The Importance of Time & Place in the U.S. Obesity Epidemic

Courtney Towner

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David G. Schlundt, Ph.D.

Running Head: Time and Place in Obesity

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Abstract

BMI in America continues to rise each year. Blacks when compared to Whites are most affected by increase in BMI and obesity as well as those who live in poor neighborhoods are also most affected. Studies have shown the enormous health risks associated with overweight and obesity and the disproportionate levels of obesity among low-income Blacks. The cross-sectional study utilized BRFSS and US census data to create Hierarchical Linear Models (HLM) with three levels. Level 1 was individual differences, level 2 was time, and level 3 was place. The HLM models were constructed to review BMI and obesity (BMI≥30). High BMI as well as obesity were associated with low income, lack of college education, and race/ethnicity. The results show that obesity rates are increasing over time, with the rate of increase starting to slow. They also show differences in the prevalence of obesity by place. These findings have implications for the treatment and prevention of obesity in the United States.

Introduction

What is obesity?

Obesity is the slow addition of excess body fat until it begins to negatively impact health (Kopelman, 2000). According to Chou, Grossman, and Schaffer, obesity represents an operation of the relationship between the energy balances of an individual over time. Furthermore, an individual's energy balance is the measure of the difference between caloric intake and expenditure during that time (2004). Obesity and overweight are determined by the measure of an individual's body fat, which is most commonly measured as body mass index (BMI). BMI measures are calculated by dividing weight in kilograms by square height in meters. A BMI measure of 30 or greater indicates that an individual is obese, and an individual with a measure between 25 and 29.9 is overweight (National Heart Lung and Blood Institute).

Body fat can also be measured by using weight circumference, skinfold thickness, and bioimpedence. Weight circumference is measured in centimeters at the middle between the ribs and the pelvis and helps quantify upper body fat deposits. Skinfold thickness is a measure of the thickness of skinfolds taken by using calipers to provide a more precise measure. These measures have a large amount of variability and do not give any real information about abdominal fat. Finally, bioimpedence uses an electrical current to measure lean mass and can give an estimate of body fat with an equation. These measures do not better predict biological results than other measures (Kopelman, 2000). Yet, BMI is most frequently used (Kopelman, 2000). Obesity is not an isolated disorder but is made up of a varied group of causes. Body weight must be calculated by assessing the intersection between "genetic, environmental, and

psychosocial factors" through mediation of energy consumption and use (Kopelman, 2000).

Why is obesity bad?

Obesity increases an individual's susceptibility to many other diseases and negative consequences of several health problems, specifically type II diabetes (Kopelman, 2000). Each year 300,000 US adults die from being obese. Also, obesity increases morbidity and decreases quality of life in individuals (Mokdad et al, 2001). Consequently, the health costs associated with obesity and physical inactivity contribute 9.4% of the US health care expenses (Mokdad, 2001). Body fat distribution is a strong predictor of cardiovascular morbidity and mortality in association with negative metabolic problems, specifically glucose intolerance, hyperinsulinemia, and elevated blood pressure. Studies also show that upper body fat in addition to an increase in visceral fat mass ass opposed to peripheral fat lead to an increase in systolic and diastolic blood pressure, hypertriglyceridemia, a decrease in HDL cholesterol, insulin resistance, and stimulates the sympathetic cardiovascular system (Simone and Grassi, 2004).

Higher levels of fat on the upper body regions are associated with an increase in glucose and insulin levels that result in an increased level of fasting plasma and a larger oral glucose level. Ultimately this can lead to an excess expenditure of free fatty acids (FFAs) from adipocytes in the stomach area. FFAs negatively impact the ability of the liver to take up insulin. The elevation caused by overweight and obesity results in an inefficient maintenance of the glucose produced. The pancreas first regulates lower intake of glucose by adjusting to an equal hyperinsulinaemia, yet the pancreas cannot

continue to maintain the hyperinsulinaemic state. Hyperinsulinaemia and insulin resistance contribute to elevated levels of fasting plasma associated with obesity and diabetes (Kopelman, 2000).

As levels of fat increase on the chest wall and within the abdomen rates of inspiration and respiration of oxygen are dramatically affected and lung volume greatly reduces. These problems are most acute during sleep and can cause episodes of sleep apnea, which is a specified amount of time during sleep when a person is not breathing (Kopelman, 2000). Increased levels of fat also cause the body to take in more oxygen and add pressure on the heart to work harder. Slowly the left ventricle begins to hypertrophy and this enlargement of the left ventricle is closely associated with BMI. The left ventricular mass increases directly with BMI or the extent of overweight (Kopelman, 2000). As the left ventricle expands the chamber can no longer sustain the higher volume during diastole, which contributes to diastolic dysfunction and can lead to congestive cardiac failure (Kopelman, 2000). Left ventricular hypertrophy also contributes to a higher risk of death and illness from cardiovascular heart disease, sudden death, and abnormal heart rhythms.

Why do people gain weight?

People gain weight when energy intake outpaces energy expenditure (Hill and Peters, 1998). Obesity and overweight is also associated with a low basal metabolic rate, low energy expenditure, low fat oxidation levels, high insulin, low sympathetic nerve system, and a low acute leptin count (Blundell et al., 2005). Given the increased prevalence of less expensive energy dense foods and the decreased levels of physical activity, rates of overweight have increased. These conditions cause obesity to occur

more often because the body naturally has efficient mechanisms to retain energy, and less control over the slow addition of extra energy when food is readily available (Hill and Peters, 1998). The intersection between physical activity and food intake most specifically affects energy balance and weight maintenance (Mayo Clinic Proceedings, 2002). Furthermore, weight maintenance plays a huge role in predicting obesity, which primarily influences energy intake.

Individuals may also be at a greater risk of gaining weight as a result of a combination of susceptibility factors that contribute to weight gain (Blundell et. al, 2005). Susceptibility factors can be broken down into “genetic, physiologic and metabolic, behavioural and psychological” (Blundell et al., 2005). In terms of any genetic susceptibility there has been no evidence that suggests that one gene causes obesity. Rather studies have found that any genetic influence may be based on the interactions of more than one gene to increase an individual’s susceptibility to obesity (Blundell et al, 2005).

Physiological susceptibility can be described within the realm of diet and eating, specifically the cues that signal to your brain that you are full or hungry and how frequently you receive these cues. Therefore research has focused on the way the body regulates levels of leptin, ghrelin, adiponectin, and cholecystokinin, which are just some of the molecules involved in those body processes. Now, studies are devoted to not just focus on homeostatic, or biological need for food, but also hedonic, or the pleasure factor associated with food. Yet the relationship between homeostatic and hedonic factors and weight gain is still being researched and has not been fully developed

(Blundell et al., 2005). Behavioral factors can be described in terms of how many times a person eats in one day and what kinds of food the person will eat.

In addition, certain psychological aspects contribute to understanding people's relationship with food. Particularly, psychological susceptibility can be broken down into a trait and a state. A state describes frequency and intensity of certain diets on an individual, while a trait is a prevailing understanding of some foods and what decision making guides long term food consumption (Blundell et al, 2005).

How common is it?

As stated earlier, obesity occurs at a BMI of 30 or greater and overweight occurs at a BMI between 25 and 29.9. The prevalence of obesity varies across location and groups of people. Obesity rates are as low as 5% in China, Japan, and many African nations, and as high as 75% in Samoa (Kumanyika, Jeffery, Morabia, Rittenbaugh, and Antipatis, 2002). The main source of information that my research will take data from is the Behavioral Risk Factors Surveillance Survey (BRFSS). The BRFSS is a telephone cross-sectional study that consists of a questionnaire, which primarily focuses on personal behaviors that aid in increasing a person's risk of 1 or more of the 10 main causes of death in the U.S. According to data taken from the BRFSS, rates of obesity increased to 20.9% in 2001 from 19.8% in 2000 (Mokdad et al, 2001).

Additionally, the percentage of people who are obese has increased by 74%, which makes up 21.4 million obese males and 22.9 million obese females. The amount of overweight participants in the BRFSS moved up to 58% in 2001 from 45% in 1990 (Mokdad, Ford, Bowman, 2003). Chou, Grossman, and Saffer compiled research from a series of surveys starting with the National Health Examination Survey (NHES) in

1959-1962 that calculated an average body mass index of 24.91 kg/m2. The National Health and Nutritional Examination Survey (NHANES), a series of cross-sectional surveys that represent the entire nation conducted by the national Center for Health Statistics (Wang and Beydoun, 2007), between 1999-2000 calculated an average BMI of 27.85 (567, 2004).

Who is at risk for obesity?

Across the US obesity and overweight are increasing across all lines of people. According to data taking from NHANES, between 1960 and 1980 there was a huge increase in prevalence of obesity in White women at 3%, White men 6%, and Black women 7%. Yet the most astounding increase was in Black men with the highest percent increase at 28%. Current data suggests that there is no marked difference in the prevalence of obesity in men between racial/ethnic divisions. On the other hand, 50% of non-Hispanic Black women who were 40 or older were obese and 80% of non-Hispanic Black women had a BMI over 25 compared to the general population with only 64% with BMIs that high (Pender and Pories, 2005). A BRFSS study taken in 2007 revealed that 36.6% of people were overweight and 26.3% of people were obese (CDC, 2008).

In terms of age, studies have shown that younger adults with a BMI greater than 25 have a higher risk of death and cardiovascular disease than older people with the same BMI. Overweight and obesity in children has rapidly increased over the years and evidence has shown higher levels of overweight and obesity in Mexican American populations when compared to non-Hispanic Blacks and non-Hispanic Whites. Data taken from the National Longitudinal Survey of Youth (NLSY) which consisted of 8,270

children between the ages of 4 and 12 proved that the prevalence of obesity had risen among white, Mexican American, and African American children. Among Mexican American children prevalence of overweight escalated to 21.8%, 21.5% in non-Hispanic Black children, and 12.3% in non-Hispanic White children by 1998 (Pender and Pories, 2005).

In modern times, another important contributor to sedentary lifestyles is the built environment. Essentially, the conveniences that have emerged from a lifestyle centered on cars have contributed to increasing obesity rates. Through discoveries in technology and transportation physical activity in daily life has been significantly reduced. The new attraction to television and computer games has increased time spent in doing sedentary activities for many adults and children. Ultimately a high-energy diet when paired with a low physical activity only emphasizes the risks associated with overweight and obesity (Hill et al., 1998).

Limitations of the built environment also influence the accessibility of people to certain foods in poorer areas. Studies have shown a significant limited access to supermarkets for people with "low-income, inner-city, and predominantly African American or Hispanic neighborhoods within US urban areas" when compared to suburban, White areas Additionally, in the US low-income predominately Black neighborhoods have a much larger exposure to fast food outlets than higher income and majority White areas (Tomic et al., 741, 2008).

A study conducted by Dubowitz et al. (2008) used data from the National Health and Nutrition Examination Survey (NHANES III) along with census tract data to figure out consumption of fruits and vegetables based on individual characteristics and with an

idea of neighborhood socioeconomic status (SES). The study concluded that neighborhood SES had a positive and marked statistic relationship with fruit and vegetable intake after individual characteristics were controlled. Ultimately, the study showed that when neighborhood SES was included that nearly half of the black-white gap in collective consumption of fruits and vegetables was attributable to neighborhood SES. Their results revealed that there is a significant correlation between race-ethnicity and neighborhood SES. Furthermore neighborhood SES may influence what dietary options are available for consumption in an area. Finally, White people may consume more fruits and vegetables because of their increased access to these foods.

Are there location differences?

Wang and Beydoun (2007) studied the interaction of gender, race, age, socioeconomic status and geographic characteristics with obesity in the U.S. They analyzed results taken from the BRFSS, NHANES, Youth Risk Behavior Surveillance Survey (YRBSS), and National Longitudinal Study of Adolescent Health (NLSAH) The YRBSS initiated in 1991 monitors high risk behaviors that contribute to the main causes of death, handicap, and social problems in youth and adults in the US NLSAH is a primarily school based study that is nationally representative for kids in grades 7-12.

The youth data from the BRFSS taken in 2005 shows there are noticeable differences in trends of obesity based on different geographic locations. Generally, states in regions of the Southeast have a much higher prevalence of obesity than states located on the West coast or Midwest and northern coasts. Additionally, in 2005 four states had obesity prevalence rates less than 20% (Colorado, Hawaii, Vermont, and Connecticut). 17 states had rates 25% or higher and three of the 17 states had

prevalence rates of 30% or higher (Louisiana, Mississippi, and West Virginia). According to research, clear distinctions between regional areas and obesity prevalence were indistinguishable in 1990, but in 1995 the differences began to emerge and instantly the states on the West coast and northeastern had a lower prevalence than other states (Wang and Beydoun, 2007).

Yet in 2000 and 2005, the shift began to show the southeastern states with a higher prevalence of obesity. In 1990, five states had prevalence rates of obesity between 15-19% with no states at a rate of 20% or higher. In 1995 prevalence rates in all 50 states was below 20%. However in 2000, 28 states had obesity prevalence rates less than 20%, and in 2005 only four states had obesity rates of 20% or more. Alternatively, 17 states had rates of 25% or more and three had a rate of 30% or more (2007). In 2001, Mississippi had the highest rate of obesity, 25.9%, and Colorado had the lowest rate, 14.4% (Mokdad, Ford, Bowman, 2003).

Statement of the Problem

As previously outlined obesity is an epidemic that is becoming increasingly common and ravaging the communities of many different states at different rates. The amount of people who were obese and overweight from 1999-2000 was 64%. 30% of those individuals were obese and 34% of those individuals were overweight (Salinsky and Scott, 2003). Additionally, as noted above, when obesity is not managed, other diseases such as type II diabetes and heart disease can develop.

The questions my research will aim to answer are:

1) Is the rate of obesity increasing in the United States?
2) What place characteristics are risk factors for rapid increase in obesity?

3) What place characteristics are protective factors for rapid increase in obesity?

Method

Data Collection

Participants. Since my research utilizes the BRFSS data from 1997-2008 we have approximately 3 million participant interviews. We, therefore, are not obtaining any new interviews from people, but relying on the data to provide us with useful information to examine BMI. Table 2 indicates the number of interviews used in data analysis from each state for each of the years.

Apparatus or Measures. To measure rates of overweight and obesity we will be using the weight and height information as self reported by the interview participants to calculate BMI. We will then use BMI to compare different ethnic, racial, and gender groups. We will also look at BMI in relation to the geographic locations. Using BMI measures will allow us to assess whether the mean for certain areas and groups falls into the overweight or obese levels.

Data Analysis Plan

A statistical method called hierarchical linear modeling (HLM) will be used to gain a better understanding of two sets of questions: 1) how does the rate of change in obesity vary over time, and 2) how does the prevalence of obesity vary from place to place?

A hierarchical model can be used when you have nested data sets. For the BRFSS data, we have fifty states plus the District of Columbia. Within each state, major metropolitan areas are identified and the rest of the state will be treated as non-

metropolitan. Within each geographic location, we have data for the years 1997 to 2008. Within each location and year, we have a varying number of individual BRFSS interviews. Multi-level modeling allows one to understand how the association between individual characteristics (including obesity) from site to site, and how they vary over time within sites. It also allows one to determine how the importance of certain characteristics as predictors of obesity varies from one site to the next, or by times within sites. When an independent measurement is made of site characteristics (e.g., using census data), one can test how the prevalence of obesity or the importance of certain predictors of obesity is associated with these independently measured site variables.

Site characteristics will be measured using the 2000 US census data. Social and housing characteristics of the census tract will be summarized using variables that measure independent dimensions of the places. First, we identified US counties with populations between 250,000 and 999,999 people. We extracted data from the 2000 US census SF3 file for all census tracts within each of the 50 states. This resulted in a sample of 64,076 tracts. Eighty-one variables describing the demographic, educational, social, and economic characteristics of the people living in the census tract were extracted from the SF3 files. Factor analysis was then conducted which resulted in a six-factor solution.

HLM Analysis

To accurately analyze all of the data collected for the study, hierarchical linear models (HLM) were used to study BMI and obesity (BMI$\geq$ 30) in relation to individual differences across time within different places. HLM was used to study the effect of BMI

within the nested data structures. Therefore, the individual differences are nested within time, while time is nested within place.

Level 1 of the hierarchical model describes individual differences, ignoring time or place. A regression or logit regression model aids in predicting an outcome with a linear combination of individual difference measures. The level 2 and level 3 models are created to evaluate the intercept parameter of the level 1 equation and how it varies across the different levels of the nesting variable (i.e., how BMI levels vary by time or county). This kind of model is often referred to as an intercept as outcomes model. Variations between units in the intercept parameter are modeled with linear equations as a function of the variables measured at the second or third level of the model. Models can be created to show the way slope parameters (measures of the direction of association as well as strength) change across nesting units. However, our analyses focused primarily on the intercept parameters.

A three-level HLM model has been used to analyze this data and the levels are described as people, time, and place. Organization of the model can differ due to whether times are nested within people (i.e. data is made of a cohort of people repeatedly measured), or people are nested within times (i.e. cross-sectional data collection). To construct the people level of the model, data can be obtained using interviews, questionnaires, archival data and various other measures. In the analysis for this data, measures of people indicate stable individual difference variables. For our models the individual level was obtained from the BRFSS data. For the time level, the data analyzed represents the years examined provided through the BRFSS data. The passage of time is represented by two parameters; a linear parameter that represents a

straight-line increase or decrease in BMI or obesity over time, and a quadratic parameter that represents a bending of the curve. A positive quadratic effect on the intercept represents a faster than linear increase. A negative quadratic effect on the intercept represents a slower than linear increase. Finally, place represents various counties in 49 of the 50 states plus the District of Columbia (county level data is not available in the BRFSS for Alaska). Geographic differences will be represented using the factor analytically derived measures from the 2000 US census.

Level 1: Individual Level

Data from the Behavioral Risk Factor Surveillance Survey (BRFSS) was used to obtain interviews from approximately 3 million participants. BRFSS data gathered from 1997-2008 from all US states plus the District of Columbia. Larger counties are identified in the BRFSS using a county FIPS code, which allows those cases to be linked to a specific geographic location. Interviews from smaller counties are not identified and were linked to all areas of the state not included in the identified counties. Averaging the factor values from all the census tracts within the geographic unit generated the geographic description for each county or for the composite rural areas. Once all of the geographic units and people were linked, the sample size for the analysis was lowered to 2,766,195 participants.

Demographic variables in the level 1 model were dummy coded for use in regression analysis. These variables included 1) sex, 2) low income, 3) medium income, 4) unknown income (compared to high income), 5) high school dropout, 6) high school education, 7) unknown education (compared to people with college education), 8) people who smoke now, 9) people who have quit smoking (compared to people who

never smoked), 10) divorced individuals, 11) widowed individuals, 12) single individuals, 13) couples (compared to married), 14) Black, 15) Hispanic, 16) other races (compared to White), 17) unemployed individuals, 18) homemakers, 19) students, 20) individuals with unknown employment, 21) retired individuals, and finally 22) disabled individuals (compared to employed) .

Level 2: Time

The data from the BRFSS was coded so that BMI over time could be tracked given the individual differences included in the variables specified above as well as across all of the county tracts in the US. The data was formatted within the HLM software so that BMI changes could be tracked from 1997-2008. Most importantly, the data was organized so that trends in BMI change could be evaluated to reveal linear and quadratic temporal trends. The level 2 is made of times (1997-2008) nested within places. There were 12,402 time within place units.

Level 3: Places

Level 3 represents geographic differences among places and is measured by the factor analytically derived census variables. There were 2,293 distinct places in the data representing both counties and rural areas within the 50 states plus the District of Columbia. Codes in the BRFSS were created to link individual data to the level 2 and level 3 variables.

Using SPSS, US census data for all housing and population variables 175 variables was extracted for all census tracts for all 50 states. Composite variables were created to represent percentages of the total population or of the total housing stock within the census tract. Eighty-one variables, which included the population and housing

adjusted percentages, were used in the factor analysis.

A factor analysis was conducted using principal components extraction and varimax rotation. A six-factor solution was obtained from the factor analysis and is displayed in Table 4. The six factors were named and interpreted as Immigrant Population, Elderly, Divorced Renters, Rural Housing, Low Socioeconomic status (SES), and High Socioeconomic status (SES). High values for **Immigrant Population** are census tracts where there is a high percentage of foreign-born individuals within the household, high percent of total population that is neither White alone nor Black/African-American alone, as well as a high percent of total population that is Hispanic/Latino. Areas with high values in **Elderly** reflected high percentages of the population that is age 65 or older, high percentage of males and females over the age of 65, and low percentages of males or females under the age of 18. **Divorced Renters** was characterized by high percentages in percent of occupied units that are renter occupied, percent of population that lives in renter occupied housing, percent of total population that is divorced, and finally percent of males and females who are divorced. Areas high in **Rural Housing** was composed of high values in percent vacant housing units, total percentage of occupied housing units that are mobile homes; percent of renter occupied housing units that are mobile homes, and finally percent of owner occupied housing units that are mobile homes. **Low SES** was characterized by high percentages of total households that are impoverished single mother households, percent of children who are in poverty, percent of households with annual income less than $10,000, percent of population in labor force that is unemployed, percent of households that are headed by single women with children, and lastly percent of households that are headed by single

women with children. High values for **High SES** consisted of percent of population with white collar jobs, percent of males with white collar jobs, percent of population that has completed a masters or more, percent of population that has completed at least some college, percent of population with annual income of $100,000 or more, and percent of households with annual income of $200,000 or more. The factor scores were computed and used to characterize geographic areas in the multilevel analyses.

Results

Description of Sample

Table 3 presents the demographic characteristics of the sample by gender and ethnicity. Blacks were more likely to fall into the low income category than Whites and Others. College education was highest for White males and lowest for Black males. Black males and females also had the highest rate of dropping out of school before high school. Blacks have twice the rate of unemployment compared to Whites. Black females reported the highest rate of disability and White females reported the highest rate of being homemakers. Black females were three times more likely to be single than White females and reported the highest rate of being divorced.

HLM Regression Analysis of BMI

The HLM model was developed in three stages: 1) a level 1 regression model was created to predict BMI from demographic variables; 2) a level 2 model was created to predict linear and quadratic changes over time within geographic units; and 3) a level 3 model was created to predict BMI differences by place using the six-factor analysis variables. The results are presented in table 3. The results in table 3 show that at level 1

age, sex, income, education, employment, marital status, and race are all significantly associated with BMI (all p's<0.0001). More specifically:

- Men were more likely to have a higher BMI than women
- People with a low income were more likely to have a higher BMI when compared to people with a high income
- High school drop outs had a higher BMI when compared to those with college
- People who smoked now had a lower BMI than people who had never smoked in their lives
- People who quit smoking had a higher BMI than those who have never smoked in their lives
- All marital statuses had a lower BMI than married individuals
- Black people were more likely to have a high BMI than White people
- Individuals who are disabled had an increased likelihood of a larger BMI than those who are employed

Level 2 of the HLM regression model showed both a linear and negative quadratic relationship. Therefore, BMI has increased linearly over time. The negative quadratic coefficient shows that the rate of increase is slightly less than linear. Therefore, the obesity epidemic was slowing down slightly between 1997-2008.

Finally, at level 3, all of the six-factor analytically derived variables were significant (p's<0.0001) except Rural Housing. Low SES was a predictor of increased BMI. This shows that areas characterized by having a higher concentration of low SES will have a higher average of high BMIs. High SES, on the other hand, was associated

with lower mean BMIs across locations. Divorced Renter was negatively associated with BMI. The variable Immigrants was also negatively associated with BMI. Suggesting that areas with a higher concentration of foreign-born and Hispanic individuals have lower average BMIs. Finally, Elderly was negatively associated with BMI showing that areas with higher number of elderly people and lower number of young people had lower average BMIs.

HLM Logistical Regression of Obese BMI

The HLM model for the logistical regression was created the same way that the HLM model for BMI was created, however, this analysis focused on BMI≥30. At level 1, all of the variables were (p's<0.001). The odds ratios at level 1 show the following:

- Relative to males the odds of obesity is 2.5% larger for females
- Compared to people in the high income bracket, the odds of obesity were 46% higher for people with low income, 28% higher for people with medium income, and 5% higher for people who did not report their income
- Compared to people with college education, the risk of obesity was 27% higher for dropouts, 61% higher for high school graduates, and 83% higher for people who did not report their education
- Compared to people who never smoked in their lives, current smokers were 32% less likely to be obese, and people who quit smoking were 6.7% more likely to be obese
- Compared to married people, divorced people were 4% less likely to be obese, widowed people were 19% less likely to be obese, single people were 8% less likely to be obese, and members of unmarried couples were 12% less likely to

be obese

- Compared to Whites, Blacks were 87.5% more likely to be obese, Hispanics were 18.6% more likely to be obese, and Other/Unknown was 7.3% more likely to be obese
- Compared to employed people, homemakers are 18% less likely to be obese, students are 43% less likely to be obese, people with employment unknown are 16% less likely to be obese, retired people are 24% less likely to be obese, and disabled people are 76% more likely to be obese

The level 2 model for obesity is very similar to the level 2 model for BMI. The linear trend suggests there is a steady increase in obesity each year. The quadratic effect shows that the rate of increase is slowing slightly over time.

For the level 3 model, 5 of the 6 variables measuring differences among places were significantly associated with the rate of obesity (all p's<0.0001). The effect for Rural Housing was not significant. Immigrant Population, Elderly, Divorced Renters, and High SES had a negative association with the rate of obesity. As the level of each of these variables increases in a geographic area, the prevalence of obesity decreases. For Low SES there was a positive relationship with obesity. Areas with a high concentration of poor, less educated, Black residents had a higher prevalence of obesity. These results were very similar to the results for BMI.

Discussion

Study Findings

This study assessed the association between BMI and obesity at the individual differences (level 1), time (level 2), and place (level 3) of the HLM model. HLM regression analysis of BMI revealed several risk factors at level 1, which included being male, lower income, and a school dropout, for increased BMI. Additionally, being Black and disabled were also risk factors of a higher BMI. At level 3, Low SES was the place variable that was a risk factor for increased BMI.

The HLM logistical regression analysis of obesity also assessed using the HLM 3 level model. At level 1, some of the risk factors for a higher likelihood of obese BMI were being female, Black, low income, and disabled. The level 3 variable, Low SES is a place risk factor because those in low SES places have an increased likelihood of having an obese BMI. These findings are consistent with other studies on obesity and low income in minorities. McAlexander et al (2009) conducted a study that focused on minorities and obesity in low-income areas. All of the participants in the study lived in low-income housing in Houston. Of those people, 68.3% were women and 47.1% had a BMI≥30.

In contrast, some of the protective factors for decreased BMI at level 1 were college education, high income, being female, being White, and employment. Individuals with these characteristics were less likely to have a higher BMI. At level 3, High SES, Immigrant Population, Divorced Renters, and Elderly could also be protective

factors. The areas with a high concentration of people over the age of 65, those who have white-collar jobs and make 100k annually, foreign-born people, and those who were divorced were all less likely to have a high BMI.

Some of the protective factors against an increase in obesity at level 1 of the HLM logistical regression model were being male, high income, college education, and being White. Additionally, at level 3, similar to BMI, Immigrant Population, Elderly, Divorced Renters, and High SES were all protective factors. Therefore, all areas with large populations of these characteristics are more likely to have a lower rate of obesity.

In terms of the level 2 variable, time, the HLM regression model for BMI shows that BMI continues to raise over time, yet that BMI is leveling off over time. Similarly, the HLM logistical regression model for obesity shows that the obesity epidemic continues. According to the linear and quadratic trend for the HLM logistical regression model, obese BMI continues to increase across time, but is slowing down.

From the HLM models for both BMI and obesity it is obvious that areas characterized by the place variable Low SES increase the likelihood of a person having a high BMI and being obese. Additionally, a disproportionately large amount of the people who make up the low SES place variable are Black/African-American and single female head of households. Given this evidence, cities need to be organized so that a place variable such as a low SES neighborhood does not contribute to people gaining weight. Local governments should be able to implement changes so that increased weight gain is not a result of where you live as much as what choices you are making. Therefore, living in an area that is lower income should not limit the availability of fresh fruits and vegetables. At the same time, initiatives such as community gardens could be

implemented so that the people in communities could grow their own fruits and vegetables seasonally. Furthermore more income integration needs to be achieved. Perhaps if more integrated housing were available some of the disparities in BMI and obesity between Blacks and Whites would decrease. The analysis from this data illuminates a huge problem in America's fight with obesity and that is the great income disparities. Therefore, to make people less fat is more than just teaching them how to prepare nutritious meals and working to forge the great divide created by the huge income disparities that exist within and between counties in the US.

Limitations and Strengths

One of the limitations of this study was using the BRFSS height and weight measures to compute BMI. The BRFSS height and weight values are self-report, therefore there could be some biases in the final BMI measures that were calculated for the data. Many times people have a tendency to over estimate their height and underestimate their weight. In creating the large data set there were some problems with assigning all of the county codes to Massachusetts. Apparently some of the counties in MA no longer exist, consequently the counties would not match with the US census data and most of MA was taken out of the data set altogether when the level 3 data was linked to the level1 data. Another limitation of this study was the fact that US census data was from 2000. This might result in a static look at place and downplay some of the major differences in place that happened between each of the years. The BRFSS data only allows analysis at the county level. As a result, analysis within counties is not possible and within county differences could be much larger than between county differences. Finally, during the data analysis case weights were not

used therefore these findings are primarily generalized to the sample, rather than to the entire US population. However, it is unlikely that our general findings would be different if case weights had been used.

One of the strengths of using the BRFSS data was to establish a nationally representative sample. The number of geographic units included in this analysis was 2,294 representing all 50 states plus the District of Columbia. Most of the previous research on place differences in obesity have been done on much more limited areas. Additionally, the data covers 11 years and reviewing these years was important to understand more about changes in obesity prevalence over time. The large sample of data for each of the 11 years allowed us to make precise statements about both the linear and quadratic trends in obesity prevalence. Finally, since the sample was so large that nearly all statistical tests were significant at $p<0.001$. It is unlikely that we committed many type I errors. In fact, we risk reporting relationships that are statistically significant but represent ultimately small effects. The odds ratios for obesity suggest, however, that many of the level 1 and level 3 effects are not just statistically significant but are in fact practically important.

Implications

As mentioned earlier, the battle of the bulging beltline in America comes down to income disparities at both the individual and geographic level. This, however, should not be a revelation given the fact that for years income disparities have drastically separated people in America. Yet, as the gap between the poorest and the richest continues to get bigger, solutions need to be created that help eliminate some of these barriers that cause people to gain weight. I think this could start at the local level. In

terms of what could be done locally, as I mentioned earlier, something like a community fruit and vegetable garden in lower income neighborhoods might help increase individuals healthy food intake. In addition, community development efforts that create good paying jobs and economic opportunities in low-income and minority communities may have a lasting effect on reducing obesity and ethnic disparities in obesity.

Table 1: Multilevel model for evaluation of BMI over time

Level	Description	Measures	Questions
3	Places	Place characteristics measured from archival data	How does BMI level of outcome (intecept) vary as a function of place
2	Times nested within locations	Archival time used to trace BMI over time	How does BMI level of outcome (intercept) vary as a function of time
1	People nested within time and place	Individual differences including demographics and behavioral outcomes	What individual differences are associated with variability outcomes

Table 2: Number of Interviews by State and Year

	year												Total
STATE	1997.00	1998.00	1999.00	2000.00	2001.00	2002.00	2003.00	2004.00	2005.00	2006.00	2007.00	2008.00	
Alabama	2092	2150	2045	2156	2700	2986	3201	3428	3069	3159	6915	6196	40097
Alaska	1483	1912	2007	2026	2759	2608	2576	2535	2730	2041	2456	2576	27709
Arizona	1861	1850	1675	2528	3055	3112	3071	4439	4401	4449	4417	5744	40602
Arkansas	1702	2838	2908	2891	2814	3753	4027	3935	5032	5338	5465	5402	46105
California	4002	4047	4152	3791	4120	4084	4322	4322	5925	5468	5469	11139	60841
Colorado	1783	1770	2986	2939	1940	3909	3915	5721	5718	5805	11388	11226	59100
Connecticut	2110	2921	3320	3710	7296	5182	4992	5659	4942	7937	7091	5853	61013
Delaware	2461	2492	2461	2607	3327	3809	3819	3876	4006	3868	3856	3843	40425
District of Columbia	1489	1431	1242	1627	1794	2286	1951	2849	3551	3799	3768	4032	29819
Florida	3407	4585	5113	4998	4396	5825	4780	6824	7845	10234	37505	10329	105841
Georgia	2246	2298	2204	3919	4286	4845	7302	4826	5800	7286	7341	5519	57872
Hawaii	2143	2122	2111	5880	4403	5819	5018	0	6216	6385	6533	6346	52976
Idaho	4803	4784	4809	4781	4588	4823	4738	5067	5432	5081	5037	4848	58791
Illinois	2781	2790	2806	3633	3807	4962	4951	3875	4850	4959	5074	4989	49477
Indiana	2311	2374	2370	2829	3861	5526	5234	6175	5339	6247	5702	4664	52632
Iowa	3530	3570	3528	3425	3427	3508	4785	4826	4831	5138	5133	5635	51336
Kansas	1852	3549	3680	4022	4315	4366	4379	8257	8219	7951	8166	8285	67041
Kentucky	3506	3594	7315	6098	7135	6679	7164	6259	6330	5906	6612	7788	74386
Louisiana	1594	1588	1617	4787	4719	4777	4836	8558	2804	6612	6231	5801	53924
Maine	1634	1550	1613	4405	2292	2311	2262	3407	3752	3831	6563	6532	40152
Maryland	4326	3163	3819	4367	4261	4188	4212	4233	8197	8391	8386	9110	66653
Massachusetts	1652	4617	4689	7749	8081	6945	7135	7689	8280	11859	20277	19341	108314
Michigan	2500	2458	2445	2508	3677	5735	3439	4764	11673	5437	7180	8977	60793
Minnesota	4723	4120	5155	2744	3811	4380	3760	4300	2749	4117	4652	4185	48696

	year												Total
STATE	1997.00	1998.00	1999.00	2000.00	2001.00	2002.00	2003.00	2004.00	2005.00	2006.00	2007.00	2008.00	
Mississippi	1540	2184	2078	2067	2888	3887	4212	5008	4262	5800	7506	7646	49078
Missouri	1812	3621	4161	4225	3996	4546	4093	4753	5028	5250	5117	4994	51596
Montana	1743	1729	1743	2884	3202	3842	3854	4815	4711	5737	5696	6564	46520
Nebraska	2605	2594	2700	2883	3457	4139	4735	8400	7923	7614	10523	15631	73204
Nevada	2442	1909	2131	2025	2480	2986	2790	2771	3031	3395	3937	4521	34418
New Hampshire	1464	1430	1192	1863	3830	4765	4760	4821	5736	5696	5704	6583	47844
New Jersey	2511	2313	2677	3595	5655	5769	10671	11247	12753	12420	6817	10935	87363
New Mexico	1756	3547	3378	3103	3472	4488	5258	6156	5329	6321	6383	5982	55173
New York	3237	2383	2506	3186	3687	4247	5241	5641	7403	5588	6183	7521	56823
North Carolina	3394	2259	2331	2875	5852	6308	8892	14185	16353	14827	14052	15100	106428
North Dakota	1771	1768	1927	1795	2415	2862	2885	2892	3844	4513	4513	4779	35964
Ohio	3012	2837	1548	3082	3239	3848	3602	6924	7197	5604	10750	12379	64022
Oklahoma	1814	2414	2812	3506	4220	6461	7290	6550	13150	6727	7133	7538	69615
Oregon	3237	1768	1741	3568	2433	2936	3802	4828	11382	4621	4748	4579	49643
Pennsylvania	3403	3412	3356	3389	3528	12877	3500	5802	12748	12599	12657	12579	89850
Rhode Island	1770	3404	3802	3371	3865	3604	3833	3768	3720	4247	4278	4579	44241
South Carolina	2096	3139	3263	3177	3038	4319	5686	6865	8132	8685	9944	9665	68009
South Dakota	2132	2055	4001	4779	4876	4574	5049	5936	6642	6309	6534	6694	59581
Tennessee	2857	2819	2866	2872	2735	3072	2454	3551	4490	4192	4769	4763	41440
Texas	2395	5769	4736	4758	5652	5734	5638	5886	5951	6312	15890	9968	78689
Utah	2808	2776	3093	2795	3534	3955	3884	4958	4946	5015	4892	5125	47781

	year												Total
STATE	1997.00	1998.00	1999.00	2000.00	2001.00	2002.00	2003.00	2004.00	2005.00	2006.00	2007.00	2008.00	
Vermont	3033	2841	3015	3477	4119	4050	4091	6549	6536	6770	6685	6541	57707
Virginia	3380	3353	3372	1906	2819	4173	5217	5278	5242	5200	5909	5048	50897
Washington	3405	3421	3453	3410	4026	4674	17702	17544	22076	22427	24626	21470	148234
West Virginia	2347	2339	2504	2242	2931	3212	3236	3330	3445	3648	4284	4011	37529
Wisconsin	2204	2170	2117	2615	3257	4156	3906	4272	4667	4604	7119	6753	47840
Wyoming	2361	2373	2343	2311	2952	3442	3880	4013	4819	4741	5939	7587	46761
Total	128520	141200	150916	172179	195022	229344	246030	282567	333207	330160	403805	387895	3000845

Table 3: Demographic Characteristics of the Sample

		Black				White				Other/Unk			
		Male		Female		Male		Female		Male		Female	
Variable	Category	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Income													
	Low	18244	23.7%	51473	33.5%	110671	11.3%	246897	17.3%	15305	19.2%	26106	24.9%
	Med	31619	41.0%	58603	38.1%	364363	37.2%	515802	36.1%	29964	37.5%	37100	35.3%
	High	22249	28.9%	32136	20.9%	471115	48.1%	571427	40.0%	29666	37.1%	32649	31.1%
	Income Unknown	4964	6.4%	11617	7.6%	33347	3.4%	95730	6.7%	4933	6.2%	9188	8.7%
	Total	77076		153829		979496		1429856		79868		105043	
Education													
	Dropout	13216	8.3%	25838	8.1%	80871	4.1%	122135	4.1%	10709	6.5%	14494	6.6%
	High School	27477	17.3%	53544	16.8%	291288	14.6%	452000	15.3%	23553	14.3%	29518	13.5%
	College	36218	22.8%	74192	23.2%	606021	30.4%	854055	28.9%	45453	27.6%	60815	27.7%
	Education Unknown	166	0.1%	258	0.1%	1320	0.1%	1669	0.1%	153	0.1%	217	0.1%
	Total	159117		319278		1992343		2955445		164669		219275	
Employment													
	Employed	47566	61.7%	85319	55.5%	648545	66.2%	749192	52.4%	53867	67.4%	57370	54.6%
	Unemployed	5684	7.4%	11696	7.6%	31816	3.2%	45766	3.2%	4969	6.2%	6178	5.9%
	Student	2269	2.9%	5797	3.8%	19141	2.0%	30146	2.1%	3225	4.0%	4858	4.6%
	Homemaker	170	0.2%	7893	5.1%	2303	0.2%	181673	12.7%	281	0.4%	13142	12.5%
	Retired	13910	18.0%	26063	16.9%	233775	23.9%	349232	24.4%	12336	15.4%	15696	14.9%
	Disabled	7252	9.4%	16660	10.8%	42368	4.3%	71569	5.0%	5005	6.3%	7568	7.2%
	Employment Unknown	226	0.3%	404	0.3%	1552	0.2%	2281	0.2%	185	0.2%	232	0.2%
	Total	77077		153832		979500		1429859		79868		105044	
Marital Status													
	Married	32949	21.4%	42233	13.8%	612856	31.3%	772999	27.1%	43830	27.5%	51837	24.7%
	Divorced	16175	10.5%	37678	12.3%	139692	7.1%	235686	8.2%	11535	7.2%	18983	9.0%

		Black				White				Other/Unk			
		Male		Female		Male		Female		Male		Female	
Variable	Category	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
	Widowed	4403	2.9%	23042	7.5%	53326	2.7%	247647	8.7%	3133	2.0%	12059	5.7%
	Single	21162	13.7%	47511	15.5%	150543	7.7%	140820	4.9%	18275	11.5%	18426	8.8%
	Couple	2178	1.4%	2853	0.9%	21311	1.1%	29872	1.0%	2874	1.8%	3476	1.7%
	Total	153944		307149		1957228		2856883		159515		209825	
Smoking													
	Never Smoked	38298	15.1%	53801	11.6%	546341	17.0%	644007	14.9%	43424	16.2%	42140	13.3%
	Smoke Now	15884	6.3%	22245	4.8%	163142	5.1%	214555	5.0%	17447	6.5%	17793	5.6%
	Quit Smoke	22414	8.8%	31556	6.8%	383199	11.9%	429452	10.0%	25977	9.7%	24347	7.7%
	Total	253880		465115		3221764		4315589		267512		316007	

Table 4: Factor Analysis of SF3 Census Variables

	Component					
Variable Description	1	2	3	4	5	6
of total households, the percent of which are impoverished single mother households	.845					
percent of children who are in poverty	.812					
percent of households with annual income less than $10,000	.811					
percent of population in labor force that is unemployed	.783					
percent of households that are headed by single women with children	.778					
percent of households with public assistance income	.764					
percent of households with annual income less than $25,000	.746					
percent of total population that is Black/African-American alone	.729					
percent of males in labor force who are unemployed	.728					
percent of total population that is white alone	-.724					
percent of females in labor force who are unemployed	.708					
percent of females with a disability	.639	-.417				
percent of noninstitutionalized population 5 years and older with a disability	.637	-.463				
percent of total population that has a high school degree (incl. equiv.) or more	-.629	.566	-.435			
percent of total population with less than a high school education	.629	-.566	.435			

Variable Description	Component					
	1	2	3	4	5	6
percent of females with less than a high school education	.628	-.546	.451			
percent of females who have a high school degree (incl.equiv.) or more	-.628	.546	-.451			
percent of males with less than a high school education	.615	-.567	.401			
percent of males who have a high school degree (incl. equiv.) or more	-.615	.567	-.401			
of single mother households, the percent that are impoverished	.604					
percent of males who with a disability	.575	-.469				
percent of households where rent is 30% or more of monthly income						
percent of households without a mortgage where monthly household expenses are 30% or more of monthly income						
percent of population with blue collar jobs		-.908				
percent of population with white collar jobs		.908				
percent of males with blue collar jobs		-.897				
percent of males with white collar jobs		.897				
percent of total population that has completed a masters or more		.858				
percent of males who have completed a masters or more		.839				
percent of females who have completed a masters or more		.829				
percent of total population that has completed at least some college	-.497	.785				
percent of females who have completed at least some college	-.483	.780				
percent of females with blue collar jobs		-.777				

Variable Description	Component					
	1	2	3	4	5	6
percent of females with white collar jobs		.777				
percent of males who have completed at least some college	-.502	.768				
percent of households with annual income of $100,000 or more		.685				
percent of households with annual income of $200,000 or more		.611				
median household income in 1999	-.530	.581				
percent of households that are English speaking			-.897			
percent of population that was foreign born			.889			
percent of total population that is Hispanic/Latino			.803			
percent of total population that is neither white alone nor Black/African-American alone			.795			
weighted average people per room in renter occupied housing			.732			
weighted average people per room in owner occupied housing			.688			
percent of population that was born in state of residence			-.491			
percent of households with a mortgage where monthly household expenses are 30% or more of monthly income			.410			
percent of population age 5 and older that was in the United States in 1995				.708		
percent of occupied units that are renter occupied	.473			.707		
percent of occupied units that are owner occupied	-.473			-.707		
percent of population that lives in owner occupied housing	-.501			-.693		
percent of population that lives in renter occupied housing	.501			.693		
percent of total population that is divorced				.675		

Variable Description	Component					
	1	2	3	4	5	6
percent of females who are divorced				.645		
percent of males who are divorced				.574		
weighted average number of units per structure in renter occupied housing units				.456		
percent of population that is age 65 or older					.910	
percent of females who are age 65 or older					.907	
percent of males who are age 65 or older					.857	
percent of females who are under age 18					-.730	
percent of population that is under age 18					-.715	
percent of males who are under age 18					-.642	
weighted average number of units per structure in owner occupied housing units						
percent vacant housing units						.666
percent occupied housing units						-.666
total percentage of occupied housing units that are mobile homes						.658
percent total units in urban area						-.650
percent of renter occupied housing units that are mobile homes						.635
percent of owner occupied housing units that are mobile homes						.623
percent of total units that lack complete plumbing facilities						.588
percent of total units that lack complete kitchen facilities						.547
percent of total population that is female						-.509
percent of total population that is male						.509

Table 5: Multi-Level Analysis of BMI

Outcome	Model	Predictor	Coefficient	d.f.	P-value
BMI	Level 3				
		Intercept	26.5746	2286	0.0000
		IMMIGRANT POPULATION	-0.2687	2286	0.0000
		ELDERLY	-0.2050	2286	0.0000
		DIVORCED RENTERS	-0.1101	2286	0.0000
		RURAL HOUSING	-0.0069	2286	0.6660
		LOW SES	0.2256	2286	0.0000
		HIGH SES	-0.4020	2286	0.0000
	Level 2				
		LINEAR TREND	0.1290	12399	0.0000
		QUADRATIC TREND	-0.0077	12399	0.0000
	Level 1				
		AGE	0.0146	2766195	0.0000
		SEX	-0.7493	2766195	0.0000
		INCOME LOW	0.9076	2766195	0.0000
		INCOME MEDIUM	0.5806	2766195	0.0000
		INCOME UNKNOWN	-0.1182	2766195	0.0000
		DROPOUT	0.5668	2766195	0.0000
		HIGH SCHOOL	0.4052	2766195	0.0000
		EDUCATION UNKNOWN	-0.4120	2766195	0.0000
		SMOKE NOW	-1.1343	2766195	0.0000
		QUIT SMOKING	0.1803	2766195	0.0000
		DIVORCED	-0.1529	2766195	0.0000
		WIDOWED	-0.6917	2766195	0.0000
		SINGLE	-0.4023	2766195	0.0000
		COUPLE	-0.3907	2766195	0.0000
		BLACK	2.1327	2766195	0.0000
		HISPANIC	0.7135	2766195	0.0000
		OTHER UNKNOWN	0.1438	2766195	0.0000
		UNEMPLOYED	0.3280	2766195	0.0000
		HOMEMAKER	-0.6411	2766195	0.0000
		STUDENT	-1.6437	2766195	0.0000
		EMPLOYMENT UNKNOWN	-0.5849	2766195	0.0000
		RETIRED	-0.7893	2766195	0.0000
		DISABLED	2.0106	2766195	0.0000

Table 6:Multilevel Analysis of Obesity

Outcome	Model	Predictor	Odds Ratio	d.f.	P-value
OBESE	Level 3				
		Intercept			
		IMMIGRANT POPULATION	0.9023	2286	0.0000
		ELDERLY	0.9423	2286	0.0000
		DIVORCED RENTERS	0.9581	2286	0.0000
		RURAL HOUSING	0.9996	2286	0.8190
		LOW SES	1.0842	2286	0.0000
		HIGH SES	0.8625	2286	0.0000
	Level 2				
		LINEAR TREND	1.0544	12399	0.0000
		QUADRATIC TREND	0.9966	12399	0.0000
	Level 1				
		AGE	1.0015	2766195	0.0000
		SEX	1.0248	2766195	0.0010
		INCOME LOW	1.4595	2766195	0.0000
		INCOME MEDIUM	1.2762	2766195	0.0000
		INCOME UNKNOWN	1.0523	2766195	0.0000
		DROPOUT	1.2685	2766195	0.0000
		HIGH SCHOOL	1.6062	2766195	0.0000
		EDUCATION UNKNOWN	0.8251	2766195	0.0000
		SMOKE NOW	0.6831	2766195	0.0000
		QUIT SMOKING	1.0673	2766195	0.0000
		DIVORCED	0.9619	2766195	0.0000
		WIDOWED	0.8076	2766195	0.0000
		SINGLE	0.9179	2766195	0.0000
		COUPLE	0.8823	2766195	0.0000
		BLACK	1.8746	2766195	0.0000
		HISPANIC	1.1858	2766195	0.0000
		OTHER UNKNOWN	1.0729	2766195	0.0010
		UNEMPLOYED	1.1355	2766195	0.0000
		HOMEMAKER	0.8206	2766195	0.0000
		STUDENT	0.5708	2766195	0.0000
		EMPLOYMENT UNKNOWN	0.8478	2766195	0.0000
		RETIRED	0.7667	2766195	0.0000
		DISABLED	1.7599	2766195	0.0000

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