used to calculate the association between the various categories of WalkScores: Walker's Paradise, Very Walkable, Somewhat Walkable, and Car-Dependent. Again, a raw regression coefficient and a regression coefficient controlling for income, race, education level, disability, age, sex, general health status, and physical activity were calculated.

To understand the association between WalkScore and physical activity, logistic regression was used to calculate an odds ratio for participation in physical activity in the last 30 days (a binary variable) based on different categories of WalkScore. Again, these odds ratios were controlled for income, race, education level, disability, age, sex, and general health status.

The software used was Stata 12 Data Analysis and Statistical Software, available from StataCorp.

⁶² <http://jeffreybreen.wordpress.com/2010/12/11/geocode-zip-codes/>

Results

Table 1: General properties of the population of BRFSS respondents (100,892) in WA State, unweighted data (Washington State US Census data in parentheses for comparison, where categories are similar⁶³)

Age		56.87 (16.69)
BMI (mean)		27.57 (± 0.59)
BMI (median)		26.63
Gender		
	Female	59.98% (50.1%)
	Male	40.00% (49.9%)
Education		
	Did not complete High School	6.3% (10.0%)
	High school diploma	24.7% (23.6%)
	Some college or technical school	32.0% (34.8%)
	College or technical school diploma	37.0% (31.6%)
Income		
	<\$15,000	6.9%
	\$15,000-25,000	16.6%
	\$25,000-35,000	13.5%
	\$35,000-50,000	17.6%
	>\$50,000	45.4%
Race		
	White	95.2% (81.6%)
	African-American	1.2% (3.9%)
	Asian-American	1.9% (7.7%)
	Pacific Islander	0.03% (0.7%)
	Native American	1.4% (1.8%)
Disability inhibiting physical activity		
	Yes	29.8%
	No	70.2%
Any physical activity in the last 30 days		
	Yes	79.8%
	No	20.2%

As is clearly visible in the demographic characteristics for the Washington state BRFSS respondents, there are some differences between BRFSS respondents and the WA state population as a whole. Some of this has to do with the different categories of race used by the BRFSS vs. the US Census, but it is still clear that the BRFSS population is much less racially diverse than the WA state population.

In terms of education, there are also differences in education between BRFSS respondents and the state population, with the BRFSS population having higher levels of educational attainment. There are also differences in categories of education between the BRFSS and the US Census, making exact parallels difficult.

⁶³ <http://quickfacts.census.gov/qfd/states/53000.html>

Income categories for the BRFSS and the US Census were unfortunately too different to compare easily.

WalkScore and BMI⁶⁴

The analysis of the association between WalkScore and BMI found that for every 10 point increase in WalkScore, BMI decreased by 0.077 points, with a p-value of 0.000 and a confidence interval of -0.009043 to -0.006441. When controlling for income, race, education level, disability, age, sex, general health status, and physical activity, the relationship changed in magnitude. Controlling for income, race, education level, disability, age, sex, general health status, and physical activity, for every 1 point increase in WalkScore, BMI decreased by 0.0041 with a p-value of 0.000 and a confidence interval of -0.005396 to -0.002708.

Table 2: BMI Levels Observed at Various WalkScore Categories, Before Controlling

WalkScore Category	25 th percentile BMI	Median BMI	75 th percentile BMI
Car-Dependent	23.68	26.66	30.48
Somewhat Walkable	23.35	26.44	30.18
Very Walkable	23.22	26.27	30.02
Walker's Paradise	22.73	25.38	29.11

When the association between BMI and WalkScore categories was examined, some larger differences in BMI were observed. As is visible in Table 2 above, there is a small, consistent inverse relationship in median BMI between people living in Car-Dependent zip codes compared to Somewhat Walkable, Very Walkable and Walker's Paradise categories.

When controlling for factors like income, race, education level, disability, age, sex, and physical activity, these differences in BMI persist but are somewhat smaller. Residents of a Walker's Paradise have a BMI that is 0.73 points lower, residents of a Very Walkable neighborhood have a BMI 0.29 points lower, and residents of a Somewhat Walkable neighborhood have a BMI 0.14 points lower.

These factors also have their own independent effects on BMI that are worth exploring as well.

Table 3: Income and BMI

Income category (yearly)	25 th percentile BMI	Median BMI	75 th percentile BMI
<\$15,000	23.62	27.40	32.35
\$15,000-25,000	23.68	27.01	31.16
\$25,000-35,000	23.68	26.68	30.48
\$35,000-50,000	23.83	26.68	30.75
>\$50,000	23.58	26.52	30.01

Table 4: Education and BMI

Education attainment	25 th percentile BMI	Median BMI	75 th percentile BMI
< High school	23.96	27.32	31.31
High School diploma	23.76	26.69	30.76
Attended College or Technical school	23.83	27.08	31.08
Graduated College or Technical school	23.10	25.88	29.35

Table 5: Self-Reported Race Category and BMI

Race	25 th percentile BMI	Median BMI	75 th percentile BMI
White	23.54	26.60	30.29
African-American	24.47	27.95	31.85
Asian-American	21.66	23.67	26.5
Pacific Islander	23.54	26.64	30.75
Native American	24.85	28.34	33.14

Although some self-reported race categories here had very small numbers of BRFSS respondents, they are included here for the sake of completeness.

Table 6: Age and BMI

Age	25 th percentile BMI	Median BMI	75 th percentile BMI
18-24 years	21.35	24.08	28.04
25-34 years	22.91	25.9	30.24
35-44 years	23.35	26.56	30.47
45-54 years	23.76	26.77	30.96
55-64 years	24.26	27.32	31.16
Over 65 years	23.54	26.41	29.71

Although weight typically rises with age, the median BMI among BRFSS respondents appears to initially increase with age and then decrease among people over 65. It is possible that either obese people are not surviving past the age of 65 or that after age 65, people become frail and begin to lose weight.

Table 7: Sex and BMI

Sex	25 th percentile BMI	Median BMI	75 th percentile BMI
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Male	24.46	27.25	30.47
Female	22.86	25.88	30.27

Table 8: Disability impeding participation in physical activity and BMI

Are you limited in any way in any activities because of physical, mental, or emotional problems?	25 th percentile BMI	Median BMI	75 th percentile BMI
Yes	24.38	27.95	32.48
No	23.29	25.90	29.60

Table 9: Leisure time physical activity and BMI

Any leisure time physical activity in the last 30 days?	25 th percentile BMI	Median BMI	75 th percentile BMI
Yes	23.43	26.31	29.89
No	24.42	28.12	32.68

Table 10: WalkScore and Physical Activity compared to a Car-Dependent zipcode

WalkScore Category	<i>Odds ratio of any physical activity in the last 30 days</i>
Somewhat Walkable	1.06(1.03-1.10)
Very Walkable	1.11 (1.04-1.17)
Walker's Paradise	1.33 (1.19-1.48)

When controlling for income, race, education level, disability, age, sex and general health status, the odds ratios were less in magnitude and no longer statistically significant.

Discussion

The association between WalkScore and BMI was in the expected direction, as WalkScore increased, BMI decreased. As expected in the hypothesis, the association decreased in magnitude but still existed in the same direction when controlling for income, race, education level, disability, age, sex, general health status and physical activity. When analyzing the WalkScore categories, the differences between BMI in each of the different categories was statistically significant, and larger in magnitude compared to the regression coefficient for each single-point difference in WalkScore.

The association between WalkScore and physical activity was less statistically significant than the association between WalkScore and BMI, but was still in the expected direction. People living in a Walker's Paradise were more likely to have been physically active in the last 30 days compared to people who lived in a Car-Dependent area. When income, race, education level, disability, age, sex, general health status were controlled, the magnitude of the differences between the WalkScore categories decreased and the p-values increased to slightly greater than 0.05, making them no longer statistically significant, according to that p-value cutoff. Since the survey question was asking: "During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?" it is possible that survey respondents did not count utilitarian walking, which is the type of walking this study is interested in. This would mean that less people than expected would report physical activity, biasing results towards the null.

The magnitude of the associations was not large, even though the associations were in the expected direction and were significant. The limitations of the study are described below. The limitations described all would likely bias the result towards the null, and so it is not surprising that the magnitude of the association is not large.

Interestingly, the factors in Tables 3-9 appear to be associated with much greater differences in BMI compared to the WalkScore categories. The characteristics of race, education, age, disability, and sex all had greater differences in the magnitude of BMI. As a behavior, recent leisure time physical activity also appeared to be more strongly associated with BMI than the WalkScore.

It is worth noting that the race category had the largest difference in magnitude of BMI, however, the BRFSS sample was so highly skewed towards white respondents that the sample sizes of people from other races represented an extremely tiny sample by comparison. It is possible that the "white" category was thus comparatively a much more representative sample, whereas the others could have been skewed by errors in sampling. Because of this over-representation of whites, it would be incorrect to draw too many conclusions about race-based differences in BMI.

Limitations

WalkScore Limitations

Although WalkScore has been validated as a method for assessing walkability that is comparable to other methods, it still has some limitations as a method. This analysis did not take advantage of the Street Smart WalkScore, which takes into account surface street geography to create walking routes, not just direct distance. Unfortunately, the Street Smart WalkScore was not available for all zip codes within a given area. This could mean that for some areas, the WalkScore could be artificially high, if the WalkScore algorithm assumes an area has high walkability based on proximity to amenities inaccessible across a freeway, for example.

WalkScore may also not reflect actual walking behavior. Factors like weather, having small children or infants, street connectivity (cul-de-sacs may make walking to amenities

difficult or impossible) perception of street crime, etc all affect whether someone chooses to walk⁶⁵. The proximity of amenities is not the only determinant of walking behavior. WalkScore also may not capture where people spend the majority of their time. Depending on work schedules, some people may spend more time at work than at home, or may have to drive long distances to commute to work or school. Also, if a BRFSS respondent moved recently, the WalkScore at their current address may not reflect the exposure that influenced their current BMI. WalkScore also does not capture neighborhood features like aesthetics, traffic noise or perceived safety, some of which can make a difference in walking behavior.

A final limitation with WalkScore is that although WalkScores exist for every point between 0 and 100, in terms of actual walking behavior, a WalkScore of 10 may not be much different from a WalkScore of 20, 30 or 40. The WalkScore category analysis was an attempt to address this problem, and did show larger differences between the WalkScore categories.

BRFSS Limitations:

The BRFSS has its own set of limitations as well, and these are well-documented given that the BRFSS has been administered yearly for 30 years. The two main limitations of the BRFSS are the selection bias in sampling the participants and information bias in reporting of weight and height for respondents.

Because the BRFSS is a land-line telephone survey, it under-samples people who are more likely to own a mobile telephone, such as younger people, renters and Latinos⁶⁶. The BRFSS also over-represents women, whites, unemployed people, households consisting of one man and one woman, and married people; it under-samples employed people, people with low education and Asians⁶⁷. As described above, this over-representation of whites led to a very skewed sample when looking at race and BMI.

Self-reported weights and heights can also be inaccurate. In the BRFSS, people mis-report their self-reported weights and heights in predictable ways. Regardless of gender, underreporting of weight increases with increasing BMI and older people over-report height, males over-report height more than females⁶⁸. This leads to a self-reported obesity

⁶⁵ Montemurro, G. R., Berry, T. R., Spence, J. C., Nykiforuk, C., Blanchard, C., & Cutumisu, N. (2011). "Walkable by Willpower": resident perceptions of neighbourhood environments. *Health & place*, 17(4), 895–901

⁶⁶ Centers for Disease Control and Prevention Fact Sheet on Improving Survey Methodology in the BRFSS 2013
http://www.cdc.gov/surveillancepractice/documents/DBS_BRFSS%20Improvements_12_232372_M_REM_5_25_2012.pdf

⁶⁷ Rao, R. S., Link, M. W., Battaglia, M. P., Frankel, M. R., Giambo, P., & Mokdad, A. H. (n.d.). Assessing Representativeness in RDD Surveys: Coverage and Nonresponse in the Behavioral Risk Factor Surveillance System. *ASA Section on Survey Research Methods*, 3495–3501.

⁶⁸ Jain, R. B. (2005). Regression models to predict corrected weight, height and obesity prevalence from self-reported data: data from BRFSS 1999-2007. *International Journal of Obesity* (2005), 34(11), 1655–64.

prevalence that is 4-5% lower than what would be predicted based on population modeling⁶⁹.

Methodology Limitations:

Relying on zip-code geographic centroid data may have generated a zip-code WalkScore that does not accurately reflect the walkability of that particular zip code. While geographic centroids are convenient to identify, they may not reflect the actual population center of a zip code⁷⁰. Population centroid data would have perhaps been a better choice, but they are not as easily available as geographic centroid data. Another method to obtain a more accurate WalkScore for each zip code would have been to pick several street addresses at random within each zip code, generate a WalkScore for each point, and then generate an average zip code WalkScore from those scores. This was beyond the scope of this project.

Zip codes themselves are not a perfect approximation of “neighborhood,” and this is another limitation of using zip codes for this project. The US Postal Service defines zip code boundaries for ease of delivering mail, not for drawing neighborhood boundaries for public health research. Unfortunately, the zip code was the finest geographical data point for the BRFSS. A more accurate approximation of neighborhood might have been the census block group, for which a geographic centroid latitude and longitude could be obtained to generate a WalkScore.

For this analysis, the data from the BRFSS were used without sampling weights. The BRFSS uses sampling methods and weights (see Methods above) to ensure an accurate reflection of the population demographics of each state⁷¹. Using survey sampling weights is beyond the scope of this project, recognizing that this approach has some significant pitfalls⁷². Since I am limiting my analysis to zip codes with larger populations and larger numbers of respondents on the BRFSS, I expect that the weighting will matter less than it would if I were including these rural zip codes.

Strengths

The main strength of this project is the sample size gained by combining multiple years into a large total number of 102,033 responses, which is a large sample size. This large sample size yielded p-values that were well below 0.05 for most results.

Another strength of this project is the wide geographic area that was analyzed. Other studies that have attempted to analyze the association between walkability and BMI have

⁶⁹ Jain, R.B. 2010 International Journal of Obesity

⁷⁰ Berke, E. M., Koepsell, T. D., Moudon, A. V., Hoskins, R. E., & Larson, E. B. (2007). Association of the built environment with physical activity and obesity in older persons. *American journal of public health*, 97(3), 486–92

⁷¹ Mokdad, A. H. (2009). The Behavioral Risk Factors Surveillance System: past, present, and future. *Annual review of public health*, 30, 43–54.

⁷² Brogan, D. J. (1998). Pitfalls of Using Standard Statistical Software Packages for Sample Survey Data. *Encyclopedia of Biostatistics* (pp. 1–18).

focused on smaller areas, such as a single urban area or county. This project looks at an entire state, with a large diversity of neighborhood designs.

Implications

As discussed above, the association between WalkScore and BMI was in the expected direction, meaning that higher WalkScores were associated with lower BMIs. Although the magnitude of this association was not extremely large, the fact that the association persisted when controlling for a host of other variables is significant from a research and a policy standpoint.

First, what this study shows is that WalkScore has excellent potential as a public health research tool in the area of walkability. Other studies have validated WalkScore's correlation with more complicated measures of walkability, but this shows that some of the same findings from other research hold true when WalkScore is used instead of those measures. Compared to GIS-based measures or assessment tools, WalkScore is relatively easy to use. Hopefully it will be used more in public health and built environment research.

In addition to showing the potential for using WalkScore, this study also has some public health and policy implications. That the association between WalkScore and BMI persisted once income, race, education level, disability, age, sex, general health status, and physical activity were controlled shows that walkability does have some relationship with BMI. It is also worth noting that although there were large differences in BMI associated with these other factors, there did appear to be an association between participation in physical activity and WalkScore.

Another important implication from this study is that social determinants of health, such as race, income and education, all influence BMI as much as WalkScore and physical activity. These social determinants are complicated to associate with physical activity and BMI but they are clearly a key part of the puzzle in associating walkability and BMI.

Finally, despite the limitations of this study, the association between WalkScore and BMI is still present and merits at least considering public health and physical activity in neighborhood design.

Areas for Further Research

There are many additional questions that could be explored based on the findings in this project:

- Choosing a finer geographic gradient than zip code to determine the WalkScore, such as census block or 9-digit zip code – this could get a closer geographic approximation of the WalkScore associated with each BRFSS respondent
- Comparing the strength of the association with other variables, like property values⁷³, that have been shown to be strong predictors of obesity

⁷³ Drewnowski A¹, Rehm CD, Solet D, Disparities in obesity rates: analysis by ZIP code area. Social Science and Medicine. 2007 Dec;65(12):2458-63

- Exploring how the analysis changes using different data sources, like Street Smart WalkScore, or using the 2011 or 2012 BRFSS data, which utilizes a different sampling method than previous data and includes mobile telephone numbers
- Using the BRFSS sampling weights in the analysis would improve the representativeness of the study population, and it would be useful to compare how this changes the relationship
- Using data from additional national surveys, such as the National Household Travel Survey to link transportation behavior to WalkScores and BMI, if possible
- Comparing the association uncovered in this study with the strength of association with other measures of walkability, such as GIS-based methods

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