Effects of Neighborhood SES and Walkability on Obesity: Comparing Adolescents and Young Adults to Assess Selection and Causal Influences

Ken R. Smith
Cathleen D. Zick
Lori Kowaleski-Jones
Barbara B. Brown
Ikuho Yamada
Jessie X. Fan

University of Utah

Paper presented at the 2008 Annual Meetings of the Population Association of America, April, New Orleans Louisiana.

Introduction

Obesity and overweight are major public health problems. An estimated 65% of US adults are overweight or obese (Hedley et al., 2004) with up to 280,000 annual deaths attributable to obesity (Allison, Fontaine, Manson, Stevens, & Vanltallie, 1999; Flegal, Graubard, Williamson, & Gail, 2005). Given rapid increases in obesity, researchers have begun to emphasize how obesogenic physical environments may account for this trend (Jeffery & Utter, 2003). Yet, observational studies linking the physical environment to the risk of being overweight or obese are limited by the fact that residents do not select their neighborhoods at random. If significant associations are found between neighborhood characteristics and residents' overweight and obesity rates in observational studies, one cannot confidently draw conclusions about causality. Neighborhood features may prevent or reduce overweight and obesity by causing people to be more physically active or choose healthier diets; alternatively, individuals with healthy body mass indices (BMIs) may choose neighborhoods that support their pre-existing healthy lifestyle.

To assess the potential for non-random selection of residents into neighborhoods, we undertake cross-sectional analyses that contrast the neighborhood determinants of youth and young adult risks of being overweight or obese, using driver license data from the Utah Population Database (UPDB). This analysis assumes that youths have no input into their parents' choice of residential location but after they leave their parents' homes, their residential location choices may be affected by their own preference for physical activity, as well as other factors such as proximity to kin, work, open space, and food-related businesses, and the social and cultural composition of the neighborhood. Under these assumptions, neighborhood characteristics are viewed as an exogenous determinant of youth BMI (Ewing, Brownson, & Berrigan, 2006) but not young adults'

BMI. This suggests that comparisons of age-specific regressions that relate neighborhood characteristics to individual BMI can shed light on the issue of neighborhood selection bias.

Neighborhood Characteristics and BMI

Past research has found relationships among walkable neighborhood designs, support for physical activity and healthy eating, and the risk of being overweight and/or obese (Doyle, et al., 2006; Ewing, et al., 2006; Giles-Corti, et al., 2003; Lopez, 2004; Ross, et al., 2007; Rundle, et al., 2007; Smith, et al., 2008). These studies use a range of walkability measures but reach fairly consistent conclusions about neighborhood walkability and BMI. For example, some research has linked higher density neighborhoods to lower BMI (Lopez-Zetina, Lee, & Friis, 2006; Lopez, 2004; Ross et al., 2007; Rundle et al., 2006; Smith et al., under review; Stafford et al., 2007; Vandegrift & Yoked, 2004). Indicators of diverse and walkable destinations in a neighborhood have been associated with lower weight (Frank, Andresen, & Schmid, 2004; Mobley et al., 2006; Rundle et al., 2006; Smith et al., under review; Stafford et al., 2007; Tilt, Unfried, & Roca, 2007). More pedestrian friendly street connectivity or accessible and high quality sidewalks have also been associated with fewer weight problems (Boehmer, Hoehner, Deshpande, Ramirez, & Brownson, 2007; Doyle, Kelly-Schwartz, Schlossberg, & Stockard, 2006; Giles-Corti, Macintyre, Clarkson, Pikora, & Donovan, 2003; Smith et al., under review). In all of these studies, neighborhood characteristics are treated as exogenous factors. That is, land use diversity, density, and design as well as the social and cultural aspects of a neighborhood are seen as predetermined factors that affect an individual's risk of being overweight or obese.

More recently, work by Plantinga and Bernell (Plantinga & Bernell, 2005; Plantinga & Brenell, 2007) challenges the assumption that neighborhood characteristics are fixed. They build and test a model where choices about residential location are made simultaneously with choices about work, leisure, and consumption. Using longitudinal data from the National Longitudinal Survey of Youth, Plantinga and Bernell estimate a cross-sectional model where BMI is estimated as a function of a contemporaneously measured county-level sprawl, based upon Ewing's index that combines measures of density and pedestrian friendly design (Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003). The results of this model are then compared to the results of a longitudinal mover-stayer model where the change residential location is modeled as a function of the pre-move BMI while the subsequent change in BMI is modeled as a function of the change in the county sprawl index. Although these later analyses are based on relatively small sample sizes (Ns ranging from 262 to 381), Plantinga and Bernell find evidence suggesting that BMI and residential location are likely simultaneously determined; individuals lose weight when they move to denser neighborhoods and lower BMI individuals choose denser neighborhoods.

The results of Plantinga and Bernell's empirical work (2007) lead them to question public policy initiatives aimed at reducing weight problems by modifying neighborhood environments to promote greater physical activity. They argue that such initiatives may serve to attract residents who already have lower BMIs thus limiting the effectiveness of such policies in reversing recent trends in obesity.

Plantinga and Bernell's analyses raise interesting questions about the underlying relationship between residential location and BMI. In this paper, we build upon their work in several ways. First, we employ more fine-grained geographies to capture neighborhood characteristics that may be associated with BMI. Plantinga and Bernell are limited to a county-level measure of sprawl which they treat as a dichotomous variable. In contrast, our analyses are based on census block group and census tract level measures of specific neighborhood characteristics that have been linked to BMI in past studies.[1] Thus, we use a smaller geographic scale and more detailed indicators of at neighborhoods that may better represent the size of the neighborhood typically associated with physical activity, such as walking (Colabianchi et al., 2007).

Second, rather than rely on a small number of movers to assess the endogeneity of residential location and BMI, we compare the estimated relationships between neighborhood characteristics and overweight/obesity risk for two groups. The first group is composed of 16 to 18 year olds who, as dependents, are likely to have little or no choice over their family's residential location. The second group is composed of individuals aged 27 to 29 who, in most instances, will have established residence independent of their families of origin and thus, can be viewed as making choices that allow for the possibility that BMI and residential location are simultaneously determined. If the relationships between neighborhood characteristics and overweight/obesity risk do not differ across the two groups, we will conclude that there is little evidence of residential self-selection by BMI. In contrast, if the relationships are significantly different by age, then this would re-affirm Plantinga and Bernell's residential selection thesis and it would show on which dimensions the selection mechanisms may be operating.

The strategy of making age comparisons to evaluate selection bias in neighborhood research builds upon prior research. Turley (Lopez Turley, 2003) examined whether the effects of neighborhood characteristics were stronger for children who lived in a neighborhood longer, suggesting that it is neighborhood factors, rather than family characteristics, that affect childhood outcomes. Kowaleski-Jones et al. (2006) used this strategy to examine selection bias in studies of neighborhood characteristics and youth outcomes. Indeed, this strategy of cross-sectional

[1] Approximately 4,000 individuals comprise a census tract while about 1,500 individuals comprise a census block group.

comparisons by age may be an effective tool in understanding the nature of selection bias in non-experimental data.

Research Design

This study utilizes data from the Utah Population Database (UPDB). The UPDB is one of the world's richest sources of linked population-based information that focus on demographic, genetic, epidemiological, and public health outcomes. It includes information on over 1.6 million individuals. Measures of BMI, overweight, and obesity, as well as spatial location are derived from driver license data that have been linked to the UPDB under an agreement with the Utah Department of Public Safety. As part of the University of Utah's Institutional Review Board approval process, the UPDB staff retains the driver license address information and provides researchers with driver license BMI information linked to census block groups via Universal Transverse Mercator (UTM) coordinates. Height and weight information are converted to BMI (weight in kg/height in m^2) and then converted again to categorical measures of overweight ($25 \leq BMI < 30$) and obesity ($BMI \geq 30$) in relation to healthy weight ($18.5 \leq BMI < 25$).

The UPDB has the advantage of extensive coverage but the potential disadvantages of self-reported weight and a time lag between the physical environment and weight measures. The weight data likely share the limitations of self-reported weight in other studies. Specifically, individuals often underestimate their weight (Gorber, Tremblay, Moher, & Gorber, 2007; Nawaz, Chan, Abdulrahman, Larson, & Katz, 2001) with especially high error rates on self-reported weight for those over age 60 (Kuczmarski, Kuczmarski, & Najjar, 2001). Nevertheless, self-reported weights, such as those in the CDC Behavioral Risk Factor Surveillance System (BRFSS), have proved valuable for monitoring obesity trends in the US (Centers for Disease Control and

Prevention, 2007; Mokdad et al., 2003). Given self-reported weight underestimation, the time lag between census and driver license data, and the fact that individuals typically gain weight over time, the estimates in this study are likely underestimates of current weight. We have no evidence that self-reported weight is geographically biased.

For the purposes of the current study, we selected all individuals in the UPDB between the ages of 16 to 18 and 27 to 29 who had valid driver licenses and lived in Salt Lake County. These age and geographic restrictions resulted in samples of 8,876 males and 8,599 females between the ages of 16 and 18, and 26,791 males and 22,556 females between the ages of 27 and 29.[2] The age category 27 to 29 is used as the comparison because these individuals are likely to have left home (White, 1994), completed schooling, and to have exercised choice in their residential location. We elect to focus on residents of Salt Lake County because of its considerable variation in neighborhood diversity, density, and design as measured for 564 census block groups in the county (Smith et al., under review).

Neighborhood characteristics taken from the 2000 Census and measured at the block group and census tract level are linked to individuals in the UPDB based on the UTM for their residence. Measures of density and walking to work are assessed at the block group level. Information on median age of houses in the neighborhood is not available at the block group level, so it is assessed at the census tract level. Pedestrian-friendly design is measured by street connectivity and our proxy for this is the number of intersections within a quarter mile of the resident's home. Street

[2] The Federal Highway Administration (2008) estimates that only 29.6% of 16 year olds had a driver license in 2006. Thus, the sample size difference between the two age groups reflects the difference in the propensity to have a driver license by age. Utah requires that drivers provide height and weight information at the time they get their license and that it be updated after a change of residence, name changes, loss of license, or at the time of renewal which is required every ten years. Assuming that most of the 27-29 year olds recently renewed their driver licenses, both age groups should have relatively current height and weight reports.

connectivity is derived from street centerline data from the Salt Lake County assessor's office (www.assessor.slco.org/cfml/GIS.cfm). The University of Utah DIGIT Lab calculated intersections within buffers that extend .25 mile from a point that approximates the location of the home (i.e., a 10-meter perpendicular offset from the center line of the road in front of the resident's home).

At the individual level, all analyses control for individual-level age and sex as recorded on the driver license. Additional socio-demographic census variables taken from the 2000 census include neighborhood racial/ethnic composition (the proportion of the block group that is Hispanic, African-American, Hawaiian/Pacific Islander, and Asian), median family income, and median age of individuals in the block group.

Logistic regressions are estimated to assess if neighborhood characteristics relate to the odds of being overweight and obese in relation to having a healthy BMI when controlling for individual and neighborhood socio-demographic characteristics. These logistic regressions are estimated separately for males and females. To test explicitly for neighborhood selection effects, we include both the 16-18 year olds and the 27-29 year olds together in the same regression. We also include a dummy variable set equal to one if the respondent is age 16-18, and set equal to zero otherwise, that is interacted with all of the independent variables in the regression. We view the coefficients for the 16-18 year olds as valid estimates of the structural relationships between neighborhood design and individual BMI *assuming that adolescents have little or no voice in residential choice*. Thus, the interaction effects become a test of neighborhood selection if the effects of neighborhood characteristics for individuals age 27-29 include the influence of their residential preferences along with "true" neighborhood effects.

All estimation uses SAS software (Cary, NC, 2002 Version 9.1.3 using PROC SURVEYLOGISTIC). Analyses adjust for statistical dependence among observations induced by clustering of cases within block groups (Binder, 1983; Särndal, Swenson, & Wretman, 1992). Given our large sample size, the significance level adopted is $p \leq .05$.

Results

Variable definitions and mean values by BMI status (i.e., healthy weight, overweight, obese) are presented in Table 1 for the females and in Table 2 for the males. Several elements of these tables are noteworthy. First, we find that while males in either age group have higher rates of overweight and obesity than their similarly aged female counterparts, the risk of being overweight or obese increases with age for both genders. For the females, 85% of the 16-18 year olds are in the healthy weight group but the figure falls to 71% for women in the 27-29 year old age group. Correspondingly, for males the figures are 77% in the healthy weight group for the 16-18 year olds and 52% for the 27-29 year olds.

[Insert Tables 1 and 2 Here]

Second, at the bivariate level, it would appear that many of the associations between the socio-demographic characteristics of a neighborhood and BMI that hold for 16-18 year olds are also present for the sample of 27-29 year olds. Specifically, overweight and obese females in both age groups are more likely to live in lower income neighborhoods, in neighborhoods with higher proportions of Hawaiians/Pacific Islanders and Hispanics, and in neighborhoods where the age of the median resident is younger, compared to similarly aged healthy-weight females. These age patterns also hold for males in Table 2.

Finally, young adults live in neighborhoods that differ from those of 16-18 year olds, and these differences are consistent with what is known about residential histories. Young adults live in neighborhoods that could be characterized as more walkable than the neighborhoods of the teen-agers. Both males and females age 27-29 tend to live in older and denser neighborhoods relative to their younger counterparts. They also tend to live in neighborhoods where higher proportions of workers walk to work and pedestrian friendly design (i.e., intersection density) is greater. But, no clear pattern emerges between these physical features of a neighborhood and BMI within age/gender groups.

Estimates for female risk of being overweight relative to healthy weight demonstrate clear patterns of statistical significance that do not vary by age group.[3] This conclusion is based on the lack of significant interaction terms in the overweight model. Females are more likely to be overweight when the neighborhood population has greater proportions of Hawaiian/Pacific Islanders and Hispanics, lower resident ages, and lower family median incomes, as shown in Table 3. Conversely, lower risks of female overweight are associated with higher proportions of the population that is Asian, higher proportions of workers who walk to work, and older neighborhood housing. These relationships hold for both the females age 16-18 and their counterparts age 27-29, suggesting no evidence of selection for these factors associated with overweight.

[Insert Table 3 Here]

[3] The coefficient associated with the age interaction on median year built does come close to being statistically significant (p=.0518).

For models that examine the risk of being obese among women, associations are somewhat more complicated. We again find that both age groups are more likely to be obese in neighborhoods with greater proportions of Hispanics and younger residents and less likely to be obese in older neighborhoods with more residents who walk to work. But, the estimates also show that more pedestrian friendly neighborhoods (i.e, those with greater intersection density within a quarter mile radius of the individual's home) are associated with higher risks of adolescent females being obese while they do not affect the risk of being obese among the older females, *ceteris paribus*. In addition, the significant relationship between decreasing median family income in the neighborhood and the increasing risks of female obesity are stronger for adolescents than it is for young adults. These results suggest that there may be some simultaneity between choice of residential location and the risk of obesity for females.

Logistic regressions for males are presented in Table 4 where we do not generally find support for the hypothesis that residential location and BMI are endogenous. The results are remarkably consistent across age groups and across the two equations for overweight and obesity risk. Both the risk of being overweight and the risk of obesity are related to lower median family income in the neighborhood, younger median age of residents in the neighborhood, greater proportions of workers who walk to work in the neighborhood, and older median ages of homes in the neighborhood. Male overweight or obesity risk is also related to greater proportions of residents in the neighborhood who are Hispanic. These statistically significant associations hold for males in both age groups.

[Insert Table 4 Here]

One age-related interaction is statistically significant in both of the males' logistic regressions. For the equation for the risk of being overweight, the proportion of the population who are Asian is positively related to the risk of being overweight among those aged 16-18 but is insignificant for males aged 27-29. Similarly, in the equation that focuses on the risk of obesity, the lower the median family income the higher the risk of obesity, but the relationship is stronger for the 16-18 year old males than it is for the 27-29 year old males.

Discussion and Conclusions

Our analyses of causal and selection mechanisms linking neighborhood characteristics to an individual's risk of having an unhealthy weight is predicated on the assumption that 16-18 year olds have little or no choice over their residential location. Consequently, neighborhood characteristics are exogenous factors affecting the BMI of these adolescents. We further assume that 27-29 year olds have considerable choice over their residential location. If preferences for physical activity and eating options affect young adults' choices about residential location, then models that treat neighborhood characteristics as exogenous are misspecified. These assumptions allow us to compare coefficients estimated for the 27-29 year olds to those estimated for the 16-18 year olds as a test of neighborhood selection effects.

We find robust effects of median neighborhood income, neighborhood ethnic composition, median age of residents in the neighborhood, the proportion of workers who walk to work, the median year the neighborhood housing was built on the risk of being overweight and obese. These results are consistent and they strongly suggest that both socio-demographic and physical features associated with neighborhood walkability affect people's level of physical activity and consequently their BMI.

The percentage of workers in a neighborhood who walk to work is typically low, averaging less than 3% in the U.S and less than 2% in Salt Lake County. Thus, walking to work by that small fraction of individuals is unlikely to be directly responsible for the lower BMI of a particular person in the neighborhood. Rather, higher proportions of individuals who walk to work likely indicate a neighborhood with other walkability features that may encourage residents to walk more generally. This same argument may hold for the housing age variable as well. Berrigan and Troiano (Berrigan & Troiano, 2002) note that older housing is associated with neighborhoods that mix business with residential land uses, and that have more sidewalks, and more interconnected streets. Our analyses demonstrate a robust effect for housing age on weight outcomes, even after controlling for other physical features of the neighborhood. Likewise, median income in a neighborhood along with the neighborhood's demographic composition may be capturing a mix of neighborhood walkability effects including increased access to recreational opportunities (e.g., gyms, community centers) and more appealing walking venues (e.g., parks).

Our analyses have key advantages over previous work by Plantinga and Bernell (2007) in our use of more numerous and more immediate measures of the neighborhood environment. In addition, we have the statistical advantage of much larger sample sizes. That said, we have weaker evidence regarding residential selection effects than Plantinga and Bernell. For females, the strongest evidence exists when estimating the risks of being obese relative to healthy weight with weaker evidence revealed in the equation estimated for the risk of being overweight relative to healthy weight. For males, the linkages between neighborhood characteristics and the risk of being overweight or obese are remarkably consistent across teen and young adults suggesting that selection effects are even weaker for men.

An intriguing finding is the interaction effect between neighborhood-level median family income and age with respect to the risk of obesity. For both genders, rising median family income reduces the risk of obesity but this association is stronger for teens than for young adults. This suggests that neighborhood income may be an axis on which selection mechanisms occur. Specifically, areal income among teens is largely based on living in neighborhoods with middle-aged parents given the presence of teens. These neighborhoods, as seen in Tables 1 and 2, have median income levels that are roughly ten thousand dollars higher than the neighborhoods in which the young adults are living. A plausible reason for this is the idea that young adults, after ”leaving the nest,” will gravitate to areas with more affordable housing given their weaker economic standing, at least in relation to what they had when living with their parents. If this is true, then one of the important neighborhood characteristics examined by most social scientists, area-level income, may be biased because of the non-random selection of residents to certain residential locations because of income. Indeed, our own estimates of the effects of block-group median family income for young adults is biased downward because of these possible selection mechanisms.

At the same time, given our research design, we found weak or non-existent selection effects between teens and young adults associated with neighborhood walkability. If our results are supported by other investigations, then they argue for continuation of the use of policy and design mechanisms to create more walkable environments.

Definitive evidence of the presence or absence of residential selection bias awaits replication of the approach used here in other geographic locations and a more diverse set of local land use measures (e.g., measures of the food environment). In addition, insights could be gained by applying Plantinga and Bernell’s instrumental variables approach and their mover-stayer model to longitudinal data sets that contain measures of the residents’ immediate neighborhood characteristics.

References

Allison, D. B., Fontaine, K. R., Manson, J. E., Stevens, J., & Vanltallie, T. B. (1999). Annual deaths attributable to obesity in the United States. *Journal of the American Medical Association, 282*, 1530-1538.

Berrigan, D., & Troiano, R. P. (2002). The association between urban form and physical activity in us adults. *American Journal of Preventive Medicine, 23*(2), 74-79.

Binder, D. A. (1983). On the variances of asymptotically normal estimators from complex surveys. *International Statistical Review, 51*, 279 - 292.

Boehmer, T. K., Hoehner, C. M., Deshpande, A. D., Ramirez, L. K. B., & Brownson, R. C. (2007). Perceived and observed neighborhood indicators of obesity among urban adults. *International Journal of Obesity, 31*(6), 968-977.

Centers for Disease Control and Prevention. (2007). Health risks in the United States: Behavioral Risk Factor Surveillance System at a glance 2007.

Colabianchi, N., Dowda, M., Pfeiffer, K. A., Porter, D. E., Almeida, M., & Pate, R. R. (2007). Towards an understanding of salient neighborhood boundaries: Adolescent reports of an easy walking distance and convenient driving distance. *International Journal of Behavioral Nutrition and Physical Activity, 4*.

Doyle, S., Kelly-Schwartz, A., Schlossberg, M., & Stockard, J. (2006). Active community environments and health - the relationship of walkable and safe communities to individual health. *Journal of the American Planning Association, 72*(1), 19-31.

Ewing, R., Brownson, R. C., & Berrigan, D. (2006). Relationship between urban sprawl and weight of United States youth. *American Journal of Preventive Medicine, 31*(6), 464-474.

Ewing, R., Schmid, T., Killingsworth, R., Zlot, A., & Raudenbush, S. (2003). Relationship between urban sprawl and physical activity, obesity, and morbidity. *American Journal of Health Promotion, 18*(1), 47-57.

Flegal, K. M., Graubard, B. I., Williamson, D. F., & Gail, M. H. (2005). Excess deaths assocatied with underweight, overweight, and obesity. *Journal of the American Medical Association, 293*, 1861-1867.

Frank, L. D., Andresen, M. A., & Schmid, T. L. (2004). Obesity relationships with community design, physical activity, and time spent in cars. *American Journal of Preventive Medicine, 27*(2), 87-96.

Giles-Corti, B., Macintyre, S., Clarkson, J. P., Pikora, T., & Donovan, R. J. (2003). Environmental and lifestyle factors associated with overweight and obesity in perth, australia. *American Journal of Health Promotion, 18*(1), 93-102.

Gorber, S. C., Tremblay, M., Moher, D., & Gorber, B. (2007). A comparison of direct vs. Self-report measures for assessing height, weight and body mass index: A systematic review. *Obesity Reviews, 8*(4), 307-326.

Hedley, A. A., Ogden, C. L., Johnson, C. L., Carroll, M. D., Curtin, L. R., & Flegal, K. M. (2004). Prevalence of overweight and obesity among us children, adolescents, and adults, 1999-2002. *JAMA, 291*(23), 2847-2850.

Jeffery, R. W., & Utter, J. (2003). The changing environment, and population obesity in the United States. *Obesity Research, 11*, 12S-22S.

Kuczmarski, M. F., Kuczmarski, R. J., & Najjar, M. (2001). Effects of age on validity of self-reported height, weight, and body mass index: Findings from the third national health and nutrition examination survey, 1988-1994. *Journal of the American Dietetic Association, 101*(1), 28-34.

Lopez-Zetina, J., Lee, H., & Friis, R. (2006). The link between obesity and the built environment. Evidence from an ecological analysis of obesity and vehicle miles of travel in California. *Health & Place, 12*(4), 656-664.

Lopez, R. (2004). Urban sprawl and risk for being overweight or obese. *American Journal of Public Health, 94*(9), 1574-1579.

Lopez Turley, R. N. (2003). When do neighborhoods matter? The role of race and neighborhood peers. *Social Science Research, 32*(1), 61-79.

Mobley, L. R., Root, E. D., Finkelstein, E. A., Khaxjou, O., Farris, R. P., & Will, J. C. (2006). Environment, obesity, and cardiovascular disease risk in low-income women. *American Journal of Preventive Medicine, 30*(4), 327-332.

Mokdad, A. H., Ford, E. S., Bowman, B. A., Dietz, W. H., Vinicor, F., Bales, V. S., et al. (2003). Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. *JAMA, 289*(1), 76-79.

Nawaz, H., Chan, W., Abdulrahman, M., Larson, D., & Katz, D. L. (2001). Self-reported weight and height - implications for obesity research. *American Journal of Preventive Medicine, 20*(4), 294-298.

Plantinga, A. J., & Bernell, S. (2005). A spatial economic analysis of urban land use and obesity. *Journal of Regional Science, 45*(3), 473-492.

Plantinga, A. J., & Brenell, S. (2007). The association between urban sprawl and obesity: Is it a two way street? . *Journal of Regional Science, 47*, 857-879.

Ross, N. A., Tremblay, S., Khan, S., Crouse, D., Tremblay, M., & Berthelot, J. M. (2007). Body mass index in urban canada: Neighborhood and metropolitan area effects. *American Journal of Public Health, 97*(3), 500-508.

Rundle, A., Diez Roux, A., Freeman, L., Miller, D., Neckerman, K. M., & Weiss, C. C. (2006). The urban built environment and obesity in New York city: A multilevel analysis. *American Journal of Health Promotion, 21*(4S), 326-334.

Särndal, C. E., Swenson, B., & Wretman, J. (1992). *Model assisted survey sampling*. New York: Springer-Verlag.

Smith, K. R., Brown , B. B., Yamada, I., Kowaleski-Jones, L., Zick, C. D., & Fan, J. X. (under review). Walkability and body mass index: Density, design, and new diversity measures.

Stafford, M., Cummins, S., Ellaway, A., Sacker, A., Wiggins, R. D., & Macintyre, S. (2007). Pathways to obesity: Identifying local, modifiable determinants of physical activity and diet. *Social Science & Medicine, 65*(9), 1882-1897.

Tilt, J. H., Unfried, T. M., & Roca, B. (2007). Using objective and subjective measures of neighborhood greenness and accessible destinations for understanding walking trips and bmi in seattle, washington. *American Journal of Health Promotion, 21*(4), 371-379.

Vandegrift, D., & Yoked, T. (2004). Obesity rates, income, and suburban sprawl: An analysis of us states. *Health & Place, 10*(3), 221-229.

White, L. (1994). Coresidence and leaving home: Young adults and their parents. *Annual Review of Sociology, 20*(1), 81-102.

Table 1. Variable Definitions and Means: Females

		Ages 16-18			Ages 27-29		
Variable	**Definition**	**Healthy Weight (N=7,279)**	**Overweight (N=979)**	**Obese (N=341)**	**Healthy Weight (N=15,947)**	**Overweight (N=4286)**	**Obese (N=2,323)**
bmi	Continuous BMI at Ind Level	21.071	27.021	33.763	21.524	27.099	34.480
med_finc	Median family income per $1,000 in the Block Group (BG)	64.490	57.202	53.076	54.948	51.416	49.789
pblack	Proportion black in BG	0.006	0.007	0.009	0.009	0.010	0.010
phawp	Proportion Hawaiian and Pacific Islander in BG	0.009	0.014	0.017	0.010	0.014	0.015
phisp	Proportion Hispanic in BG	0.087	0.123	0.150	0.112	0.140	0.152
pasian	Proportion Asian in BG	0.023	0.026	0.028	0.025	0.025	0.027
med_age	Median age of residents in the BG	29.029	28.229	27.913	29.332	28.362	28.019
age	Individual's age	17.473	17.543	17.504	27.964	28.008	28.013
pdensity_sqmile s	Population density per sq. mile in the BG	4845.360	5245.380	5281.670	5504.410	5680.860	5680.170
pworkerw	Proportion of workers who walk to work in the BG	0.011	0.013	0.011	0.022	0.019	0.019
medyrbt	(1999 - median year built in the census tract	21.586	22.625	22.938	25.929	24.341	24.416
InSect_QM	Number of intersections within .25 miles of the individual's address	35.039	36.306	38.252	38.824	39.234	39.300

Table 2. Variable Definitions and Means: Males

		Ages 16-18			Ages 27-29		
Variable	**Definition**	**Healthy Weight (N=6,803)**	**Overweight (N=1,511)**	**Obese (N=562)**	**Healthy Weight (N=13,986)**	**Overweight (N=9,613)**	**Obese (N=3,192)**
bmi	Continuous BMI at Ind Level	21.229	26.848	33.776	22.406	26.966	33.781
med_finc	Median family income per $1,000 in the Block Group (BG)	65.161	60.525	55.901	54.121	52.980	50.873
pblack	Proportion black in BG	0.006	0.007	0.008	0.010	0.010	0.010
phawp	Proportion Hawaiian and Pacific islander in BG	0.009	0.012	0.014	0.011	0.013	0.014
phisp	Proportion Hispanic in BG	0.085	0.111	0.126	0.125	0.137	0.150
pasian	Proportion Asian in BG	0.022	0.026	0.027	0.027	0.027	0.027
med_age	Median age of residents in the BG	29.078	28.607	28.098	29.481	28.876	28.485
age	Individual's age	17.484	17.492	17.516	27.967	28.011	28.053
pdensity_sqmiles	Population density per sq. mile in the BG	4721.320	5103.670	5353.780	5752.230	5588.080	5694.770
pworkerw	Proportion of workers who walk to work in the BG	0.011	0.012	0.012	0.025	0.022	0.020
medyrbt	(1999 - median year built in the census tract	21.147	22.048	22.178	27.115	25.334	24.935
InSect_QM	Number of intersections within .25 miles of the individual's address	34.409	36.114	36.416	39.069	39.075	39.315

Table 3. Parameter Estimates of the Logistic Regressions for Females

Parameter	Unit Change	Overweight vs. Normal Weight					Obese vs. Normal Weight				
		Est.	S.E.	Odds Ratio	95% CI		Est.	S.E.	Odds Ratio	95% CI	
Intercept		-0.43	0.15				-0.34	0.21			
Median family income per $1,000 in the Block Group (BG)	1,000	-0.01	0.00	0.99	0.99	0.99	-0.02	0.00	0.98	0.98	0.99
Proportion black (BG)	0.1	2.27	1.27	1.254	0.977	1.61	-0.80	1.72	0.923	0.659	1.293
Proportion Hawaiian & Pacific Islander (BG)	0.1	1.86	0.74	1.204	1.042	1.391	1.57	0.90	1.17	0.98	1.396
Proportion Hispanic (BG)	0.1	1.08	0.19	1.114	1.073	1.157	1.41	0.24	1.152	1.099	1.206
Proportion Asian (BG)	0.1	-1.72	0.63	0.842	0.744	0.952	0.49	0.75	1.05	0.906	1.217
Median age of residents (BG)	1	-0.01	0.00	0.99	0.98	1.00	-0.03	0.01	0.98	0.96	0.99
TEEN (=1 if 16-18)	1	-0.44	0.36	0.65	0.32	1.30	-0.68	0.56	0.51	0.17	1.52
Population density per sq. mile (BG)	1,000	0.00	0.00	1.019	1.006	1.032	0.00	0.00	1.005	0.989	1.021
Proportion of workers who walk to work (BG)	0.025	-3.99	0.66	0.905	0.876	0.935	-5.50	0.89	0.872	0.835	0.91
1999 minus median year built (census tract)	10	-0.01	0.00	0.931	0.904	0.959	0.00	0.00	0.956	0.92	0.994
Number intersections w/in .25 miles of individual's address	10	0.00	0.00	0.997	0.974	1.02	0.00	0.00	0.99	0.961	1.019
TEEN X Median family income per $1,000 (BG)	1,000	-0.01	0.00	0.99	0.99	1.00	-0.02	0.01	0.99	0.97	1.00
TEEN X Proportion black (BG)	0.1	-6.09	3.40	0.544	0.279	1.058	2.43	4.72	1.275	0.506	3.214
TEEN X Proportion Hawaiian & Pacific Islander (BG)	0.1	1.62	1.62	1.176	0.856	1.615	0.54	2.32	1.056	0.67	1.663
TEEN X Proportion Hispanic (BG)	0.1	-0.02	0.48	0.998	0.908	1.097	0.35	0.73	1.035	0.897	1.194
TEEN X Proportion Asian (BG)	0.1	2.20	1.37	1.247	0.953	1.63	0.04	1.91	1.004	0.691	1.459
TEEN X Median age of residents (BG)	1	0.00	0.01	1.00	0.98	1.02	0.01	0.02	1.01	0.98	1.05
TEEN X Population density per sq. mile (BG)	1,000	0.00	0.00	0.971	0.941	1.002	0.00	0.00	0.943	0.9	0.988
TEEN X Proportion of workers who walk to work (BG)	0.025	3.69	2.04	1.097	0.992	1.212	-2.15	3.57	0.948	0.796	1.128
TEEN X 1999 minus median year built (census tract)	10	0.01	0.00	1.079	0.999	1.166	0.00	0.01	1.037	0.922	1.167
TEEN X Number of intersections within .25 miles of the individual's address	10	0.00	0.00	1.022	0.964	1.084	0.01	0.00	1.096	1.006	1.193
Model Chi-Square		884.13**					1017.5**				

**p<.01

Table 4. Parameter Estimates of the Logistic Regressions for Males

Parameter	Unit Change	Overweight vs. Normal Weight					Obese vs. Normal Weight				
		Est.	S.E.	Odds Ratio	95% CI		Est.	S.E.	Odds Ratio	95% CI	
Intercept		0.22	0.11				-0.29	0.17			
Median family income per $1,000 in the Block Group (BG)	1,000	0.00	0.00	1.00	0.99	1.00	-0.01	0.00	0.99	0.99	0.99
Proportion black (BG)	0.1	0.41	0.96	1.041	0.862	1.258	0.52	1.43	1.054	0.795	1.396
Proportion Hawaiian & Pacific Islander (BG)	0.1	0.36	0.59	1.037	0.924	1.164	0.48	0.83	1.049	0.892	1.234
Proportion Hispanic (BG)	0.1	0.53	0.14	1.054	1.026	1.084	0.78	0.20	1.081	1.04	1.124
Proportion Asian (BG)	0.1	-0.61	0.44	0.941	0.863	1.026	-0.76	0.67	0.927	0.813	1.057
Median age of residents (BG)	1	-0.01	0.00	0.99	0.99	1.00	-0.01	0.01	0.99	0.98	1.00
TEEN (=1 if 16-18)	1	-1.53	0.26	0.22	0.13	0.36	-0.66	0.44	0.52	0.22	1.22
Population density per sq. mile (BG)	1,000	0.00	0.00	0.989	0.979	0.998	0.00	0.00	0.994	0.98	1.009
Proportion of workers who walk to work (BG)	0.025	-1.71	0.42	0.958	0.938	0.978	-4.35	0.72	0.897	0.866	0.929
1999 minus median year built (census tract)	10	-0.01	0.00	0.948	0.927	0.97	-0.01	0.00	0.926	0.895	0.958
Number intersections w/in .25 miles of individual's address	10	0.00	0.00	1.004	0.987	1.02	0.00	0.00	0.997	0.973	1.022
TEEN X Median family income per $1,000 (BG)	1,000	0.00	0.00	1.00	0.99	1.00	-0.01	0.00	0.99	0.98	1.00
TEEN X Proportion black (BG)	0.1	-1.87	2.79	0.829	0.48	1.432	-1.81	4.15	0.834	0.37	1.883
TEEN X Proportion Hawaiian & Pacific Islander (BG)	0.1	1.25	1.45	1.133	0.853	1.506	1.16	2.03	1.123	0.755	1.67
TEEN X Proportion Hispanic (BG)	0.1	0.53	0.39	1.055	0.977	1.138	-0.19	0.59	0.981	0.875	1.1
TEEN X Proportion Asian (BG)	0.1	2.45	1.10	1.278	1.03	1.586	2.11	1.71	1.235	0.883	1.727
TEEN X Median age of residents (BG)	1	0.00	0.01	1.00	0.99	1.02	0.00	0.01	1.00	0.98	1.03
TEEN X Population density per sq. mile (BG)	1,000	0.00	0.00	1.017	0.989	1.045	0.00	0.00	1.022	0.981	1.065
TEEN X Proportion of workers who walk to work (BG)	0.025	1.71	1.45	1.044	0.972	1.12	0.91	2.28	1.023	0.915	1.144
TEEN X 1999 minus median year built (census tract)	10	0.01	0.00	1.056	0.993	1.124	0.00	0.00	1.05	0.953	1.158
TEEN X Number of intersections within .25 miles of the individual's address	10	0.00	0.00	1.04	0.994	1.088	0.00	0.00	1.027	0.956	1.104
Model Chi-Square		1767.82**					939.57**				

**p<.01