Geographic Distribution of Diagnosed Diabetes in the U.S.

A Diabetes Belt

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Background: The American "stroke belt" has contributed to the study of stroke. However, U.S. geographic patterns of diabetes have not been as specifically characterized.

Purpose: This study identifies a geographically coherent region of the U.S. where the prevalence of diagnosed diabetes is especially high, called the "diabetes belt."

Methods: In 2010, data from the 2007 and 2008 Behavioral Risk Factor Surveillance System were combined with county-level diagnosed diabetes prevalence estimates. Counties in close proximity with an estimated prevalence of diagnosed diabetes $\geq$11.0% were considered to define the diabetes belt. Prevalence of risk factors in the diabetes belt was compared to that in the rest of the U.S. The fraction of the excess risk associated with living in the diabetes belt associated with selected risk factors, both modifiable (sedentary lifestyle, obesity) and nonmodifiable (age, gender, race/ethnicity, education), was calculated.

Results: A diabetes belt consisting of 644 counties in 15 mostly southern states was identified. People in the diabetes belt were more likely to be non-Hispanic African-American, lead a sedentary lifestyle, and be obese than in the rest of the U.S. Thirty percent of the excess risk was associated with modifiable risk factors, and 37% with nonmodifiable factors.

Conclusions: Nearly one third of the difference in diabetes prevalence between the diabetes belt and the rest of the U.S. is associated with sedentary lifestyle and obesity. Culturally appropriate interventions aimed at decreasing obesity and sedentary lifestyle in counties within the diabetes belt should be considered.

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Introduction

The American "stroke belt," defined in terms of a contiguous group of states with high age-adjusted stroke mortality rates, was first identified in the mid-1960s.[1] The states that define the stroke belt are Alabama, Arkansas, Georgia, Indiana, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia. The stroke belt's identification contributed to further study of the etiology of stroke and to helping target interventions to high-risk states.[2,3]

Diabetes is similar to stroke in that it is strongly affected by behavioral, cultural, and environmental factors clustered and overlaid on genetic susceptibility. However, U.S. geographic patterns of diabetes have not been as specifically characterized in the manner that stroke has been. Identification of areas of high prevalence of diabetes could have an impact on understanding of diabetes.

Recently, the CDC produced estimates of the prevalence of diagnosed diabetes for every U.S. county or county equivalent.[4] Figure 1 displays a map of the estimated prevalence of diagnosed diabetes for 2007, with counties/county equivalents shaded to represent the percentage of the population with diagnosed diabetes, dividing the counties into quintiles. This map suggested to the authors the existence of a "diabetes belt," to be precisely defined later, probably not previously characterized because of the lack of county-level diabetes surveillance data.

This paper (1) proposes a definition of the diabetes belt; (2) examines how residents of that belt compare with

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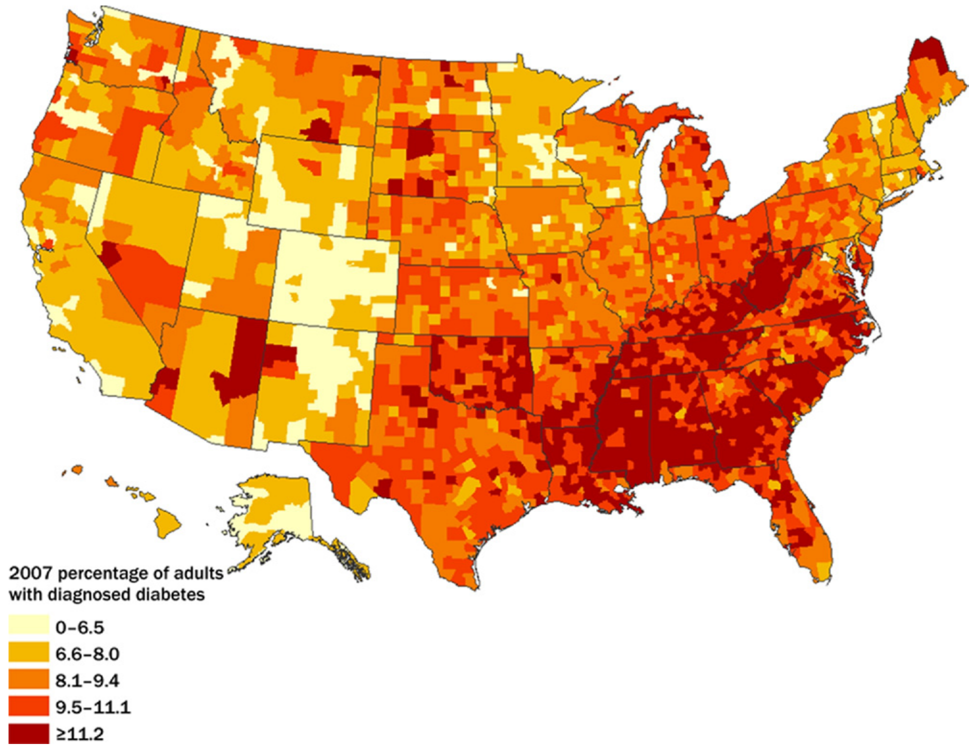

Figure 1. Estimates of prevalence of diagnosed diabetes, by county, 2007

residents of the rest of the country in demographics and prevalence of selected risk factors for diabetes and in the association of demographics and risk factors associated with diabetes; and (3) calculates the fraction of the excess risk of diabetes associated with residence in the diabetes belt that is attributable to selected risk factors.

Methods

Data Source

Data from the 2007 and 2008 Behavioral Risk Factor Surveillance System (BRFSS) were used. The BRFSS is a state-based system of health surveys that annually assesses key behavioral risk factors and chronic conditions among non-institutionalized U.S. adults aged ≥18 years. Nationally, the median state response rates for BRFSS were 50.6% (2007) and 49.8% (2008). The BRFSS collects county-level data but, because of sample-size limitations, most analyses are done at a state or national level. Using random-digit-dialing methods, the BRFSS selects participants from civilian residents with telephones.[5] Diabetes status was assessed by the answer to the question *Have you ever been told by a doctor that you have diabetes?* Women who reported having diabetes only during pregnancy (i.e., gestational diabetes) were not counted as having diabetes. Sedentary lifestyle was assessed by the question *During the past month, other than your regular job, did you participate in any physical activities such as running, calisthenics, golf, gardening, or walking for exercise?* BMI was calculated from self-reported height and weight. Respondents with a self-reported height and weight that resulted in a calculated BMI≥30 kg/m^2 were considered obese. All analyses were performed in 2010.

Definition of Diabetes Belt

The CDC estimates of diagnosed diabetes prevalence for all counties/county equivalents were spatially smoothed, using a Bayesian multilevel model with a conditional autoregressive prior.[6,7] Smoothed estimates were imported into ArcGIS, version 9.3, to identify geographic patterns in diabetes prevalence. A visual inspection suggested that counties with a high prevalence of diabetes are concentrated in the Southeast region. Counties in close proximity in the Southeast region and that had an 11.0% or higher prevalence of diabetes were considered to be in the diabetes belt. Counties with a high prevalence and that were neither in close proximity to the Southeast region nor to other high-prevalence counties were not included in the diabetes belt. This method defined a congruent, although not necessarily continuous, geographic area.

Statistical Analysis

All analyses were done using BRFSS design variables and weights, making the analyses representative of the population sampled and providing correct SEs. SAS-callable SUDAAN, version 9.2, was used for all analyses.

Dichotomized or categorized versions of demographics and risk factors (gender; age [≤40 years, 40–64 years, ≥65 years]; education [<high school graduate, high school graduate, some college, college graduate]; sedentary lifestyle; obesity; and race/ethnicity [non-Hispanic white, non-Hispanic African American, Hispanic, and non-Hispanic other]) were created. The prevalence of these demographics/risk factors was compared between the diabetes belt and the rest of the U.S. The factors selected were chosen because all have been associated with diabetes.[8] Income, although it has been associated with diabetes, was not considered because of the large

Table 1. Characteristics of diabetes belt vs rest of U.S. (estimate) and AORs for having diagnosed diabetes, for diabetes belt and rest of U.S.

	Prevalence of disease and risk factors (% [95% CI])		AOR (95% CI) for having diagnosed diabetes	
Characteristics	**Diabetes belt (*n*=91,822)**	**Rest of U.S. (*n*=721,676)**	**Diabetes belt**	**Rest of U.S.**
Has diagnosed diabetes	11.7 (11.4, 12.0)	8.5 (8.3, 8.6)	NA	NA
Male	47.5 (46.9, 48.1)	48.8 (48.5, 49.0)	1.2 (1.1, 1.3)	1.3 (1.2, 1.3)
Age (years)				
<40	38.0 (37.4, 38.6)	39.7 (39.5, 40.0)	ref	ref
40–64	44.2 (43.9, 45.0)	43.4 (43.2, 43.7)	4.8 (4.2, 5.5)	5.5 (5.1, 5.9)
≥65	17.6 (17.3, 17.9)	16.8 (16.7, 17.0)	10.5 (9.2, 12.1)	13.9 (12.9, 15.1)
Education				
<High school graduate	14.3 (13.9, 14.6)	11.1 (10.9, 11.3)	1.8 (1.6, 2.1)	1.5 (1.4, 1.6)
High school graduate	35.9 (35.3, 36.5)	28.1 (27.9, 28.4)	1.3 (1.1, 1.4)	1.4 (1.3, 1.4)
Some college	25.8 (25.3, 26.3)	26.5 (26.3, 26.7)	1.4 (1.3, 1.5)	1.4 (1.3, 1.4)
College graduate	24.1 (23.6, 24.5)	34.3 (34.0, 34.5)	ref	ref
Sedentary lifestyle	30.6 (30.1, 31.1)	24.8 (24.5, 25.0)	1.3 (1.2, 1.4)	1.5 (1.4, 1.6)
Obesity	32.9 (32.3, 33.4)	26.1 (25.9, 26.3)	3.1 (2.9, 3.3)	3.3 (3.2, 3.4)
Race/ethnicity				
Non-Hispanic white	70.0 (69.4, 70.5)	68.8 (68.5, 69.0)	ref	ref
Non-Hispanic African- American	23.8 (23.3, 24.4)	8.6 (8.5, 8.8)	1.5 (1.4, 1.6)	1.9 (1.8, 2.0)
Hispanic	2.8 (2.6, 3.1)	15.4 (15.1, 15.6)	1.0 (0.6, 1.1)	1.6 (1.5, 1.7)
Non-Hispanic other	3.4 (3.2, 3.6)	7.3 (7.1, 7.4)	1.1 (0.9, 1.3)	1.7 (1.6, 1.9)

Data source: 2007–2008 Behavioral Risk Factor Surveillance System. All differences in risk factors between the diabetes belt and the rest of the U.S. are significant at p=0.01.
NA, not applicable

number of missing values in the current data set. Hypertension and dietary factors, also associated with diabetes, were not considered because neither was available for both 2007 and 2008. The association between diabetes and other factors available from BRFSS but not considered in this analysis (e.g., smoking status) is weaker than that between diabetes and the factors discussed above.

Differences were evaluated using chi-square tests. Results were considered significant if $p<0.05$. Six individual-level logistic regression models, all with "has diagnosed diabetes" as the dependent variable, were fit. These models, and how they were used, are described below. A model using all the factors in Table 1 (except "has diagnosed diabetes") as independent variables plus a dummy variable for in/not in the diabetes belt and two-way interactions between this dummy variable and all other variables in the model was fit (Model 1). These interactions, which measure how risk factors' effects differ inside and outside the diabetes belt, were considered because the authors hypothesized that these effects might differ. When this model was fit, all interactions were significant. To facilitate interpretation of the differences between the diabetes belt and the rest of the U.S., models stratified by residence in/not in the diabetes belt were fit (Models 2 and 3, respectively).

To estimate what excess risk for diagnosed diabetes in the diabetes belt was associated with a group of selected covariates, the percentage change of the OR with and without the covariates using the expression $[(OR1 - OR2)/(OR1 - 1.0)] \times 100\%$ was calculated, where OR1 represents OR derived from the basic model, OR2 represents OR after adjusting for additional covariates, and 1.0 represents OR when no excess risk exists. Demographics and risk factors were divided into the categories of "modifiable" (obesity, sedentary lifestyle) and "nonmodifiable" (gender, age, race/ethnicity, education). A model containing only a dummy variable for "in diabetes belt" was fit (Model 4). Additional models with this dummy variable and all modifiable risk factors (Model 5) and with this dummy variable and all nonmodifiable risk factors (Model 6) were fit.

Results

Details of the spatial smoothing are not reported, for brevity. However, the results of this smoothing appear in Figure 2. Figure 2 displays a map of the 644 counties that define the diabetes belt. This belt includes portions of the

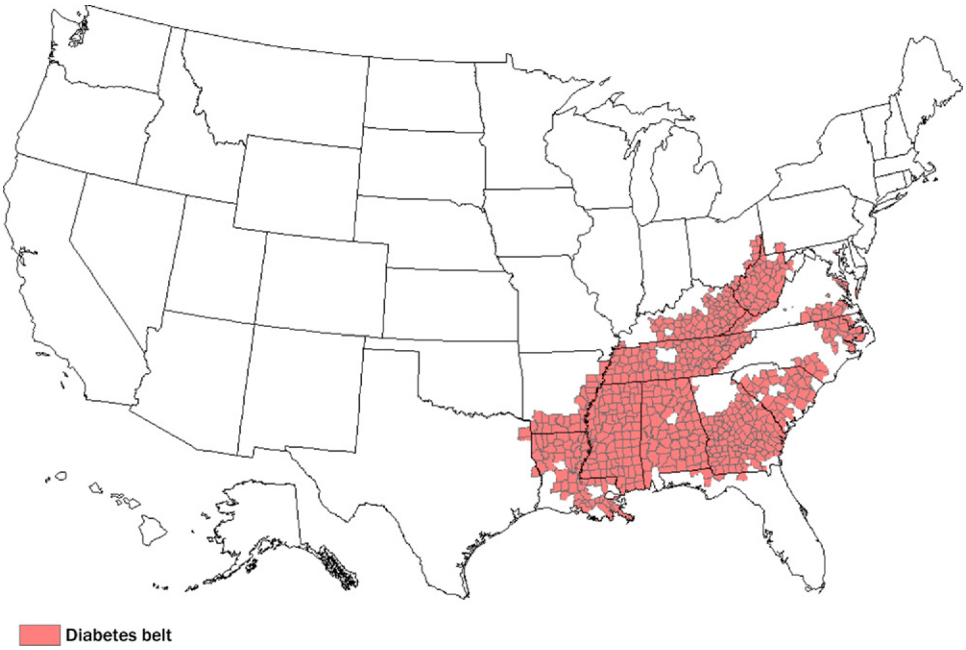

Figure 2. Diabetes belt counties

states of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, and West Virginia, as well as the entire state of Mississippi. The prevalence of diabetes in the diabetes belt was 11.7% (95% CI=11.4%, 12.0%). The prevalence of diabetes in the rest of the country was 8.5% (95% CI=8.3%, 8.6%).

Table 1 compares demographics and risk factors in the diabetes belt with the rest of the U.S. (all differences significant at $p<0.01$). The population of the diabetes belt counties contained substantially more non-Hispanic African Americans than that of the rest of the country (23.8% for the diabetes belt, 8.6% for the rest of the country). The prevalence of obesity (32.9% vs 26.1%) and sedentary lifestyle (30.6% vs 24.8%) was greater in the diabetes belt than in the rest of the U.S., and the proportion of people with a college degree was smaller (24.1% vs 34.3%). Although large sample sizes made age and gender differences significant, these differences were small.

All two-way interactions between the in/not in diabetes belt dummy variable and all other risk and demographic factors considered (Model 1) had $p<0.05$ (results not shown). Reporting these interactions directly makes the results difficult to interpret. To facilitate interpretation, Models 2 and 3, which stratified the analysis into those in/not in the diabetes belt, were fitted. Table 1 presents model results. The AORs increased more with age outside the diabetes belt than they did within the diabetes belt, and having less than a high school education was a stronger risk factor within the diabetes belt than outside the diabetes belt.

Models 2's and 3's intercepts (which define the modeled probabilities of diagnosed diabetes for someone in the reference category for all factors) differed substantially. For those in the diabetes belt, the modeled probability that someone in the reference category for all factors would have diagnosed diabetes was 0.011 (95% CI=0.008, 0.014). For those not in the diabetes belt, the modeled probability was 0.006 (95% CI=0.006, 0.007).

Using Models 4 and 5 (results not shown, for brevity), it was calculated that 30% of the excess risk for those in the diabetes belt was associated with modifiable factors. Using the results of Models 4 and 6 (results not shown, for brevity), it was calculated that 37% of the excess risk was associated with nonmodifiable factors.

Discussion

To the authors' knowledge, this paper is the first to identify a diabetes belt. Both diabetes and stroke belts are primarily located in the southeastern U.S. However, differences exist. Much of West Virginia is in the diabetes belt, but not in the stroke belt. Indiana is part of the stroke belt but contains no diabetes belt counties.

Public health is often carried out at a county level. Identifying a diabetes belt via counties allows policymakers to identify regions where need is greatest, except in cases where need is great for the entire state. For example, had the diabetes belt been identified at a state level, Georgia would likely have been part of it. Figure 2 shows that portions of Georgia are not in the diabetes belt. With this information, policymakers can more efficiently target scarce resources toward those counties most in need.

There are multiple differences between the demographics of those who reside in the diabetes belt and the rest of the U.S. Perhaps the most striking is the greater percentage of non-Hispanic African Americans in the diabetes belt. This finding suggests that interventions that are specifically targeted toward people of non-Hispanic African-American ancestry should be considered in appropriate locations within the diabetes belt. The belt also has a smaller proportion of people of Hispanic ethnicity than the rest of the nation. Because Hispanic ethnicity is a risk factor for diabetes,[9] people of Hispanic ancestry might contribute relatively little to the greater prevalence of diagnosed diabetes within the diabetes belt.

Many risk factors associated with diabetes (e.g., obesity, non-Hispanic African-American ancestry, age $\geq$65 years)[9] were less strongly associated in the diabetes belt than they were in the rest of the U.S. This might be attributable to the nondiabetes belt population being more heterogeneous. Regardless, the intercept term of Model 2 (diabetes belt) was larger than the intercept term of Model 3 (rest of U.S.), indicating that everyone in the diabetes belt—including those who had few risk factors (e.g., young, non-Hispanic white, non-obese people)—was at greater risk of diabetes than similar people outside the belt. The reasons for this might be associated with social, cultural, and possibly genetic factors within the area identified as the diabetes belt.

This study was subject to several limitations. Analyses were based on BRFSS, which has some inherent limitations (e.g., recall bias, social desirability bias, inability to reach houses without land-line telephones). Similarly, the BRFSS provides cross-sectional data. Therefore, no information about either how long obese respondents had been so or how long people leading sedentary lifestyles had been doing so was available. Type 1 and 2 diabetes were not distinguishable, although the latter nationally accounts for 90%–95% of the total cases of diabetes.[8] The current definition of the diabetes belt was based on estimated county-level prevalence of diabetes and did not account for these estimates' uncertainties.

The cut-off value for inclusion in the diabetes belt (11.0%) is arguable. Had a value of 12% been chosen, the resulting "belt" would have consisted of many isolated pockets. Had a value of 10% been chosen, the resulting belt would have been much more diffuse and harder to interpret. The authors did not use the 11.2% cut-off the quintiles represented in Figure 1 because it would have made little difference in the identified belt, and an 11.0% cut-off is conceptually simpler than an 11.2% cut-off. However, different cut-offs would have resulted in somewhat different belts.

The BRFSS does not support accounting for undiagnosed diabetes. Results might change if counties substantially differed in the proportion of undiagnosed diabetes. Counties in the diabetes belt tend to be at low levels of economic development. Lower levels of economic development often mean less access to care,[10] which could reduce detection of diabetes. However, the diabetes belt had a greater percentage of African Americans than the rest of the country. African Americans are at greater risk for diabetes, so providers might be more vigilant in detecting diabetes among African Americans. It is not known to what extent these factors cancel, nor is the remaining bias' direction.

Diabetes status was self-reported. Previous research has shown that self-reported diabetes, when compared to medical records, has a 99.7% specificity and a 66.0% sensitivity.[11] It is not known if sensitivity and specificity vary geographically. As diabetes prevalence can change over time, counties might move in or out of the diabetes belt. Thus, membership in the diabetes belt needs to be thought of as dynamic. Similar changes have occurred in the stroke belt.[2]

Finally, many counties that have high diabetes prevalence are not included in the diabetes belt. For example, some counties in Michigan and Oklahoma had a prevalence of diabetes $\geq$11.0% but were not included in the belt. Similarly, isolated counties in Florida were excluded. Many of these counties are poor and some have large American-Indian populations; American Indians have a very high prevalence of diabetes.[12]

Although prevalence of diabetes within the diabetes belt exceeds that of the rest of the U.S., there is hope to reduce the disparity. Much of the diabetes belt consists of areas that were once primarily agricultural. People in the diabetes belt might have continued to consume a high-calorie diet, appropriate for agricultural labor, after the need for this increased consumption had passed. Although the authors are aware of no county-level data on caloric consumption that would support examination of this hypothesis, it is consistent with the finding that 30% of the excess risk was attributable to the modifiable risk factors of obesity and sedentary lifestyle. If the prevalence of obesity and sedentary lifestyle within the diabetes belt could be brought into line with that of the rest of the U.S., the disparity in diabetes prevalence between the diabetes belt and the rest of the U.S. would eventually be reduced, because reductions in obesity and sedentary lifestyle would reduce diabetes incidence. It is strongly recommended that public health officials consider culturally appropriate interventions to decrease obesity and sedentary lifestyle for counties within the diabetes belt.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the CDC.

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