Where Weight Waxes and Wanes: Spatial Variation in Adult Body Mass Index

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

University of Utah

Approximately 66 percent of U.S. adults are overweight (Ogden et al., 2006).[1] Overweight adults are at greater risk of a range of health problems (Billington et al., 2000), including hypertension, diabetes, and several types of cancers (U.S. Department of Health and Human Services, 1998). The *Strategic Plan for NIH Obesity Research* (U.S. Department of Health and Human Services, 2004) emphasizes the need to understand the environmental factors associated with problems of overweight.

In this paper, we examine the roles that neighborhood factors are playing in American adults' shifting energy balance. Data for this investigation come from the Utah Population Data Base (UPDB). The UPDB contains vast data holdings including records about genealogies, births, deaths, residences, health status, residential address, and height/weight. For these analyses, U.S. Census information on neighborhood characteristics measured at the block-group level has also been linked to the UPDB using Geographic Information Systems (GIS) databases. This unique linked data set allows us to assess the extent to which neighborhood design, population density, and land-use diversity may be associated with American adults' growing propensity to be overweight for an entire urban county population in Utah.

[1] Overweight is defined as a body mass index (BMI) of 25.0 or higher, computed as weight in kilograms divided by height in meters squared.

Background

Recent research has examined how characteristics of neighborhoods are associated with measures of overweight. Neighborhoods that are designed to support active uses, such as walking, may encourage greater physical activity and thereby prevent overweight and obesity. Walkable neighborhoods are those designed to include the "3Ds": population density, diversity of destinations, and pedestrian friendly designs (Cervero & Kockelman, 1997). High densities and diverse land uses together mean that many people are within walking distance of many desirable destinations. Well-connected streets, a measure of pedestrian friendly design, further support walking by allowing walking trips to be relatively short, direct, and convenient.

Research done to date reveals that the built environment indices of walkability relate to adult body mass index (BMI) inconsistently when large metropolitan area measures are used. In two studies, all measures of the 3Ds are unrelated to weight outcomes (for BMI and obesity, Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003; for BMI, Kelly-Schwartz, Stockard, Doyle, & Schlossberg, 2004); however, a measure of density was inversely related to higher risk of overweight and obesity in a third study (Lopez, 2004).

When geographic areas smaller than the metropolitan level are examined, neighborhood walkability relationships with BMI are more consistent. At the county level, measures of density and pedestrian friendly design (i.e, small block sizes) relate to lower levels of BMI and lower odds of obesity (Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003). At the level of the one-kilometer buffer around each respondent's home, white male BMI has been found to be lower in areas of greater density, land use diversity, and street connectivity while white female BMI has been found to be lower in areas of greater density and land use diversity (Frank, Andresen, & Schmid, 2004). When Frank et al.'s measures are assessed at the zip code level, a study of women shows that greater land use diversity is related to lower BMI (Mobley et al., 2006). A walkability index involving density, street connectivity, land use diversity, and retail floor area was used in one study at the one-kilometer buffer around respondent's homes. This investigation included residents from pre-selected moderately low and high walkability neighborhoods based on census block group measures. Increasing levels of this combined index of walkability predicted lower levels of BMI (Frank et al., 2006).

In sum, the strongest links between BMI and community design have been based on county, zip code, or one kilometer buffer measures, rather than larger areas, such as metropolitan areas. For this study, we utilize a smaller-scale Census block group and one kilometer buffer measures of density and pedestrian friendly design, specifically, street connectivity.

Materials and Methods

This study assesses how adult BMI varies spatially for the county with the largest population in Utah, Salt Lake County. Using data on 567 block-groups from the 2000 Census for Salt Lake County as well as additional measures derived from local Geographic Information Systems (GIS) databases, we operationalize our measures for the 3Ds.

The analysis relies on individuals identified from the Utah Driver's License Division (DLD) records maintained by the Utah Department of Public Safety (DPS). These drivers license records contain information on height, weight, gender, and age. Through an agreement between DPS and the Utah Population Database (UPDB) at the University of Utah, we obtained IRB approval to use the DLD data for this research. As part of the agreement, the UPDB worked with the Digitally Integrated Geographic Information Technologies (DIGIT) Lab at the University of Utah to convert all addresses from the drivers license data to universal transverse mercator (UTM) coordinates. This permitted each person's residence shown on a drivers license to be linked to a UTM-mapped Census block-group.

Our measures of the 3D's that capture key elements of neighborhood walkability are based on the 2000 Census at the block-group level:

1. *Density*: population per square mile
2. *Pedestrian-Friendly Designs*: Intersections within a 0.25 mile radius of the residence (obtained from the Utah DIGIT Lab).
3. *Diversity*: Instead of measuring diversity by means of land use mix variables, which are not readily available (Rodriguez, Young, & Schneider, 2005), we use two additional measures of walkability that are available in census data files. First, we analyze housing age in the block group as a proxy measure of many aspects of walkability (Berrigan & Troiano, 2002). Older neighborhoods may have many walkability features, such as sidewalks, street connectivity, and mixed uses. Berrigan and Troiano found that residents of urban areas built before 1974 were significantly more likely to walk than residents of newer housing. Second, the census measure of the proportion of census tract that walks to work is taken as a proxy for mixed land uses. Those who walk to work clearly live within walking distance of an employment site, suggesting mixed land uses for the neighborhood.

Additional block-group variables that are included in the analyses consist of controls for racial/ethnic composition (three variables that capture the proportion of the block-group that is Hispanic, African-American, or Hawaiian/Pacific Islander), median family income, and median age.

Statistical Methods: Both ordinary least squares regression (OLS) and logistic regressions are estimated to assess how the 3D's, along with additional covariates, affect BMI and the odds of overweight, respectively. OLS and logistic regressions are estimated based on samples stratified by gender and age groups (25-34, 35-44, 45-54, and 55-64). Within each age group, an additional covariate is included that controls for individual-level age. Robust standard errors are estimated to account for clustered responses from using DLD information that include individuals living in the same neighborhood. All estimation uses SAS software (PROC SURVEYREGRESSION and PROC SURVEYLOGISTIC).

Results

Table 1 displays descriptive statistics for the two gender-specific samples. Each sub-sample comprises nearly one-quarter of a million persons.

Table 1 here

Results for the OLS and logistic regressions are similar but the results for both specifications are shown in Tables 2 and 3, respectively. For brevity, we note here only those results for the logistic regressions for overweight. Among the 3Ds, the most consistent and strongest effects for reducing the odds of overweight are captured by the measures for diversity of land use. This means that individuals living in neighborhoods that are older and that have higher numbers of workers walking to walk have lower odds of being overweight. Neighborhoods with pedestrian-friendly design as measured by intersection density are also associated with lower odds of being overweight but not as consistently nor as significantly as the diversity measures. Population density has a generally weak influence on the odds of being overweight. Neighborhoods with high median family income and lower proportions of racial/ethnic minorities are associated with lower odds of overweight.

Table 2 and 3 here

Conclusion

Neighborhood characteristics, as identified by density, diversity, and design, are hypothesized to be associated with walkability and therefore body mass index. We find support for these associations as they relate to diversity and design but not for density. With this analysis, we have shown the advantages of using linked databases that cover nearly the entire adult population (at least those who drive) to investigate the associations between neighborhood measures and measures of individual health. More work is underway that examines a broader range of counties and that considers the role of migration selection into different neighborhoods. We anticipate that this additional work will be completed and added to the paper by early next spring.

Table 1. Descriptive Statistics	Men		Women	
	25-64		**25-64**	
	N = 243,330		**N = 223,552**	
	Mean	Std. Dev.	Mean	Std. Dev.
BMI at Individual Level	26.50	4.44	24.69	5.31
Dummy overweight=1 at Individual Level	0.61	0.49	0.37	0.48
Median family income per $1,000 at Individual Level	56.41	19.67	58.00	19.49
Proportion black at Block Group Level	0.01	0.01	0.01	0.01
Proportion Hawaiian Pacific Islander at Block Group Level	0.01	0.02	0.01	0.02
Proportion Hispanic at Block Group Level	0.12	0.12	0.11	0.11
Proportion Workers Walk to Work at Block Group Level	0.02	0.03	0.02	0.03
Intersection 0.25 Mile at Individual Level	37.83	15.36	37.89	15.39
Median age at Block Group Level	29.42	5.31	29.53	5.40
Population per square mile at Block Group Level	5432.98	3126.44	5331.52	3036.44
Median year structure built at Census Tract level	1973.47	15.43	1974.10	15.28
Age	41.01	10.96	41.45	11.06

Table2. OLS Regression for the Effects of the 3D's (Density, Design, and Diversity) on BMI by Gender and Age

Men- BMI	**25-64**		**25-34**		**35-44**		**45-54**		**55-64**	
	N = 243,330		**N = 85,308**		**N = 65,881**		**N = 56,394**		**N = 35,747**	
	b	*p-value*	*b*	*p-value*	*b*	*p-value*	*b*	*p-value*	*b*	*p-value*
Intercept	28.1309	0.0001	26.4607	0.0001	28.1867	0.0001	28.9770	0.0001	29.5880	0.0001
Median family income per $1,000 at Block Group Level	-0.0117	0.0001	-0.0123	0.0001	-0.0109	0.0001	-0.0095	0.0001	-0.0121	0.0001
Proportion African-American at Block Group Level	-2.1783	0.1897	-1.2304	0.4524	-1.7876	0.3578	-3.0554	0.2131	-4.4364	0.1075
Proportion Hawaiian and Pacific Islander at Block Group Level	1.6478	0.0395	2.0668	0.054	0.7040	0.4782	2.3742	0.0708	1.1410	0.4254
Proportion Hispanic at Block Group Level	0.8115	0.0002	0.9894	0.0001	0.9644	0.0005	0.9023	0.0052	0.1041	0.7964
Population per sq mile at Block Group Level (per 1000)	-0.0143	0.0998	-0.0266	0.0076	-0.0229	0.0287	0.0004	0.9692	0.0289	0.0356
Proportion workers walk to work at Block Group Level	-5.3758	0.0001	-4.7507	0.0001	-5.7892	0.0001	-4.8679	0.0001	-6.9993	0.0001
Year built at census tract Level (per 10)	0.1812	0.0001	0.1442	0.0001	0.1806	0.0001	0.2249	0.0001	0.2307	0.0001
Intersection 0.25 miles (per 10)	-0.0100	0.2834	0.0226	0.0458	-0.0303	0.0311	-0.0302	0.0656	-0.0325	0.0685
Median age at Block Group Level	-0.0308	0.0001	-0.0168	0.0001	-0.0279	0.0001	-0.0376	0.0001	-0.0308	0.0001
Age	0.0830	0.0001	0.1933	0.0001	0.0739	0.0001	0.0627	0.0001	0.0175	0.0223
	R^2 = 0.052		R^2 = 0.029		R^2 = 0.017		R^2 = 0.018		R^2 = 0.016	

Women- BMI	**25-64**		**25-34**		**35-44**		**45-54**		**55-64**	
	N = 223,552		**N = 75,594**		**N = 58,807**		**N = 54,226**		**N = 34,925**	
	b	*p-value*	*b*	*p-value*	*b*	*p-value*	*b*	*p-value*	*b*	*p-value*
Intercept	27.5177	0.0001	25.2030	0.0001	27.0718	0.0001	29.1990	0.0001	29.9871	0.0001
Median family income per $1,000 at Block Group Level	-0.0346	0.0001	-0.0239	0.0001	-0.0394	0.0001	-0.0393	0.0001	-0.0353	0.0001
Proportion African-American at Block Group Level	-1.7253	0.5122	-2.4405	0.3875	-2.2943	0.5037	1.2668	0.6957	-2.7991	0.4564
Proportion Hawaiian and Pacific Islander at Block Group Level	6.9368	0.0001	6.3388	0.0001	7.8336	0.0001	5.4774	0.0013	8.5091	0.0001
Proportion Hispanic at Block Group Level	3.8844	0.0001	3.9092	0.0001	4.7227	0.0001	3.7712	0.0001	3.1092	0.0001
Population per sq mile at Block Group Level (per 1000)	0.0073	0.6261	0.0071	0.6301	-0.0003	0.9851	0.0110	0.5749	0.0147	0.4650
Proportion workers walk to work at Block Group Level	-7.4446	0.0001	-7.8988	0.0001	-8.3737	0.0001	-5.8714	0.0001	-4.9370	0.0156
Year built at census tract Level (per 10)	0.1418	0.0001	0.1043	0.0014	0.1556	0.0001	0.1790	0.0001	0.1834	0.0001
Intersection 0.25 miles (per 10)	-0.0211	0.1552	-0.0369	0.0237	0.0028	0.9039	-0.0194	0.3983	-0.0193	0.3956
Median age at Block Group Level	-0.0380	0.0001	-0.0211	0.0064	-0.0263	0.0011	-0.0549	0.0001	-0.0527	0.0001
Age	0.1111	0.0001	0.1442	0.0001	0.0990	0.0001	0.1299	0.0001	0.0692	0.0001
	R^2 = 0.085		R^2 = 0.040		R^2 = 0.054		R^2 = 0.057		R^2 = 0.050	

Table 3. Logistic Regression for the Effects of the 3D's (Density, Design, and Diversity) on Odds of Overweight by Gender and Age

Men- Overweight	**25-64**			**25-34**			**35-44**			**45-54**			**55-64**		
	N = 243,330			**N = 85,308**			**N = 65,881**			**N = 56,394**			**N = 35,747**		
	b	*OR*	*p-value*	*b*	*OR*	*p-value*	*b*	*OR*	*p-value*	*b*	*OR*	*p-value*	*b*	*OR*	*p-value*
Intercept	1.057		0.000	0.471		0.000	1.131		0.000	1.388		0.000	1.530		0.000
Median family income ($1,000) at Block Group Level	-0.003	0.997	0.000	-0.005	0.995	0.000	-0.003	0.997	0.000	-0.001	0.999	0.060	-0.002	0.998	0.030
Proportion African-American at Block Group Level	-0.328	0.721	0.311	0.288	1.334	0.566	-0.502	0.605	0.406	-0.028	0.972	0.969	-2.550	0.078	0.007
Proportion Hawaiian/Pacific Is. at Block Group Level	0.323	1.382	0.093	0.875	2.399	0.004	-0.351	0.704	0.316	0.303	1.354	0.485	-0.269	0.764	0.636
Proportion Hispanic at Block Group Level	0.331	1.392	0.000	0.387	1.473	0.000	0.434	1.543	0.000	0.209	1.232	0.048	-0.068	0.934	0.635
Population per sq mile at Block Group Level (1000)	-0.007	0.993	0.000	-0.012	0.988	0.000	-0.009	0.991	0.003	0.002	1.002	0.599	0.010	1.010	0.044
Proportion worker walk to work at Block Group Level	-2.185	0.112	0.000	-2.238	0.107	0.000	-2.421	0.089	0.000	-1.892	0.151	0.000	-2.183	0.113	0.000
Year built at census tract Level (10)	0.090	1.094	0.000	0.069	1.071	0.000	0.086	1.089	0.000	0.112	1.119	0.000	0.136	1.145	0.000
Intersection 0.25 miles (10)	-0.007	0.993	0.010	0.011	1.011	0.014	-0.020	0.981	0.000	-0.027	0.974	0.000	-0.015	0.985	0.061
Median age at Block Group Level	-0.013	0.988	0.000	-0.009	0.991	0.000	-0.012	0.988	0.000	-0.014	0.986	0.000	-0.010	0.990	0.000
Age	0.039	1.040	0.000	0.090	1.094	0.000	0.033	1.033	0.000	0.022	1.023	0.000	0.014	1.014	0.002
Log Likelihood	-2LL 324240.44			-2LL 117821.62			-2LL 86138.12			-2LL 69723.81			-2LL 41681.55		

Women- Overweight	**25-64**			**25-34**			**35-44**			**45-54**			**55-64**		
	N = 223,552			**N =75,594**			**N = 58,807**			**N = 54,226**			**N = 34,925**		
	b	*OR*	*p-value*	*b*	*OR*	*p-value*	*b*	*OR*	*p-value*	*b*	*OR*	*p-value*	*b*	*OR*	*p-value*
Intercept	0.654		0.000	-0.068		0.375	0.533		0.000	1.252		0.000	1.474		0.000
Median family income ($1,000) at Block Group Level	-0.015	0.985	0.000	-0.013	0.987	0.000	-0.017	0.983	0.000	-0.016	0.984	0.000	-0.013	0.987	0.000
Proportion African-American at Block Group Level	-0.729	0.483	0.050	-0.830	0.436	0.182	-0.647	0.524	0.368	-0.379	0.685	0.628	-1.420	0.242	0.143
Proportion Hawaiian/Pacific Is. at Block Group Level	2.584	13.247	0.000	2.857	17.413	0.000	2.485	12.001	0.000	2.142	8.516	0.000	2.440	11.474	0.000
Proportion Hispanic at Block Group Level	1.339	3.816	0.000	1.469	4.346	0.000	1.656	5.238	0.000	1.044	2.840	0.000	0.785	2.192	0.000
Population per sq mile at Block Group Level (1000)	0.003	1.003	0.113	0.006	1.006	0.065	0.001	1.001	0.673	0.001	1.001	0.823	0.002	1.002	0.707
Proportion worker walk to work at Block Group Level	-3.262	0.038	0.000	-3.890	0.020	0.000	-3.686	0.025	0.000	-2.616	0.073	0.000	-2.129	0.119	0.000
Year built at census tract Level (per 10)	0.073	1.076	0.000	0.065	1.067	0.000	0.077	1.080	0.000	0.077	1.080	0.000	0.084	1.087	0.000
Intersection 0.25 miles (per 10)	-0.009	0.991	0.003	-0.018	0.982	0.001	0.003	1.003	0.627	-0.008	0.992	0.207	-0.011	0.989	0.139
Median age at Block Group Level	-0.015	0.985	0.000	-0.010	0.990	0.000	-0.012	0.988	0.000	-0.021	0.979	0.000	-0.018	0.982	0.000
Age	0.043	1.043	0.000	0.063	1.065	0.000	0.036	1.037	0.000	0.048	1.049	0.000	0.032	1.032	0.000
Log Likelihood	-2LL 294912.45			-2LL 88964.36			-2LL 76376.19			-2LL 74023.25			-2LL 48258.57		

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