Social-Environmental Determinants and Geospatial Distribution of Cardiovascular Deaths among Adults in Two Central Texas Areas

by

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ABSTRACT

Introduction: Over the last half century, obesity has become a public health priority throughout the United States of America (U.S.). The World Health Organization (WHO) defines adult obesity as abnormal fat accumulation, caused or worsened by excessive calorie intake paired with lack of physical activity, which may impair health (69). In Texas, data about the prevalence of obesity are obtained by the Texas Department of State Health Services (TDSHS) through the administration of a monthly telephone survey to a representative sample of adults over the age of 18. This information is collected in the Behavioral Risk Factor Surveillance System, or BRFSS. Overweight and obesity are risk factors for many cardiovascular diseases. Socio-ecological influences play a role in obesity when the built environment surrounding an individual leads to the creation of behavioral patterns in diet and exercise and affect health.

Objective: The objective of this study was to investigate the geospatial distribution and social-environmental determinants of cardiovascular deaths among adults in two Central Texas areas from 2005 to 2008. The two areas considered were Northeast Travis County and San Antonio; both were populations targeted by the Steps BRFSS program. The social environmental determinants included physical indicators of the neighborhood-level built environment, such as sidewalks, as well as the resulting social behavior or outcome, such as physical activity level or BMI. The study considered two measures of cardiovascular death, frequency and variance of type of death.

Methods: A composite database containing information about survey participants' BMI, two indices of neighborhood features, and information about deaths due to selected cardiovascular disease was created. ArcGIS software was used to exclude all cardiovascular death data points that did not fall within the defined areas. This was possible because of the latitude and longitude information given on the death certificate. The SPSS statistics data editor program was used to perform univariate statistical data analyses on BMI, two neighborhood features indices, and cardiovascular death. The indices calculated were a walkability predictive index and a recreational resources index. A latent growth curve analysis was performed using HLM 06 in order to analyze the change in multiple levels of data over time.

Results: Those individuals living in both areas were classified as overweight but not obese. The four-year mean BMI for those in area 1 was slightly higher than area 2. The four-year mean walkability predictive index of area 1 was lower than area 2. Area 1 had a higher recreational resources index than area 2. Of the total 289 cardiovascular deaths, 126 of these occurred in area 1 and 163 occurred in area 2. The most frequently occurring code was I21.9; this code signifies death due to acute myocardial infarction. It was determined from the latent growth curve analysis that area 2 increased in cardiovascular death variance while the variance of area 1 remained relatively constant over the four-year period.

Discussion: Concerning the social environmental variables, area 1 had a low BMI, a high walkability, and large amount of recreational resources. Area 1 was seen to have a high variance in types of cardiovascular death with no significant change in this variance over time. On the other hand, area 2 had a high BMI, and low walkability. Area 2 was seen to have a significant increase in variance in types of cardiovascular death over time. In area 2, the changes in walkability, recreational resources, and BMI are predictive of changes in cardiovascular death. The significance of an area's variation in types of cardiovascular death can be understood in a clinical sense. As social-environmental factors in area 2 became more indicative of healthier living over time, cardiovascular death became more dispersive. Therefore, it is logical to conclude that these deaths are less likely due to a specific obesity problem.

INTRODUCTION

The Prevalence of Obesity

Over the last half century, obesity has become a public health priority throughout the United States of America (U.S.). The World Health Organization (WHO) defines adult obesity as abnormal fat accumulation, caused or worsened by excessive calorie intake paired with lack of physical activity, which may impair health (69). According to the Centers for Disease Control and Prevention (CDC), overweight and obesity ranges in adults are defined by their "body mass index," or BMI. To calculate this index, the following formula is used:

$$\text{BMI} = \text{weight (kilograms)}/\ [\text{height (meters)}]^2$$

If using units of pounds and inches, the same calculation is performed but the product is multiplied by 703. Although an indirect measure of body fat calculated through measurements of height and weight, BMI correlates with an individual's amount of body fat in most cases. BMI is used to classify categories of obesity: overweight ≥ 25, obese ≥ 30, severely obese ≥ 40, and morbidly obese ≥ 50. BMI in children and adolescents under 18 years of age is calculated differently to take into account age and gender differences. Of course, BMI is only a single indicator of possible weight-related health risks (13).

Overweight and obesity alone are the fifth leading risk for death worldwide claiming at least 2.8 million adult lives annually. In 2008, 1.5 billion adults were overweight and 500 million adults were obese globally (69). In the U.S., chronic disease and conditions such as obesity occur in almost half of all people and account for seven of the ten most prevalent causes of death. Four of those chronic diseases, heart disease, stroke, cancer, obesity, and arthritis, are responsible for three-quarters of the annual $2 trillion spent on medical care in the U.S. and cost about $1 trillion per year in lost productivity (18). Although some subgroups are disproportionately affected, the consequences of the obesity epidemic have been documented in both sexes, across all ages, ethnicities, and socioeconomic strata (36).

In the case of obesity, preventable health-risk factors such as inadequate physical activity and poor nutrition contribute significantly to the condition (18). Increased consumption of energy-dense foods high in fat, salt, and sugar along with a decrease in daily physical activity leads to accumulation of fat (69). Changes in society over the last several decades are thought to contribute to the prevalence of obesity. These changes include unhealthy school and work dietary environments, more meals eaten outside the home, motorized transportation, increased leisure time computer use, and increased television viewing. Overall, a complex web of factors contributes to an increase in energy intake and decrease in energy expenditure; this energy imbalance is fundamental to the increase in obesity (36).

Trends in BMI and obesity from the past half century have been analyzed and reported periodically for U.S. children, adolescents, and adults. BMI changes from 1960 to 2010 have been calculated from height and weight measurements collected through the National Health and Nutrition Examination Survey (NHANES) (22, 48). The NHANES program periodically surveys a nationally representative sample of the U.S. to collect information on the health and nutritional status of adults and children, including BMI (14). There was no significant change in obesity prevalence in any age group from 1960-1980. For persons ages 12 to 19 in the U.S., the prevalence of childhood and adolescent obesity steadily increased in the 1980's and 1990's until a plateau occurred from 1999 to 2010 (48). This trend is paralleled in the adult obesity data from 1960 to 1999. From 1999 to 2010, obesity (BMI $\geq$ 30) in persons age 20 and up increased in the U.S. at a slower rate, but without evidence of a decline (Figure 1) (22, 48).

Data from 2009-2010 show that 16.9% of U.S. children and adolescents ages 2 to 19 were considered obese with a BMI greater than or equal to the 95th percentile on the CDC's BMI-for-age growth charts (48). For U.S. adults in 2009-2010, the age-adjusted prevalence of obesity was 35.5% among adult men and 35.8% among adult women; this is not a significant change compared with data from 2003-2008. The age-adjusted prevalence of overweight and obesity combined was 68.8% overall, 73.9% among men, and 63.7% among women (22).

In Texas, data from the Behavioral Risk Factor Surveillance System (BRFSS) provides data on obesity and overweight adults over the age of 18 through monthly telephone surveys (63). Given that the previous data on U.S. prevalence is based on NHANES data and not data from the BRFSS, the prevalence of obesity in Texas is approximately the same as the national percentages. Overall, 31.7% of Texas adults surveyed had a BMI $\geq$ 30 with 32.5% among men and 31% among women. Additionally, 66.6% of adults had a BMI $\geq$ 25 indicating the combined percentage for overweight and obese; this is a significant increase from the 40% of Texas adults that were obese or overweight in 1991. By current estimates, nearly 75% of Texas adults will be overweight or obese by 2040 (61).

From the data above, there is no evidence that the prevalence of obesity among any age group is declining and currently obese and overweight conditions affect more than 200 million Americans (4). In fact, the prevalence of severe and morbid obesity, BMI > 40 and BMI > 50, have increased significantly since 2000. As the most serious health problems are associated with these levels of BMI, the current slowing in the overall overweight/obesity trend may represent an underestimate of the consequences of this epidemic on population health (19). Thus, obesity remains a priority public health concern (32).

Obesity in Young Adults

The transition from adolescence to adulthood is a critical time in which independent health behavior patterns are formed; once formed, these habits can affect the intake and expenditure of energy of an individual for a lifetime. Obesity in the transitional ages of 18-29, encompassing a group known as emerging and young adults, has been understudied compared to older adult and even childhood cases (45). While the collapsing of ages in the BRFSS does not allow for examination of each subgroup individually, the term “emerging adult” is typically defined as ages 18-25 while “young adult” refers to individuals approximately 26-30 years of age (3). Increases in higher education and delays in marriage have shifted in such a way as to necessitate the separation of these two adult life stages (45).

In the last 30 years, the prevalence of obesity among adults ages 18-29 has more than doubled (45). From 1991-1998, the BRFSS indicated that the greatest increase in obesity prevalence was among emerging and young adults 18-29 years of age (41). As reported in 2012, 31.9% of women and 33.2% of men in this age group were considered obese (22). Emerging adulthood has many unique characteristics that make an individual partial to the development or cessation of behavioral risk factors for obesity. The first 3 to 4 months of college are a typical time for rapid weight gain averaging a 2 to 7 pound gain. These changes include increased independence, a search for self-identity, and new responsibilities related to finances and employment. During this transition, nutritional and physical activity changes can lead to increased risk of excess weight gain and fat accumulation (45).

Lack of physical activity in this age group is a determinant of the high level of obesity. Moving in with a significant other, getting married, and becoming a parents are all specific life events correlated with a decline in physical activity during emerging and young adulthood (9). From adolescence to young adulthood, adverse changes in physical activity have been found; these include a decrease in moderate to vigorous exercise in females and an increase in leisure time computer use in males (44). In fact, only 12.7% of young adults meet national guidelines for physical activity (30).

Dietary changes also accompany this transition from adolescence to adulthood, especially during time on university campuses (45). Fast-food restaurant use is highest in young adulthood (51) with a majority of adults aged 20-29 consuming less than 1 serving fruit and vegetables per day (17). The Bogalusa Heart Study followed children from adolescence into adulthood and found a substantial decline in healthy eating habits during this transition. Findings showed that emerging and young adults (19-28 years) consumed less fruits and dairy and more sweetened drinks, high sodium snacks, and red meat than they did previously (20). Factors influencing this diet change and incidental weight gain include the availability of unhealthy foods on college campuses, late night eating, calories consumed via alcoholic beverages, lack of time to prepare healthy meals, and stress-induced eating (45).

As a critical time for establishing independent healthy behaviors, understanding the complexity of the factors involved in weight gain in emerging and adolescent adults is an important goal. The effects of unhealthy weight gain at this age can be observed through obesity-related disease and mortality in middle-aged adults. Obesity-related disease in adults under 50 is an indication of obesity onset during childhood, adolescence, or young and emerging adulthood (45). By altering unhealthy childhood habits or by acquiring new healthy ones, the adoption of low-risk behavior patterns at emerging and young adulthood is vital to the prevention of obesity-related chronic disease in later life.

Obesity as a Significant Risk Factor for Other Diseases

Overweight and obesity constitute the fifth leading risk for global death due to the wide array of organs that are affected by levels of high body fat. BMI levels above 25 are a risk factor for cardiovascular diseases, diabetes, musculoskeletal disorders, and some types of cancer including breast and colon (69). Overweight and obesity are also strongly associated with hypertension, hypercholesterolemia, asthma, and arthritis (19, 40). According to the WHO, 44% of diabetes cases, 23% of ischemic heart conditions, and up to 41% of certain cancer diagnoses are due to overweight or obese conditions in the patient (69).

While it was previously established that overweight and obesity had a wide range of negative effects in adult bodies, it is now known that high BMI in children and adolescents is significantly correlated with various chronic disease risk factors as well (28). By tracking the weight and health status of children into adulthood, it has become clear obese children are at risk for long-term health problems and at risk for becoming obese adults (48). Evidence shows that on average, 40% (and as high as possibly 80%) of children with high BMI will become obese adults (6). Children with high BMI are at risk of elevated blood pressure and lipid concentrations and can thus become obese adults at risk for both cardiovascular and metabolic conditions (CVD) (49).

Out of all the cardiovascular health risk factors, obesity is especially significant because it affects several other CVD risk factors (4). Obesity at any age is associated with CVD risk factors including accelerated atherosclerosis, elevated blood pressure (BP), dyslipidemia, metabolic syndrome, type II diabetes mellitus, and altered vascular and heart function (54). Obesity-related inflammation is the main cause of insulin-resistance (pre-diabetes) and atherosclerosis. Atherosclerosis is a chronic inflammatory disease of the arteries and accounts for most deaths due to myocardial infarction and stroke. It has often been noted that obesity-related vascular changes parallel those seen with increased vascular age (4). This is the underlying reason why the earlier and longer an individual lives under obese conditions, the more quickly vascular aging occurs and the higher the risk of CVD (39).

Obesity and overweight related metabolic conditions include insulin-resistance and diabetes (49). Studies have shown that impaired glucose tolerance, including insulin resistance, is associated with the prevalence of obesity in all age groups (58, 68). Obesity causes insulin resistance by impairing insulin signaling and interfering with glucose transport (42). When paired with other risk factors that increase the occurrence of CVD and diabetes, insulin resistance can escalate to metabolic syndrome (43). Insulin resistance and metabolic syndrome are possible precursors for type II diabetes mellitus. Thus, the diagnoses for type II diabetes have increased significantly in youth, and most of these childhood diagnoses are made in obese children (6). For children born in the U.S. in 2000, the lifetime risk of being diagnosed with type II diabetes mellitus is estimated at 30% for males and 40% for females (36).

Other metabolic conditions such as dyslipidemia and hypercholesterolemia contribute to the diagnosis of metabolic syndrome in obese and overweight patients. High triglyceride levels and low high-density lipoprotein cholesterol levels characterize Dyslipidemia, or an abnormal lipid profile, in at-risk youth (6). Regarding obese adolescents, it is 1.5 to 2 times more likely for them to be diagnosed with hypercholesterolemia than a non-obese adolescent (24). In summary, at any age, overweight and obesity are risk factors for a variety of diseases that affect both cardiovascular and metabolic health.

Risk Factors for Obesity

There are many factors that affect nutrition and physical activity in a given area and thus affect the prevalence of obesity. Biological, psychological, environmental, behavioral and social factors have all been tied to obesity, with socioeconomic and social ecological risk factors being prominently studied in the last decade.

Socioeconomic Factors

Socioeconomic status (SES) is usually a measure of the combination of education, income, and occupation of an individual (1). In certain races, a lower SES is associated with a higher risk of obesity, although the association between SES and obesity has been weakening over time (66). While SES may not be a major risk factor for obesity in itself, it has been shown that social origin may have a long-term effect on weight status. Through its role in the creation of behavioral patterns in diet and exercise, the total environment surrounding a developing individual may influence weight more than SES variables (50). This implies that something more than SES is driving tendencies for accumulation of excess body fat via energy imbalance.

Conceptual Models for Obesity

The SES of an area is only a single variable in a broader category of environmental factors that affect a population's physical activity and diet. For example, lower-income neighborhoods have three times more fast-food restaurants and convenience stores, thus limiting healthy eating options. Also, neighborhoods with low SES often have unsafe conditions or fewer resources conducive to outdoor activities and exercise (5). A model created by the CDC divides causal factors of obesity into spheres of influence. This socio-ecological model focuses on the relationship between an individual and his or her social environment (Figure 2) (27).

Focusing on the increased caloric intake and decreased physical activity as the primary factors creating the obesity problem, the socio-ecological model includes factors from four different realms: individual factors, behavioral settings, sectors of influence, and social norms. On an individual level, genetics and hormones affect metabolism while the setting surrounding an individual can affect his or her behavioral responses. Social behaviors such as eating and exercising can be influenced by a person's interpersonal relationships. Within this setting, broader norms imposed by social or cultural influences can also affect individuals' energy expenditure and intake. Lastly, sectors of influence include policy-makers, the physical environment, and economic conditions that can limit or promote a healthy energy balance (27).

Social Ecological Factors

Social ecological factors and the socio-ecological model can be used to explain the obesity-related energy imbalance as a consequence of a variety of influences (27). The sphere involving the many sectors of influence on an individual is especially complex. Concerning energy intake, many environmental factors have been linked to the development of obesity. In the search for healthy foods, the influence of access, monetary cost, and opportunity (time) cost are significant. Fresh produce and other healthy eating options are often higher in monetary cost because of their perishable nature; they also are less easily obtained in areas with higher densities of convenience stores and fast-food restaurants. Several studies have clearly tied consistent fast-food consumption to high BMI and daily fruit and vegetable intake to lower BMI. According to BRFSS, 76.6% of adults in the U.S. consume less than the daily requirement of 5 servings of fruits and vegetables (14). The influence of industry can also be seen in the availability of extra-large portion sizes (70).

With the factors above causing excessive energy intake, the other side of the obesity equation is equally important. Physical inactivity is an important contributor to fat accumulation, while physical exercise obviously reduces adipose tissue (4). A consistent exercise regime can decrease risk for type II diabetes mellitus and metabolic syndrome in adults (42). Only 3 in 10 adults regularly engage in leisure-time physical, with little change in this statistics from 2004 to 2010 (57). About two-thirds of boys and one-quarter of girls report doing twenty minutes of sustained moderate to vigorous physical activity three times per week (56).

When analyzing energy expenditure, many factors can be linked to decreased physical activity. In adolescents and children, sex (male), age (inverse), community sports, amount of sedentary time after school/weekends, program/facility access, and time spent outdoors were all variables consistently associated with physical activity (56). The "walkability" of an area can be diminished by the presence of poorly maintained sidewalks, infrequent intersections, and a perception or reality of unsafe conditions (70), while areas with high connectivity encourage walking and bicycling (4). Suburban sprawl and length of commute to work or school have both been correlated to BMI. On the other hand, green space, the presence of water, and access to paved trails and recreational facilities can positively influence physical activity (70).

The Built Environment

When analyzing the role of the environment on obesity, physical factors of the environment around an individual were recognized as significant. In this sense, the term "environment" is defined broadly and includes all features in the space outside an individual (67). The subset of broadly defined environmental features related to family, work, and school in the larger context of the community became known in literature as the built environment (25). The built environment includes the range of structural features in a residential area including urban design, type of land-use patterns, transportation networks and resources, and activity options such as parks, recreational facilities, and the presence of sidewalks or trails (5, 25). These factors affect diet, physical activity, active commuting, neighborhood walkability, and neighborhood safety that in turn affect obesity (25). For example, physical activity could depend on access to parks and community sports, land-use patterns, and type of transport in the area. Likewise, density and location of different types of food venues could influence eating habits (10).

In recent literature, prominently studied community level factors include accessibility of recreational facilities, neighborhood safety, accessibility to convenience stores and restaurants, and school lunch programs (25). These characteristics of the built environment can act as either barriers or supports to healthy habits by deterring or promoting a balanced diet and physical activity. Commonly today, the residential environment has moved toward a pattern of sprawl with a lack of mixed land-use due to zoning and a design that favors motorized transportation. The role of these built environmental patterns, as well as the role of parks and green spaces, on physical activity and obesity rates must be studied in order to identify susceptible geographic populations. Collaboration between researchers and city-planners could encourage healthy habits through changes in industrial design, architecture, urban planning, and landscape design (67).

Measures of the built environment can be subdivided into which side of the energy imbalance equation they affect- intake or expenditure (10). Physical activity facilities, transportation networks, land use, sprawl, and urban design are all factors of the built environment that affect physical activity. To measure the effect of these built factors on activity, energy expenditure, and ultimately obesity, indicators of physical activity opportunities in the environment must be chosen that can be quantified and then placed within a geographic constraint. Such indicators include recreational and park facilities, public open space, vegetation indices, sidewalk and bicycle trails, and land-use patterns.

The same type of analysis can be done for built environment factors affecting nutrition and healthy eating habits. In this case, the physical environment features include the different types of food venues with indicators such as supermarkets, convenience stores, full-service restaurants, and fast-food restaurants. The indicators of the built environmental features can then be measured through count, density, proximity, walkability, area, length etc. Density and proximity are especially important as measures of quantifying the food environment, while walkability is a measure more fit for the physical activity setting (16). In order to link the affect of these built variables to their location, areas must be defined by standards such as county and zip code (10). This process allows researchers to analyze the effects of certain built environment variables on the obesity statistics of the surrounding community, and to identify spatial inequalities that could be remedied by urban planners (16).

Several environmental assessment methods are used to collect the data needed to perform such analyses on built environment features. Indirect methods include census data, Geographic Information Systems (GIS) data, and street network data. Intermediate methods include perceived environment measures completed by residents, geospatial land use data, aerial photographs, and global positioning systems (GPS). Direct methods include in person audits of environmental characteristics as completed by a trained observer. Obviously direct methods would be the most accurate, but these methods would cost a significant amount of time and money. Indirect methods are most commonly used due to their ready availability, but often have limitations regarding the means by which the data was collected (5).

GIS is one of the objective indirect approaches for assessing the built environment. GIS are methods utilizing computer and software tools to combine spatial information from a variety of different sources into a single format (10, 65). GIS organizes and combines spatial data about the built environment and analyzes it according to geographic location (10). The term geospatial is utilized in literature to address the type of spatial analysis achievable through GIS software (38). Certain GIS software has the capacity to use existing maps to calculate road distance between a residence and a convenience store or amount of green vegetation in an area from an aerial photograph (65). By integrating and mapping these kinds of data in the context of time and location, GIS analyzes several layers of variables to get a more complete understanding of relationships in time and space (8). Using nationally collected data on the built environment and advances in epidemiology such as multilevel statistics, GIS can calculate precise measures for small areas on a large-scale (52).

Factors of the Built Environment that Affect Obesity

In the past decade, many studies have analyzed the effects of different built environment characteristics on BMI, physical activity, and obesity-related disease prevalence (37, 47, 53). Built environment variables studied include vegetation and green space (29, 37), food retail type and proximity (37), park amenities and facilities (47, 53), park proximity (53), intersection density (47), retail floor area ratio (47), connectivity (47), county sprawl (21), age of suburb design (44), sidewalk presence and condition (33), housing density (55), and walkability (35). These studies focused on a variety of ages including children, adolescents, and adults. Indirect, intermediate, and direct methods of environmental assessment were utilized including direct questioning of residents (47), aerial photographs of green spaces (37), and GIS surveys of park and retail locations (33).

These studies used a variety of methods to measure the effect of built environment variables on physical activity or BMI; many of these studies came to contradictory conclusions depending on the measures utilized. For example, Liu et al. (37) measured the amount of neighborhood vegetation surrounding children ages 3 to 18 in Marion County, Indiana. Utilizing aerial photographs and a normalized difference vegetation index, GIS software calculated the amount of vegetation surrounding each subject's residence. Associations between the vegetation index and the child's overweight status were examined, and it was found that increased neighborhood vegetation was associated with a decreased risk of overweight status for children living in high population density areas. The study concluded that aspects of the built environment, such as vegetation, influence physical activity patterns and are thus determinants of child weight status (37). Other studies have corroborated the findings of Liu et al. For example, Gomez et al. (29) found that the distance to the nearest open play space was significantly associated with outdoor physical activity in adolescent males.

Many studies have taken different approaches to the concept of an outdoor recreational area. Instead of considering the general amount of space available, studies looked at specific park and recreational facilities in relationship to the weight status of children, adolescents, and adults (34, 47, 53, 55). Potwarka et al. (53) examined three proximity-based park variables in relation to weight status among children in a Canadian city. The availability of parks, parkland, and park facilities within 1 kilometer (km) of a child's residence was calculated with GIS-produced municipal park maps; parents reported information about a child's height and weight. While no association was found regarding proximity to park and parkland, children with a park playground within 1 km of their home were five times more likely to have a healthy weight status than children who did not. The study concluded that certain park facilities may be more important in supporting physical activity in children than park space in general (53). Likewise in regard to children's physical activity, Burdette et al. (7) found no correlation between playground proximity and overweight status in pre-school children ages 3 to 5, while Roemmich et. al. (55) found an association between park proportion and physical activity in children ages 4 to 7.

Kaczynski et al. (34) conducted a similar study on an adult population in Canada. They studied whether park size, number of park features, or distance to a park from a subject's home were related to the park's use for physical activity. GIS sources were used to make maps of each participating neighborhood and the Environmental Assessment for Public Recreation Spaces instrument provided data on park features. While size and distance of parks were not found to be significant, parks with more features, specifically trails, had the highest correlation with park use. Again, this study concluded that certain park features are predictors of physical activity while general park space is not (34).

Another measure on which studies choose to focus is walkability (33, 35, 47). Walkability is defined many ways, but it is simply the "extent to which the built environment is walking friendly." Factors affecting walkability include street connectivity, land use mix, presence and quality of sidewalks and trails, and residential density (2). Jago et al. (33) examined self-reported and GIS environmental characteristics in relation to physical activity among 10 to 14 year old boys in Houston, Texas. Accelerometry was used to measure physical activity and participants completed a report concerning their observed environment. Sources from GIS identified the number of parks, gyms, trails, grocery markets, and restaurants within a one-mile radius of the participant's residence. After statistical analysis, only sidewalk characteristics were found to be associated with light intensity levels of physical activity. The study concluded that sidewalk features were likely significant due to their impact on walkability (33).

Other studies have researched the relationship among built environmental features, walkability and active commuting, physical activity levels, and weight status (35, 47). It is often reported that increased connectivity in a residential area is positively correlated with physical activity and decreased risk of obesity in adults due to increased walkability (5); yet when examining this environmental feature's effect on youth, low-connectivity areas such as ones with a high number of cul-de-sacs were correlated with decreased risk of overweight and obesity. Norman et al. (47) used GIS to find variables reflecting community design and access to recreational facilities for adolescents ages 11 to 15. Accelerometers were worn by the participants to measure physical activity. It was concluded that these low traffic areas provide a safe place for young people to play outside and thus increased physical activity and healthy weight status (47).

Similarly, suburban neighborhoods are believed to restrict physical activity if they have low walkability, zoning, and automobile dependence due to sprawl. Yet, adolescents in older suburban communities are actually more likely to be active. Nelson (46) used data from a national survey including self-reported information on weight, height, physical activity, and sedentary behavior in adolescents. Cluster analyses identified homogenous neighborhood groups with similar neighborhood characteristics. Results showed that adolescents living in older suburban areas were more likely to be physically active than residents of newer suburbs. It was concluded that school-run sports and facilities, community centers and clubs, and low crime rates contributed to increased physical activity despite a generally decreased walkability in the area. While this decreased walkability might deter adults from activity, adolescent healthy weight status is positively affected by the built environment in suburban areas (46).

With the obesity epidemic showing no signs of decline, the effect of the built environment on physical activity and weight status has clearly been a topic of interest for the past decade. Translational research in this area can be performed efficiently and thoroughly with advances in GIS. In this study, the built environment was studied through factors labeled as *social-environmental*. These factors included physical indicators of the neighborhood-level built environment, such as sidewalks, as well as the resulting social behavior or outcome, such as BMI. The purpose of this research was to investigate the social-environmental determinants and geospatial distribution of cardiovascular deaths among adults ages 18 to 49 in two Central Texas areas from 2005 to 2008.

METHODOLOGY

Study Population

The study population consisted of central Texas adults ages 18 to 49 in two areas from 2005 to 2008. Area 1 covered approximately 404 square miles and was defined by 20 contiguous zip codes in northeast Travis County; the population was primarily African American (60). Area 2 covered approximately 68 square miles and was defined by the boundaries of 79 census tracts within the San Antonio Independent School District; the population of area 2 was primarily Hispanic American (59).

Data Sources

Data were collected from two sources, the Steps BRFSS database and the Texas Vital Statistics Annual Reports. The Steps BRFSS is a modified version of the national BRFSS administered by the CDC. This program collects information through the administration of monthly telephone surveys to a representative sample of the target community population over 18 years of age. Survey questions are designed to target three disease outcomes (diabetes, asthma, and obesity) along with three related risk factors (low physical activity, unhealthy eating habits, and tobacco) (15).

Between 2005 and 2008, the Steps BRFSS targeted the populations of the two Central Texas areas, Northeast Travis County and San Antonio. Data regarding demographics, BMI, and neighborhood features were obtained from the Steps BRFSS, while data regarding cardiovascular mortality in these areas were accumulated from the Texas Vital Statistics Annual Reports from 2005-2008. Latitude and longitude of residence, year of death, age of death, and cause of mortality were collected. The cause of mortality was recorded in the form of ICD-10 codes, or International Classification of Diseases codes, 10^{th} revision.

Information from the two data sources was filtered and manipulated to create a composite database for analysis. BMI (calculated from self-reported height and weight measurements) and neighborhood feature measures were extracted from the Steps BRFSS database. Using the data about neighborhood features, 2 indices were calculated to reflect each survey participant's neighborhood walkability and neighborhood recreational resources. Texas mortality data about certain non-congenital causes of cardiovascular death, specified by ICD-10 codes, were collected from the Texas Vital Statistics Annual Reports. The composite database created from these two sources contained information about survey participants' BMI, the 2 indices, and information about deaths due to selected cardiovascular disease. It was aggregated as a single file into SPSS (Statistical Package for the Social Sciences) Statistical Data Editor. In the format given by the CDC, the responses to each question were labeled with a descriptive name that could be tied to its associated survey question.

Study Design

Neighborhood Features Indices

Two indices regarding neighborhood features were calculated from the Steps BRFSS data, a walkability predictive index and a recreational resources index. A state-added module entitled, "Neighborhood", contained questions regarding walkability and recreational resources in the area within one half-mile or a ten-minute walk from the participant's house (62, 64). Ten questions were asked; the responses from 5 of them were grouped to calculate a "walkability predictive index" and 5 other responses were grouped as a "recreational resource index." The walkability predictive index included responses to questions about street lighting, crime and safety, the presence of sidewalks, and an overall self-reported rating of neighborhood walkability (Figure 3). The index was additive and calculated using a median split of the distribution of the responses because response choices to these questions were not necessarily binary. A binary index was created; a score of 1 indicated "walkable" and a 2 indicated "not walkable".

The recreational resource index was a composite variable that was based on responses to the 5 other questions in the Neighborhood module of the Steps BRFSS. These questions included the presence of public recreation centers, the use of private or membership only recreation facilities, and the use of schools, shopping malls, trails, parks, playgrounds, or sports fields for public recreation (Figure 3). Each question provided only binary response options, and thus the index was strictly additive. A range between 1 and 2 was given for each participant's index, with a 2 indicating a larger number of available recreational resources.

Texas Mortality Data

Due to the strong correlation between cardiovascular disease and obesity, cardiovascular death data was exclusively analyzed. Five categories of cardiovascular disease encompassing 126 ICD-10 codes were considered. The diseases, defined by ICD-10 codes, included essential (primary) hypertension and hypertensive renal disease hypertensive heart disease with or without renal disease, ischemic heart disease, cerebrovascular disease, and atherosclerosis (Table 1). Texas mortality data was collected in the SPSS format and aggregated using the Statistics Data Editor. Using the latitude and longitude data given for each remaining morbidity report, ArcGIS 9 was used to determine whether the death fell within the defined boundaries of areas 1 and 2. If the reported mortality met these requirements of ICD code and location, it was included in the analysis.

Data Analysis

Variables

Four variables were analyzed in this study. The two distinct Central Texas areas, Northeast Travis County and San Antonio, represented the variable of space. The four-year period between 2005 and 2008 was the variable of time. The study considered two measures, frequency and variance, of cardiovascular death represented by ICD-10 codes. Three social-environmental variables were analyzed including BMI, walkability, and recreational resources.

Software Tools

Three main software tools were used in the execution of this project. First, GIS was used to define the study's geographic boundaries and to create visualizations of certain results. The software utilized was ArcGIS 9, version 9.3. The second tool, SPSS Statistical Data Editor, is a computer program used for statistical analysis. The third tool, Hierarchical Linear Modeling (HLM) 06, was used to create a latent growth curve (LGC) mixed model that relates two layers of data.

Data Analysis Steps

First, all cardiovascular death data points that did not fall within the defined areas were excluded using ArcGIS 9, version 9.3 and the latitude and longitude information given on the Texas death certificate. Next, univariate analyses of BMI, the two indices, and cardiovascular death were performed using SPSS Statistics Data Editor. Lastly, a latent growth curve analysis was performed using HLM to analyze the change in multiple levels of data over time.

Latent Growth Curve Analysis

There were two layers of data in this study, social-environmental factors and cardiovascular death. Because of the nesting of the cardiovascular deaths within the social environmental factors of two areas, a data analytic plan that could explore changes over time while adjusting for the multilevel nature of the data was necessary. A latent growth curve, or LGC, captures group level growth based on the relationships between the observed measures across time. By using LGC, time becomes a predictor of CVD death, and allows the testing of hypotheses about the effects of social-environmental factors on change in cardiovascular death over time. In the use of LGC, time is analyzed as a continuum, as opposed to snapshots.

Analyses proceeded in 2 levels. By using LGC to create a mixed model, Level 1 constants become level 2 outputs. Level 1 tested the hypothesis: cardiovascular deaths change over time. This level of analysis determined if there was significant change over time. The level 2 analysis tested the hypothesis: social-environmental factors and location affect cardiovascular death over time.

RESULTS

Univariate Analyses

The univariate analyses included analysis of BMI, the 2 indices, and cardiovascular deaths.

Social-Environmental Factors

The mean four-year BMI was calculated for the study population broken down by area. Those individuals living in both areas were classified as overweight but not obese. The mean BMI for those in area 1 was 27.34 and that for area 2 was slightly higher at 28.54 (Table 2). The four-year means for the two calculated indices were also calculated and broken down by area. The four-year mean walkability predictive index of area 1 was lower than area 2 with the values being 1.205 and 1.28, respectively (Table 3). Area 1 had a higher recreational resources index than area 2 with values of 1.7675 and 1.7275, respectively (Table 3).

Cardiovascular Deaths

The number of cardiovascular deaths in both areas combined was 289. These deaths were associated with 28 distinct ICD-10 codes. The most frequently occurring code was I21.9, which signifies death due to acute myocardial infarction. Of the total cardiovascular deaths, 126 of these occurred in area 1 and 163 occurred in area 2. Over the four-year study period, the number of deaths increased steadily in area 2 over time from 32 to 49, while number of deaths in area 1 remained relatively consistent with an average 31.5 deaths per year (Figure 4).

Using SPSS, a histogram was created to find the most frequently occurring codes for cardiovascular death. Overall, there were 5 high frequency codes for the combined areas (Figure 5). As mentioned previously, the most frequent code was acute myocardial infarction (I21.9). The next most frequent codes in decreasing order were chronic ischemic heart disease (I25), atherosclerotic heart disease (I25.1), hypertensive heart disease without (congestive) heart failure (I11.9), and intracerebral hemorrhage (I69.1) (Table 4). In area 1, the top five ICD-10 codes followed the same order of prevalence as seen overall (Table 5). The five most frequent ICD codes in Area 2 were the same, however there were increased numbers of deaths due to atherosclerotic heart disease and intracerebral hemorrhage compared to Area 1 (Table 6).

Next, the variance in ICD codes by area over time was analyzed. These data were represented graphically (Figures 6-9). The number of different ICD-10 codes in each area was represented by shades of blue. Darker blue indicates a lesser variance. Over the four-year period, area 2 increased in variance while the variance of area 1 remained relatively constant.

The Predictive Model: Latent Growth Curve Analysis

As previously explained, the latent growth curve (LGC) analysis has two levels. Level 1 of the predictive model tested the hypothesis: cardiovascular death changes over time. To do this, HLM generates slopes and intercepts for each level 1 unit of analysis. These were significant at a p-value of less than 0.05. In this study, level 1 units were the four time points represented by year 0, 1, 2, and 3. An individual growth model of CVD deaths at time, t, for area, i, was generated using the following equation:

$$CVD_{ti} = \gamma_{0i} \pm \chi_i (Time)_{ti} + e_{ti}$$

$$CVD_{ti} = 1.73 + 0.075\,(Time_{0\ldots3})_{ti} + 0.043_{ti}$$

A higher CVD number indicates more dispersion or greater variance. Level 2 of the predictive model tests the hypothesis: social-environmental factors and location affect cardiovascular death over time. The following equation takes into account BMI, the two neighborhood feature indices, and the area:

$$\mu_{ti} = \Omega_{ti} (BMI_{ti})(RC_{ti})(WALK_{ti})(Area_{ti}) + r_{ti}$$

$$\mu_{ti} = \Omega_{ti} (0.035)(0.12)(0.006)(-0.038) + r_{ti}$$

These values were significant at a p-value of less than 0.05. The outcomes from these level 2 equations became level 1 constants.

From these equations, a latent growth curve was calculated (Figure 10). Initially, the social-environmental variables of walkability, recreational resources, and BMI affected the initial amount of variance in cardiovascular death variance at the beginning of the study period. The greater slope of the area 2 curve depicts that the dispersion of cardiovascular death in this area increased significantly over time.

DISCUSSION

This study examined the effect of certain aspects of the built environment on variance in cardiovascular death. The univariate analysis results provided indications of the general built environment, weight status, and cardiovascular death in both areas. Concerning the social environmental variables, area 1 had a low BMI, a high walkability, and large amount of recreational resources. Area 1 also was seen to have a high variance in types of cardiovascular death with no significant change in this variance over time. On the other hand, area 2 had a high BMI, and low walkability. Area 2 was seen to have a significant increase in variance in types of cardiovascular death over time.

Several conclusions can be drawn from the predictive model. Initially, the social-environmental variables of walkability, recreational resources, and BMI affected the initial variance in 2005 for cardiovascular death in both areas. Area 1 had high variance compared to area 2, yet in area 1, there was no significant change in cardiovascular death over time. In area 2, cardiovascular death began more concentrated represented by lower variance, and was increasingly dispersive over time. In area 2, the changes in walkability, recreational resources, and BMI are predictive of changes in cardiovascular death.

While the effect on variance in types of death is a topic that has not been addressed in literature prior to this study, the effect of different built environment variables on physical activity and healthy weight status has been prominently studied in the last decade. This study corroborated with several other studies that demonstrated a positive effect of recreational facilities and park amenities on healthy weight status. In accordance with our study, Potwarka et. al. (53) concluded that certain park facilities may be more important in supporting physical activity than park space in general. The findings in our study also supported the work of Kaczynski et al (34). Kaczynski's study showed that parks with more features, specifically trails, had the highest correlation with park use. The recreational resources index used in our study supported the idea that certain facilities such as public recreation centers, private or membership only recreation facilities, and schools, shopping malls, trails, parks, playgrounds, or sports fields open for public recreation are important for maintaining healthy weight status and preventing obesity-related disease within a population.

Concerning walkability, Jago et al. (33) concluded that sidewalk features have a significant effect on physical activity levels due to their impact on walkability (33). The walkability predictive index in our study took into account the presence of sidewalks. Our study also supported the hypothesis that walkability increases physical activity and assists a population in maintaining healthy habits; this is reflected by the correlation of a good walkability score with lower BMI and increased variance in cardiovascular death.

The significance of an area's variation in types of cardiovascular death can be understood in a clinical sense. High variance in cardiovascular deaths shows that people are dying from a variety of cardiovascular causes. As social-environmental factors in area 2 became more indicative of healthier living over time, cardiovascular death became more dispersive. Therefore, it is logical to conclude that these deaths are less likely due to a specific obesity problem. Conversely, low variance shows that singular diseases are causing the deaths of a large amount of people. This could indicate an obesity epidemic in the area.

These results have significance in the realm of public health. With the identification of the most frequently occurring kinds of cardiovascular death, specifically in an area with low variance, resources can be more efficiently targeted for prevention. In an area with more dispersive cardiovascular death, a single and broader program could target multiple types of disease and prevent more cardiovascular deaths overall.

There were several limitations to this study. First, because the Steps BRFSS surveys do not record the zip code of the survey participant, the data could not be analyzed on this level, as would be ideal. Due to this, the study had to generalize large geographic regions. Second, the cardiovascular death data was limited to probable obesity-related deaths, but this process is not without error and might include some deaths not related to obesity.

With the help of GIS and the abilities of the GIS team at the TDSHS, many more projects could easily further the work done in this study. First, due to the nature of the area 1 Steps BRFSS survey, area 1 cardiovascular death could be analyzed in smaller geographic sub-areas. Secondly, other obesity-related questions from the Steps BRFSS surveys could be analyzed in relation to cardiovascular death. Potential survey modules include the weight-control module that targets those trying to lose or maintain a certain weight and asks questions regarding their methods.

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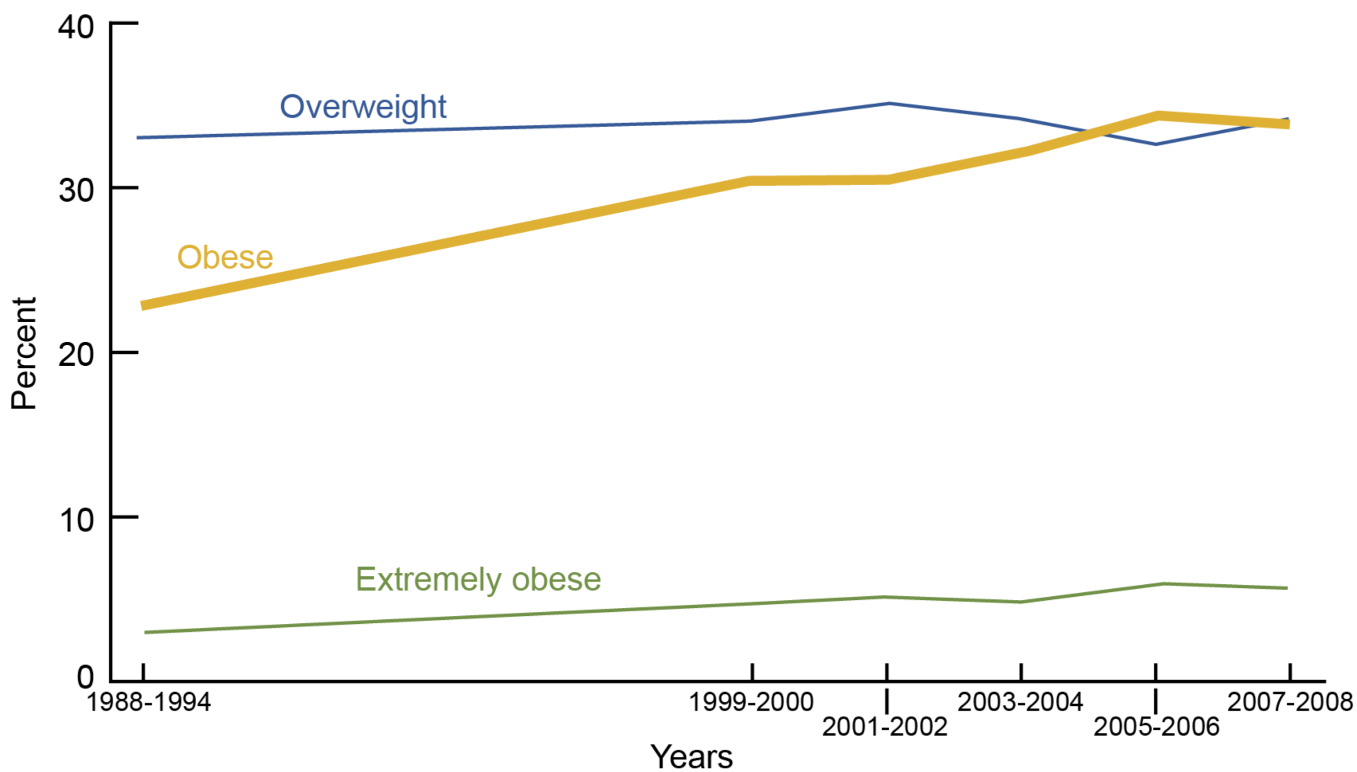
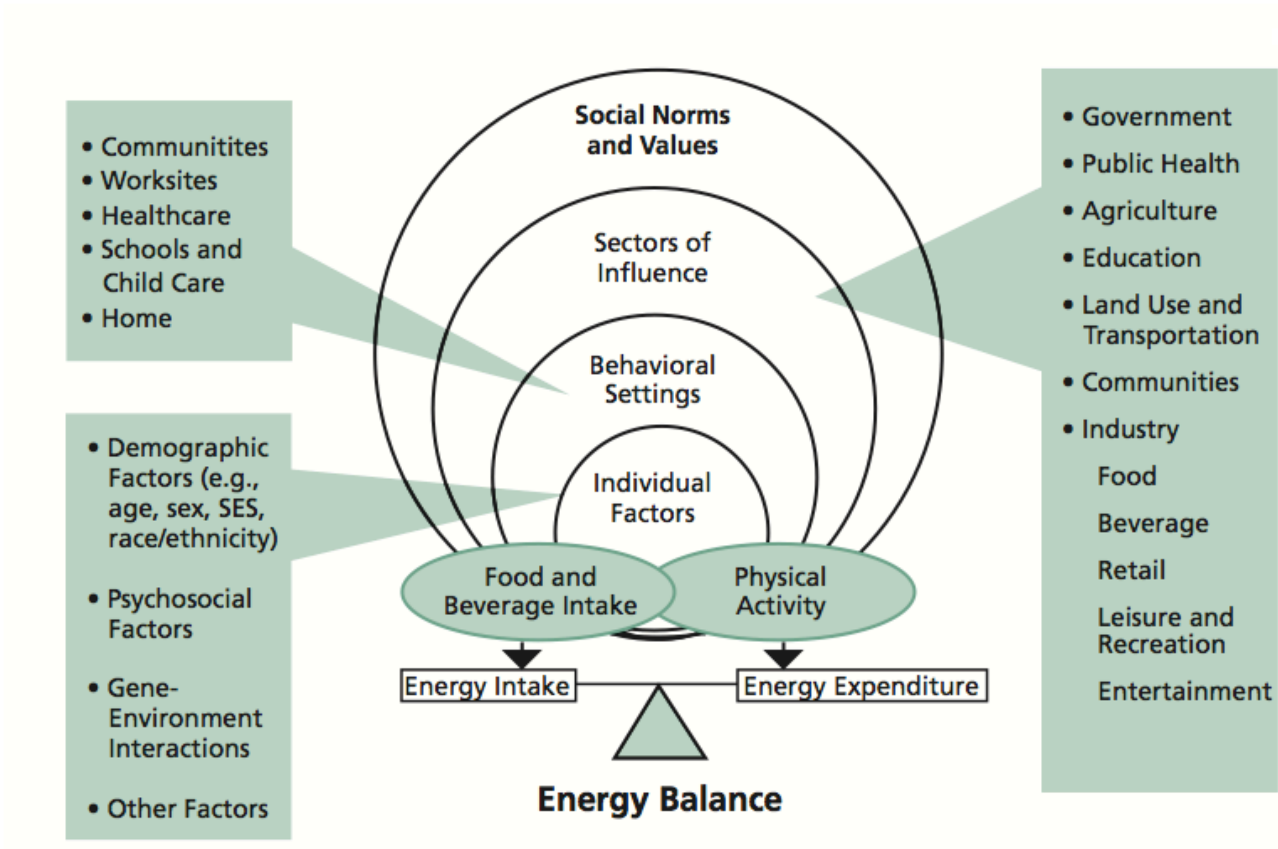
Figures and Tables

Figure 1. Trends in U.S. Obesity.
Trends in overweight, obesity, and extreme obesity among adults aged 20 years and over: United States, 1988-2008.



Taken from: Ogden, C.L., and Carroll, M.D. 2010. NCHS Health E-Stat.

Figure 2. Conceptual Models for Obesity: a Socio-ecological Model.



Taken from: **Yancey, A.** 2007. Social ecological influenceson obesity control: instigating problems and informing potential solutions. Obesity Management. **3**:74-79.

Figure 3. Steps BRFSS Neighborhood Module Questions.

Overall, how would you rate your neighborhood as a place to walk? Would you say…
1. Very pleasant
2. Somewhat pleasant
3. Not very pleasant
4. Not at all pleasant

For walking at night, would you describe the street lighting in your neighborhood as…
1. Very good
2. Good
3. Fair
4. Poor
5. Very poor

How safe from crime do you consider your neighborhood to be? Would you say…
1. Extremely safe
2. Quite safe
3. Slightly safe
4. Not at all safe

Does your neighborhood have any sidewalks?
1. YES
2. NO

Do you use any private or membership only recreation facilities in your community for physical activity?
1. YES
2. NO

Do you use any walking trails, parks, playgrounds, or sports fields in your community for physical activity?
1. YES
2. NO

Do you use any shopping malls in your community for physical activity and/or walking programs?
1. YES
2. NO

Do you use any public recreation centers in your community for physical activity?
1. YES
2. NO

Do you use schools that are open in your community for public recreation activities?
1. YES
2. NO

Taken from: **Texas Department of State Health Services.** 2005-2008. San Antonio Steps BRFSS Questionairre.

Figure 4. CVD Deaths by Year and Area, 2005-2008.

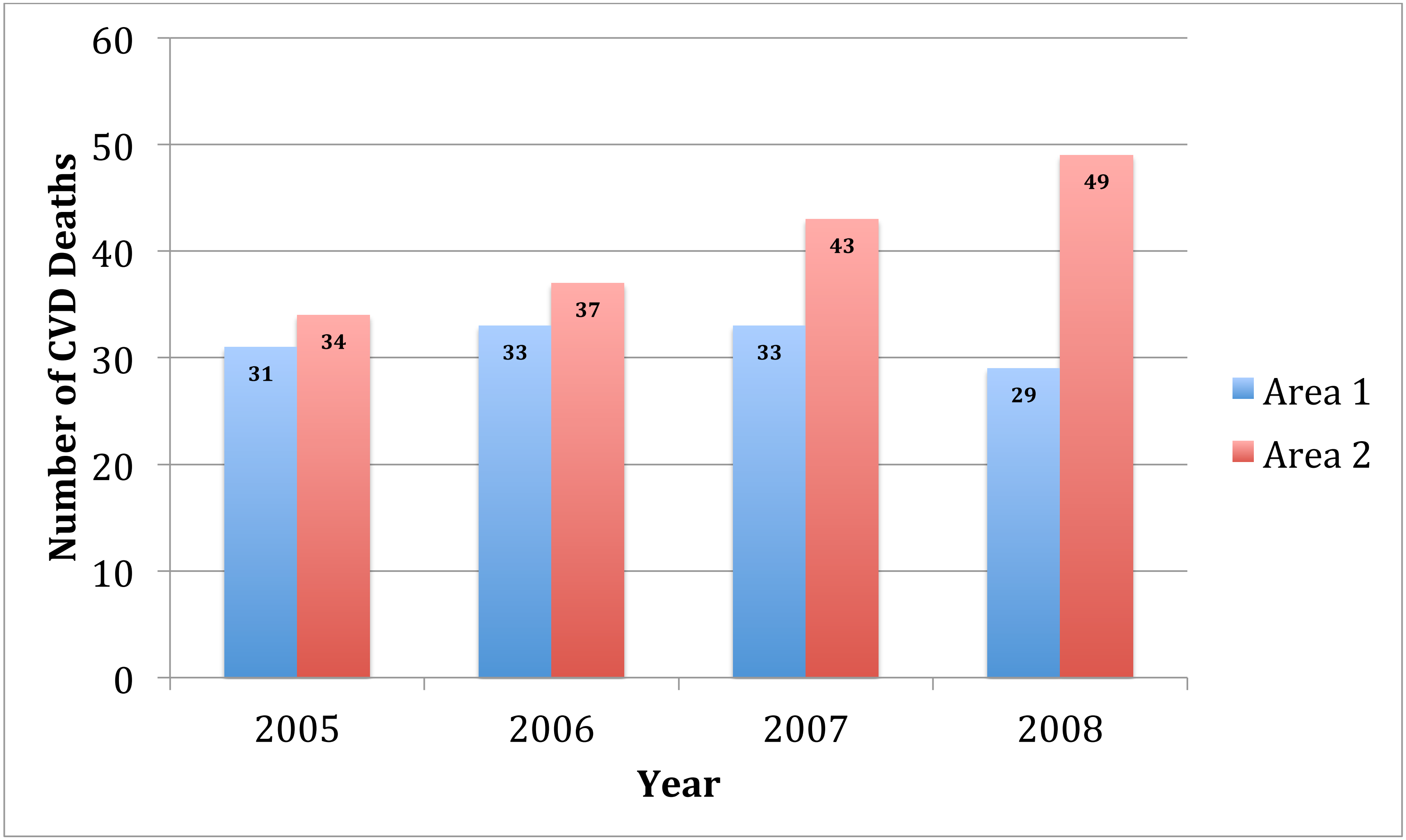


Figure 5. Frequency of ICD-10 Codes for Combined Areas.

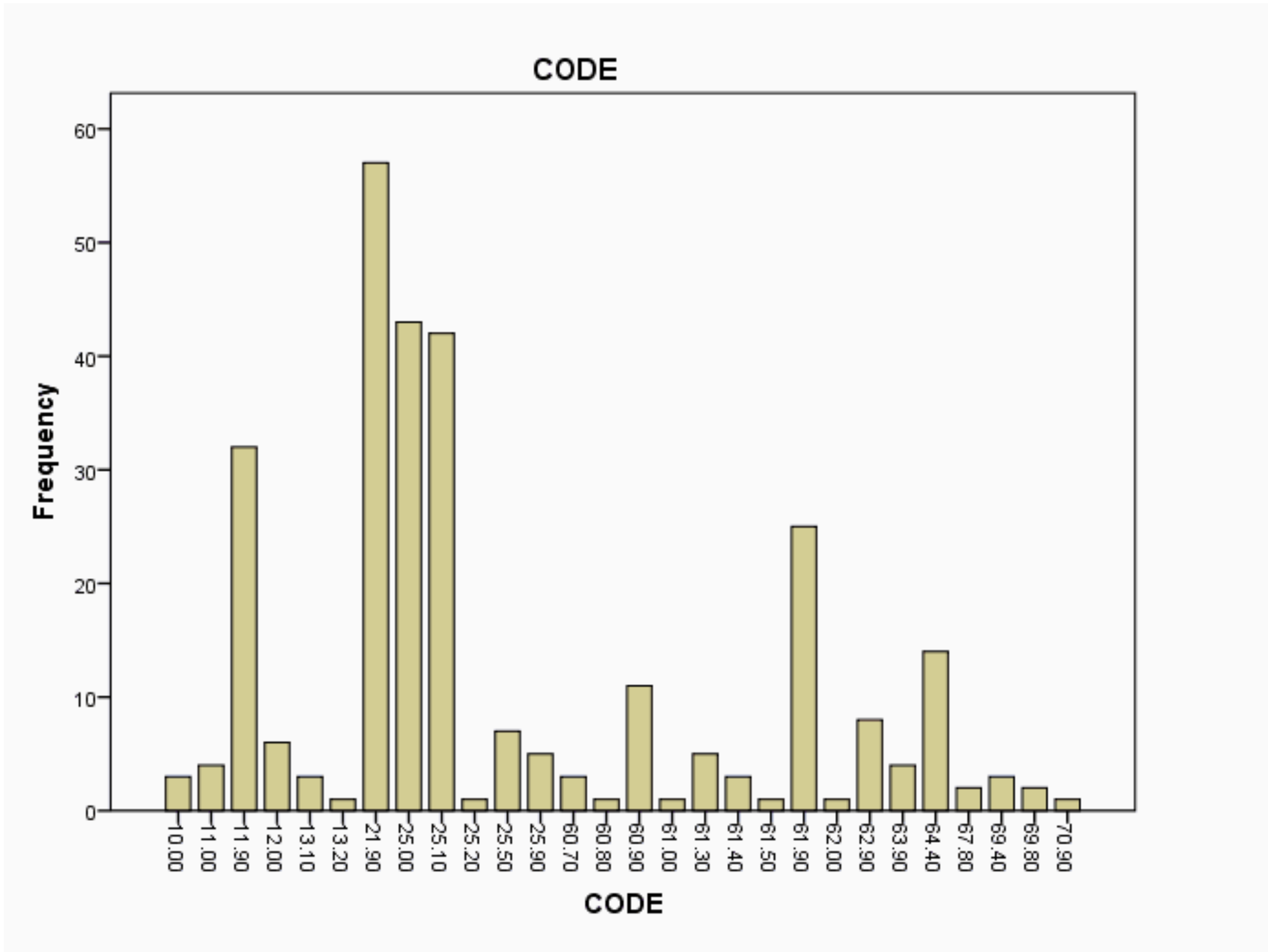
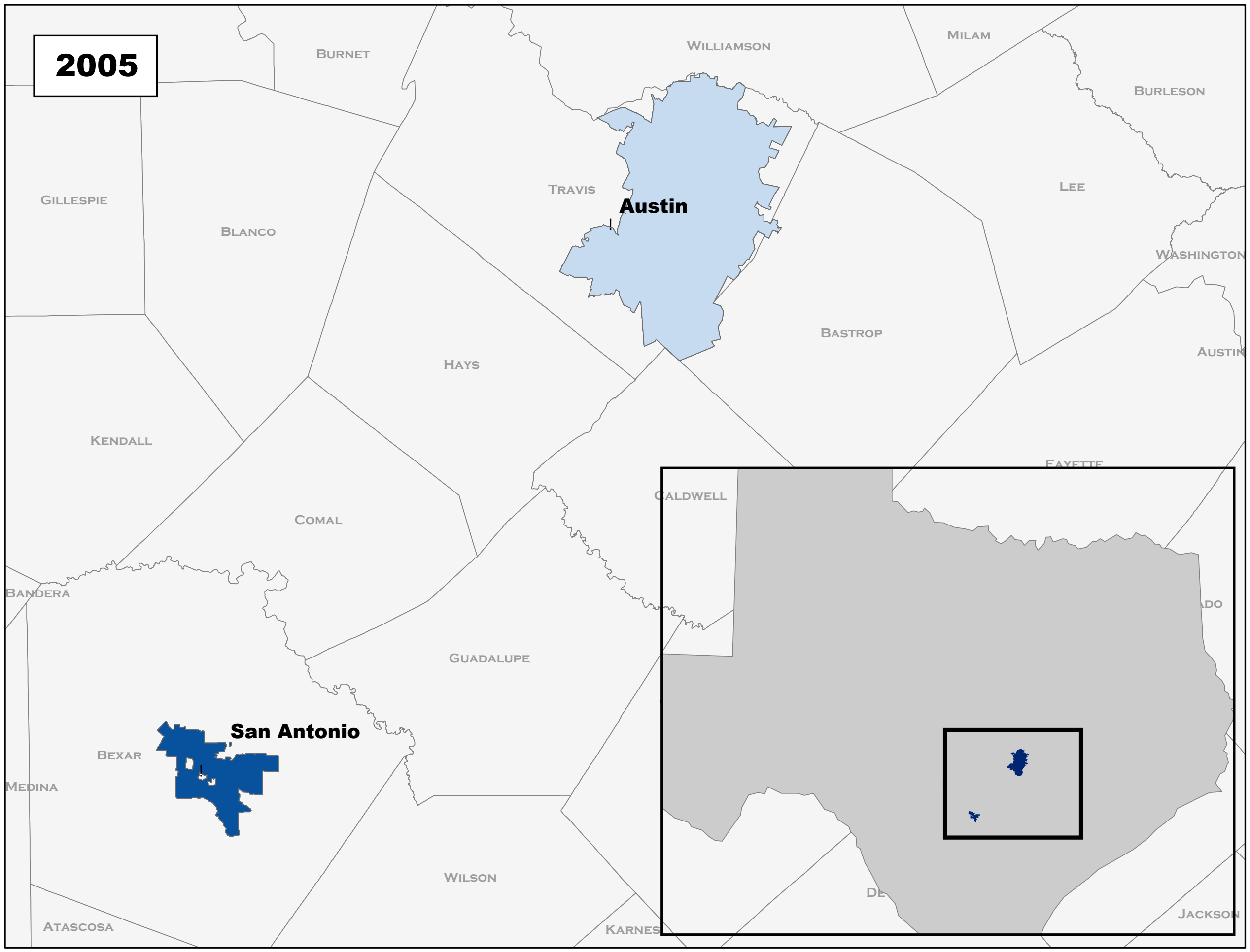
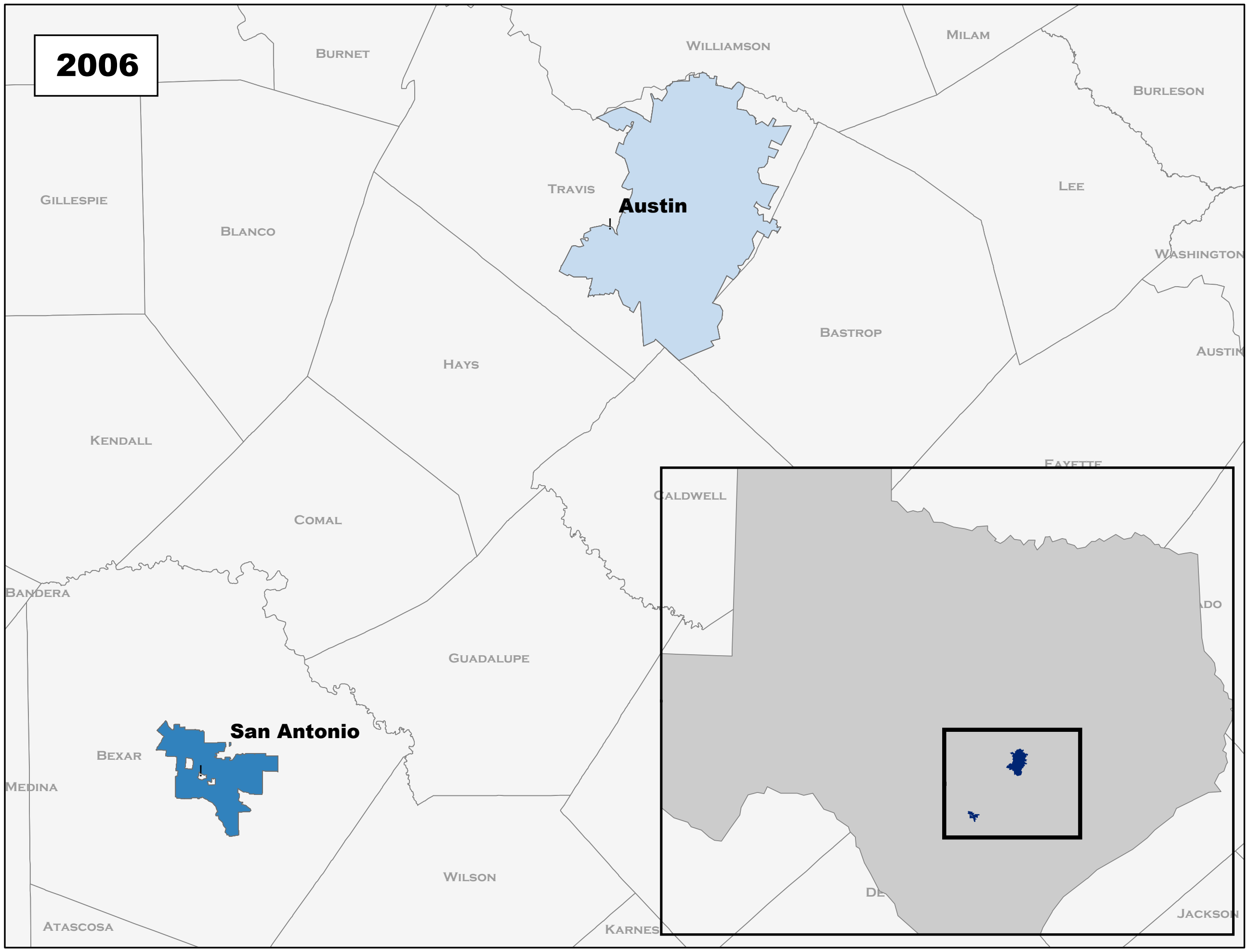


Figure 6. Variance in ICD-10 Codes, 2005.



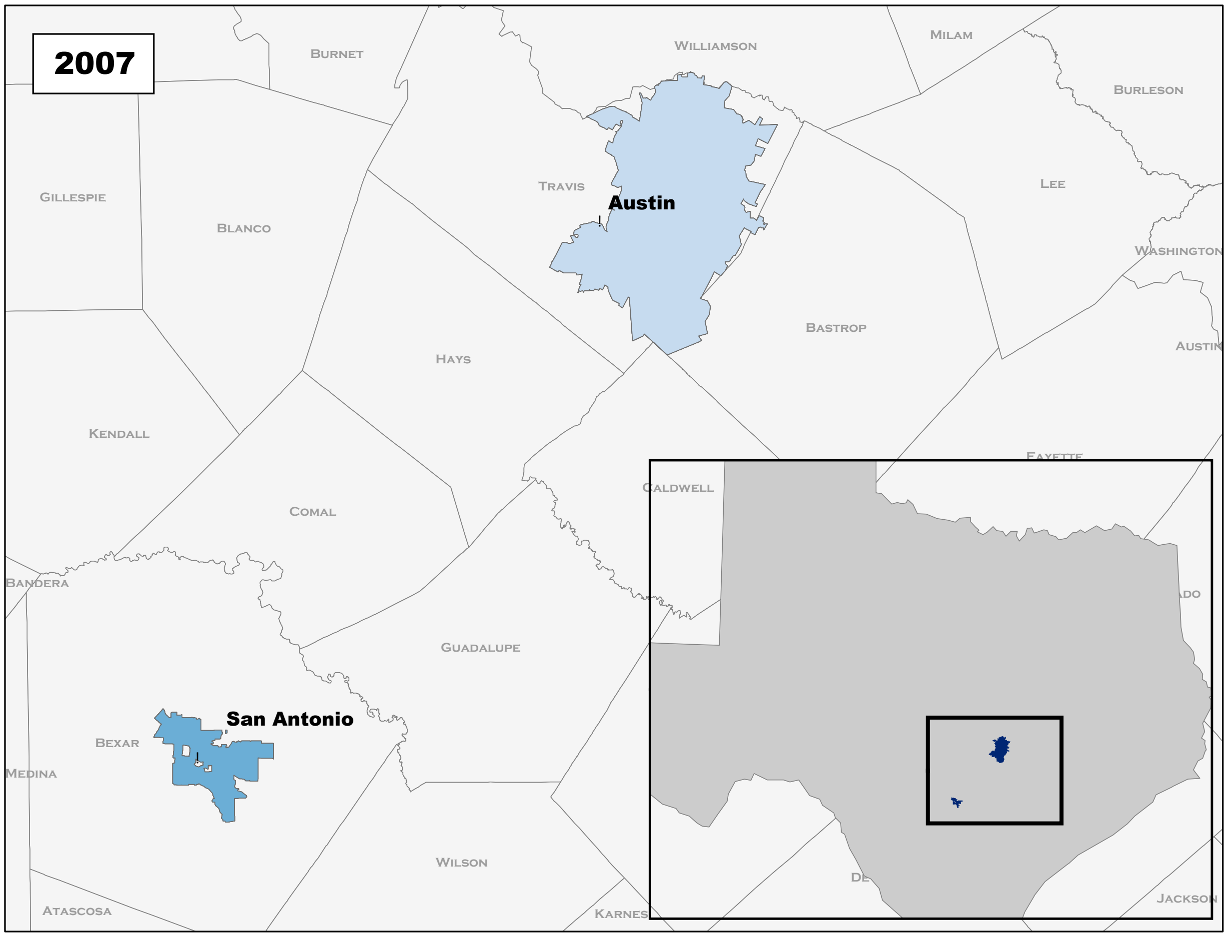
*Darker blue color indicates less variance

Figure 7. Variance in ICD-10 Codes, 2006.



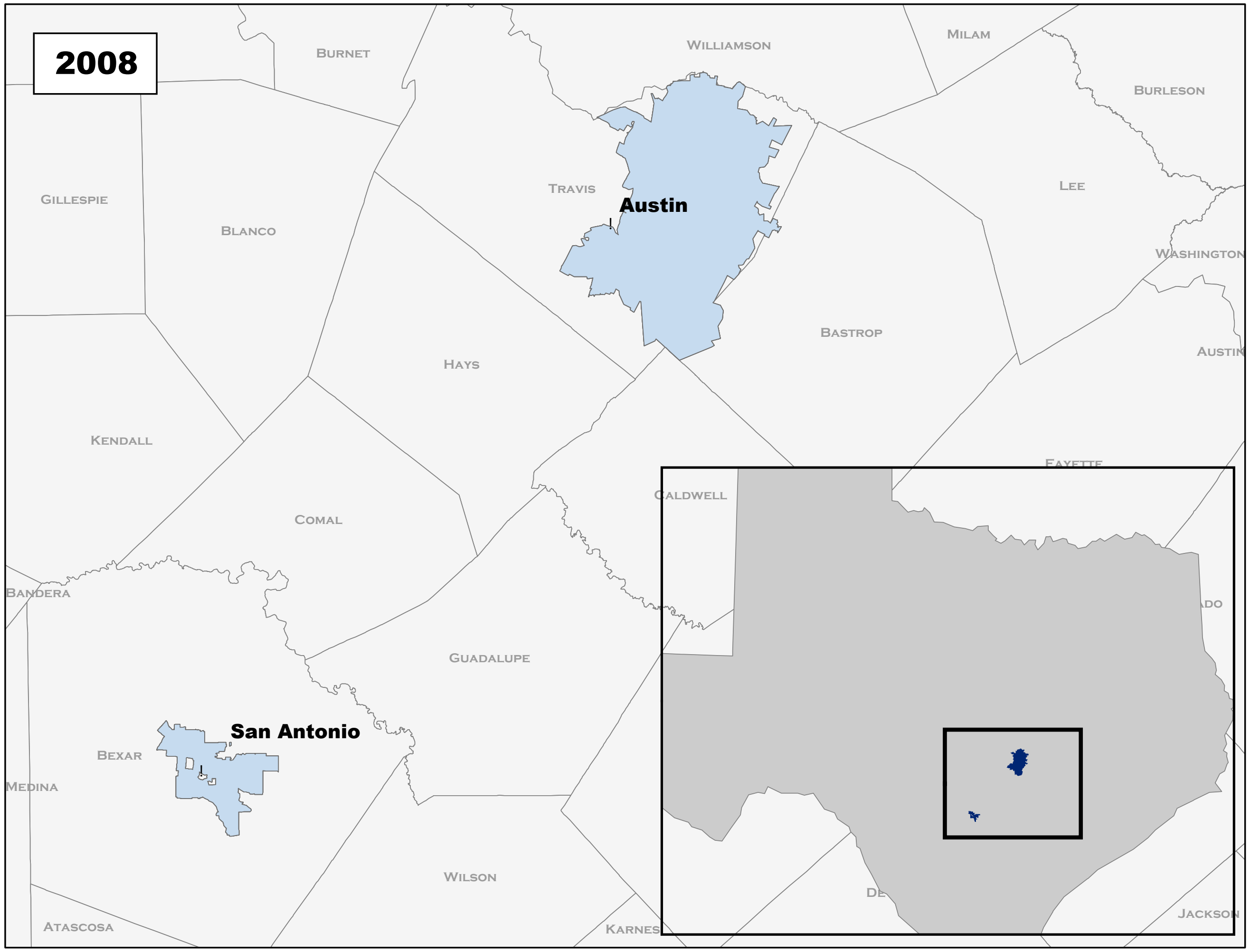
*Darker blue color indicates less variance

Figure 8. Variance in ICD-10 Codes, 2007.



*Darker blue color indicates less variance

Figure 9. Variance in ICD-10 Codes, 2008.



*Darker blue color indicates less variance

Figure 10. Latent Growth Curve.

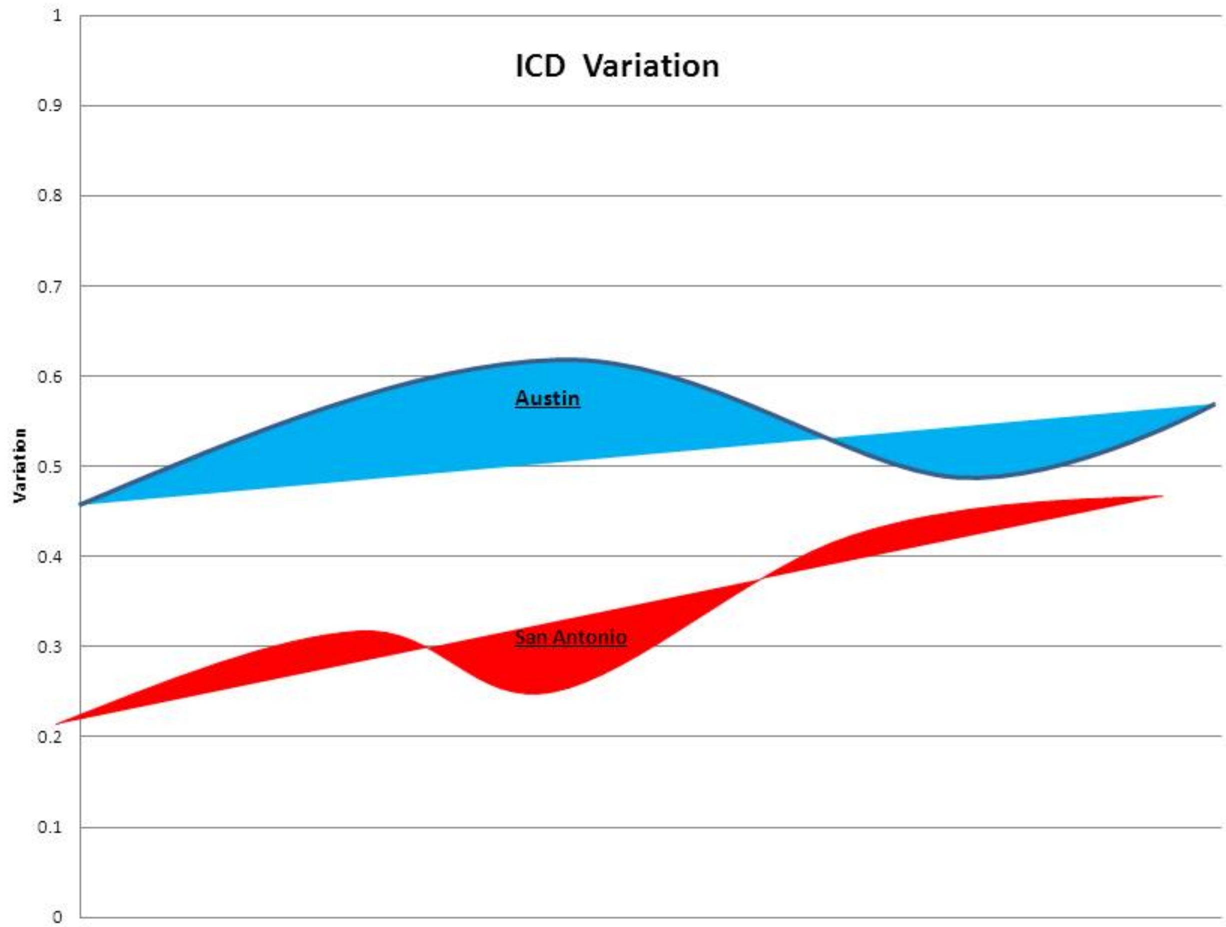


Table 1. Considered ICD-10 codes.

Disease	**Codes**
Essential (primary) hypertension and hypertensive renal disease	[I10, I12]
Hypertensive heart disease with/without renal	[I11, I13]
Ischemic Heart disease	[I20-I25]
Cerebrovascular disease	[I60-I69]
Atherosclerosis	[I70]

Table 2. Mean BMI by Area, 2005-2008.

	Area 1	**Area 2**
Four Year Mean BMI	**27.34**	**28.54**

Table 3. Mean Indices by Area, 2005-2008.

Four Year Mean Index	Area 1	Area 2
Walkability Predictive Index	**1.28**	**1.205**
Recreational Resources Index	**1.7275**	**1.7675**

Table 4. Most Frequent ICD-10 Codes for Combined Areas.

Rank	ICD-10 Code	Disease	Frequency
1	I21.9	Acute myocardial infarction, unspecified	57
2	I25	Chronic ischemic heart disease	43
3	I25.1	Atherosclerotic heart disease	42
4	I11.9	Hypertensive heart disease without (congestive) heart failure	32
5	I61.9	Intracerebral hemorrhage, unspecified	25

Table 5. Most Frequent ICD-10 Codes for Area 1 (NE Travis County).

Rank	ICD-10 Code	Disease	Frequency
1	I21.9	Acute myocardial infarction, unspecified	23
2	I25	Chronic ischemic heart disease	21
3	I25.1	Atherosclerotic heart disease	21
4	I11.9	Hypertensive heart disease without (congestive) heart failure	19
5	I61.9	Intracerebral hemorrhage, unspecified	11

Table 6. Most Frequent ICD-10 Codes for Area 2 (San Antonio).

Rank	ICD-10 Code	Disease	Frequency
1	I21.9	Acute myocardial infarction, unspecified	34
2	I25.1	Atherosclerotic heart disease	23
3	I25	Chronic ischemic heart disease	22
4	I61.9	Intracerebral hemorrhage, unspecified	17
5	I11.9	Hypertensive heart disease without (congestive) heart failure	11