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Racial, Ethnic, and Urban/Rural Differences in Transitions into Diabetes: Evidence from the Health and Retirement Survey Biomarker and Self-Reported Data

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Cover Page Footnote

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ABSTRACT

We examine differences in transitions between stages of type 2 diabetes across racial, ethnic, and urban/rural statuses. The individual-level data from the 2006 to 2012 waves of the Health and Retirement Survey (HRS) and county-level data from the 1990-2000 U.S. Censuses, the Dartmouth Atlas of Health Care, and the Inter-university Consortium for Political and Social Research are used to analyze the transition from the stage of prediabetic to diabetic, and the transition from having no diabetes to being prediabetic and diabetic. The HRS includes both biomarker data and self-reported doctors' diagnoses of diabetes, which allow us to identify people who are prediabetic and undiagnosed diabetics. The likelihood of reporting the transition from prediabetes to diabetes increases with the degree of rurality. Adding county-level proxies for structural disadvantage and individual-level correlates to the regressions attenuate race/ethnicity and rurality disparities in the development of diabetes.

KEYWORDS

Biomarker, racial/ethnic disparities, rurality, stages of diabetes

INTRODUCTION

The prevalence of diabetes has been increasing in the United States. Between 1990 and 2015, the number of people living with diagnosed diabetes more than tripled from 6.21 million to 23.35 million (Centers for Disease Control and Prevention 2018), and the incidence rates of diagnosed diabetes range from 3.3 cases per 1,000 in 1980 to 7.8 cases per 1,000 in 2007 (Boyle et al. 2010). Diabetes is a disease that occurs when blood sugar is too high in the bloodstream. In people with diabetes, the body either does not produce enough insulin, which is a hormone that controls blood sugar, or the body cannot use the insulin it produces effectively. When insulin levels are too low or cells stop responding to insulin, too much blood sugar stays in bloodstream, which can cause serious health problems including heart disease, vision loss, kidney disease, and morbidity (Centers for Disease Control and Prevention 2020). There are two main types of diabetes[1]. Type 1 diabetes occurs most frequently in children and accounts for less than 10 percent of all diabetes cases (Mobasseri et al. 2020). Type 2 diabetes is more common in adults and is the focus of this study. In type 2 diabetes, cells are not able to utilize the insulin produced by the body. Treatment includes lifestyle changes, metformin taken orally, insulin injections, or combination therapy, and the recommended treatment depends on the stage. Stage 1 represents “insulin resistance,” Stage 2 “prediabetes,” Stage 3 “type 2 diabetes,” and Stage 4 “type 2 diabetes with complications.” For those diagnosed with Stage 1 diabetes, medical advice focuses on lifestyle adjustments through diet and exercise to prevent the disease from progressing (Mechanick et al. 2018).

The burden of diabetes in the U.S. is substantial. For individuals, the psychological and quality-of-life costs are significant (Pearce, Pereira, and Davis 2013; Falco et al. 2015). Medical care costs are high and increasing (Brandle et al. 2003; Walker et al. 2020). The economic burden associated with diabetes and prediabetes exceeded $327 billion in 2017, consisting of $237 billion in direct medical costs and $90 billion in reduced productivity. This national estimate is 51 percent higher than the $218 billion estimate for 2007 (American Diabetes Association 2018). In addition, diabetes ranked fourth among the causes of age-standardized Disability-Adjusted Life Years (DALY) in the U.S. in 2016, and the DALYs attributed to diabetes in the U.S. increased by 11 percent between 1990 and 2016 (The U.S. Burden of Disease Collaborators 2018).

Unhealthy lifestyle behaviors such as poor diet and lack of exercise are the major causes driving the increase in diabetes to epidemic proportions. Individual-level characteristics also affect the prevalence of diabetes. As people age, they are more likely to develop diabetes, and the estimated prevalence of diabetes among seniors aged 65 years and over in the U.S. reached 26.8 percent in 2018 (Centers for Disease Control and Prevention 2020). The other demographic factors are changes in racial and ethnic composition[2]. The U.S. Census Bureau's (2015) projections suggest that over 50 percent of Americans will be nonwhite by 2044. It is well-documented that racial and ethnic minorities have a higher prevalence of diabetes than non-minority individuals (Golden et al. 2012). Multiple factors contribute to these disparities. Biological factors include insulin resistance, hyperglycemia, visceral adiposity, and obesity, which vary across racial and ethnic groups (Golden et al. 2012). Racial and ethnic minorities experience more stress than non-Hispanic Whites, which leads to higher allostatic loads that are related to diabetes (Golden et al. 2012). Health behaviors such as exercising and self-monitoring of blood glucose also vary by race and ethnicity (Spanakis and Golden 2013). Racial and ethnic minorities are more likely to live in low-income neighborhoods than non-Hispanic whites, which affects health through ability to exercise, access to healthy foods, and exposure to crime and other stressors. Access to health care also varies across racial and ethnic groups due to access to health insurance and provider locations, among other factors (Spanakis and Golden 2013).

Residential differences are associated with individual health, above and beyond individual-level characteristics (Duncan, Jones, and Moon 1996; Robert 1998; Subramanian, Kawachi, and Kennedy 2001; Macintyre, Ellaway, and Cummins 2002; Boardman 2004; Dubowitz et al. 2008; Monnat and Pickett 2011). National standards consistently recommend that diabetic patients receive care from a multidisciplinary team of physicians, nurses, nutritionists, and exercise experts certified as diabetes educators with knowledge of behavioral psychology (Ceballos, Coronado, and Thompson 2010). However, residents of rural America experience a relative shortage of physicians (Rosenblatt and Hart 2000; Eberhardt, Ingram, and Makuc 2001) and are more likely to have limited access to health care services (Bolen et al. 2000; Waidmann and Rajan 2000; Mainous et al. 2004) than residents of urban America. Such health delivery challenges of rural America make rural residents less likely to have regular check-ups, thus limiting access to adequate diabetes care and increasing the likelihood of rural people having to seek urgent or emergent diabetes care (Basu, Friedman, and Burstin 2004). Exercise plays a major role in the prevention and control of diabetes. Adherence to an exercise program is critical for optimal health in individuals with diabetes (Colberg et al. 2010). Resources and senior-focused amenities such as a senior club are centered within urban areas (Vogelsang 2016), and rural people are less likely to have opportunities to participate in group exercise than urban people. However, the extent to which these structural differences exist for transitions between stages of type 2 diabetes is unclear because prior research in this area has been restricted to a certain state or geographic region (Goonesekera et al. 2015) or focused on the population with diabetes at a fixed point in time.

As James and her coauthors (2017) show, people of color in rural communities generally suffer worse health than non-Hispanic Whites in those communities. When examining racial and ethnic disparities in a rural context, it is important to recognize the specific kinds of resilience that rural communities may confer. Different locales expose individuals to different regional historical, policy, environmental, and social contexts. For example, rural non-Hispanic Black adults are much more likely to live in the South, with legacies of segregation. The aim of this analysis is to assess whether there are associations among the characteristics of rurality and race/ethnicity and the outcome of the development of diabetes in older adults and to what extent individual- and county-level determinants explain transitions along the continuum of rurality. The questions are addressed with data from the Health and Retirement Study that is a national survey of U.S. adults above the age of 50 years, the 1990-2000 U.S. Censuses, the Dartmouth Atlas of Health Care, and the Inter-university Consortium for Political and Social Research. We examine separately the transition from prediabetic to diabetic, and the transitions from having no diabetes to being prediabetic and diabetic.

BACKGROUND

Contribution of this Study

This paper extends previous research on racial, ethnic, and urban-rural differences in diabetes in four ways. First, we use both biomarker data and self-reported doctors' diagnoses of diabetes, which allow us to identify people who are prediabetic as well as undiagnosed diabetics. Estimates based only on self-reports of physicians' diagnoses may underestimate diabetes (Golden et al. 2012). Second, we focus on type 2 diabetes by employing logistic models with national data representing U.S. adults over 50 years of age. Third, we assess whether individual characteristics and county-level contextual features explain the urban-rural differences in the development of diabetes. Fourth, we use longitudinal data to focus on individual transitions from prediabetes into diabetes and from a normal state into prediabetes and diabetes. This paper complements previous research and suggests directions for future research.

Hypotheses of this Study

We hypothesize that the degree of rurality will be associated with transitions between stages of type 2 diabetes in the following way. The average individual living in a nonmetropolitan county will have greater odds of reporting the development of diabetes than the average individual living in a metropolitan county, and this difference in odds will increase as rurality increases. We also hypothesize the associations with rurality will be attenuated when controlling for additional contextual factors.

DATA AND DESCRIPTIVE STATISTICS

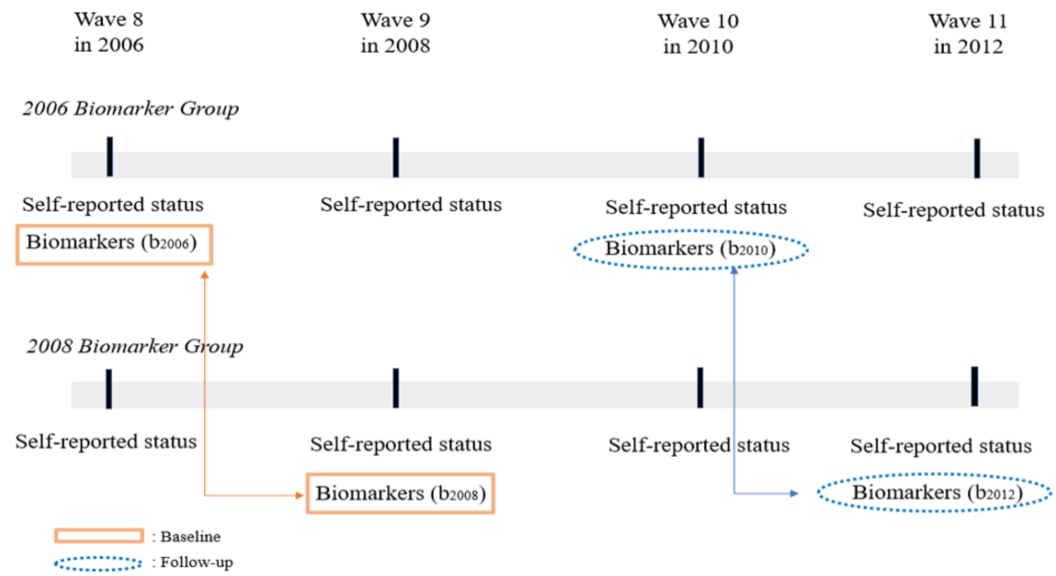
Data

Individual-level data are taken from the 2006-2012 Health and Retirement Study. The Health and Retirement Study (HRS) is a biennial panel survey of U.S. households sponsored by the National Institute on Aging and conducted by the University of Michigan’s Institute for Social Research (Juster and Suzman 1995). Originally begun in 1992 with a representative sample of Americans born between 1931 and 1941, the HRS is representative of the entire U.S. population over 50 years of age with a national sample of over 30,000 individuals.

Respondents are surveyed for self-reported outcomes biennially, whereas the HRS expanded to include biomarkers in Enhanced Face-to-Face (EFTF) interviews conducted on randomly selected rotating halves of the panel in each wave starting in 2006. The sample was selected at the household level, and each selected household was required to include at least one age-eligible member. To examine the differences between the samples of those who decided to provide biomarkers and those who decided against it, we took the baseline data and compared the samples. Non-Hispanic White Americans were more likely to complete the interview and provide the biological samples than non-Hispanic Black Americans or Hispanics, and people living in metro counties were more likely to provide biological samples than people living in nonmetro counties.

During the interviews, researchers measured and collected two types of biological samples to evaluate biomarkers: blood and saliva. Saliva is for DNA extraction, and blood is used to measure 5 biomarkers, which are total cholesterol, High-Density-Lipoprotein (HDL) cholesterol, Glycated hemoglobin (HbA1c, an indicator of glycemic control over the past 2-3 months), C-reactive protein, and Cystatin C (Crimmins et al. 2013). Interviewees were notified about their biomarker results by mail. Figure 1 describes the timing of data collection in the HRS panel in two timelines. A line with squares depicts the baseline, and a dashed ellipse illustrates the follow-up. Weir (2008) describes how the integration of biomarkers into the HRS validates and adds information to self-reported health, improves modeling of pathways to health, and allows participants to ascertain what they had not previously known about their health.

Figure 1: Timing of Biomarker Measurements in the HRS



Source: Health and Retirement Study 2006-2012. Figure created by authors using restricted HRS data.

County-level correlates of transitions into being diabetic were drawn from the Health and Retirement Study Contextual Data Resource (HRS-CDR). The HRS-CDR is a restricted data set that enables researchers to study the effects of place on health and well-being among the HRS respondents (Ailshire, Mawhorter, and Choi 2020). This study uses the Dartmouth Atlas of Health Care and the 1990-2000 U.S. Censuses. The HRS-CDR Dartmouth Atlas of Health Care documents how medical resources are distributed and used in the United States, and the Decennial Censuses are comprised of demographic and socioeconomic characteristics on the U.S. population and each of the 3,142 U.S. counties. Data to identify health professional shortage areas were drawn from the County Characteristics Data set, which is produced by the Inter-university Consortium for Political and Social Research (ICPSR 2008). This study was approved by the University of Illinois at Urbana-Champaign's Institutional Review Board (IRB).

Measurements

To analyze the development of diabetes using logistic models for transitions from being prediabetic to being diabetic and transitions from being non-diabetic to being prediabetic and being diabetic, we classified stages of type 2 diabetes. We used both self-reported diagnosed diabetes and glycated hemoglobin in the biomarker data. The HRS indicated self-reported diagnosed diabetes by asking a respondent to report whether a doctor told the respondent that he/she had diabetes or high blood sugar. If the respondent reported no diabetes, we analyzed the Hemoglobin A1c result to identify undiagnosed diabetes, prediabetes, or normal conditions. Consistent with the American Diabetes Association's (2014) guidelines, individuals with an A1c of lower than 5.7 percent are normoglycemic, which implies no diabetes. An A1c range of 5.7 to 6.4 percent identifies individuals with high risk for future diabetes, to whom the term prediabetic is applied. Because a person with diabetes would have an A1c level of 6.5 percent or higher, we defined this person as diabetic even if he/she had no self-reported diagnosed diabetes.

One of our principal independent variables is the rurality of the county within which the respondent resides. We used the county as the contextual unit of analysis because the county is small enough to reflect local social and economic conditions (McLaughlin, Stokes, and Nonoyama 2001) and is also a relevant geographic unit for the delivery of many social services such as public health. We divided respondents among three levels of rurality based on the Rural-Urban Continuum Codes classified by the US Department of Agriculture's Economic Research Service (USDA ERS 2003)[3]. In our study, (1) Large central/fringe areas are counties in metropolitan areas of 1 million population or more (reference category), and (2) Medium/small areas are counties in metropolitan areas with populations of less than 1 million. To ensure large enough sample sizes in each of the diabetes stages, we combined all nonmetropolitan categories together, hereafter referred to as (3) rural areas. Throughout, we refer to metropolitan counties as urban and nonmetropolitan counties as rural.

Descriptive Statistics

Of the 25,331 respondents aged over 50 in the United States (except for Alaska and Hawaii) eligible for the 2006-2012 waves of the HRS interview, 25,327 provided their diabetes status. A total of 18,756 respondents participated in blood-based biomarker data collection in the EFTE interview, and 17,763 submitted their HbA1c values at least once over the 2006-2012 waves. Consenting respondents were biomarked once every four years, and we focused on the 7,276 individuals who appeared both in the baseline and in the follow-up because we aimed to investigate transitions into diabetes. The analyses lastly excluded 721 individuals who had missing data about their geographic information, SES, health behaviors, or county-level contextual variables[4]. These lead us to include 6,555 respondents.

Table 1 displays descriptive statistics for our sample. The first three columns show 873 respondents who were prediabetic at baseline, and the latter three columns show 3,466 respondents who were non-diabetic at baseline. For the logistic models estimating the transition from being prediabetic to being diabetic, we excluded (1) 1,544 respondents who had diabetes in the baseline, and (2) 4,138 respondents who were normoglycemic in the baseline. The result is a total sample of 873 individuals. For the logistic models estimating the transition from being non-diabetic to being prediabetic and diabetic, we excluded (1) 3,089 respondents who had prediabetes or diabetes in the baseline and had a total sample of 3,466 respondents.

Among those who were prediabetic in the baseline, 28.5 percent of residents in large central/fringe counties went on to develop diabetes. In contrast, about 34.7 percent of residents in rural counties became diabetic in the follow-up. Individuals living in rural counties had the lowest levels of education and were most likely to have household incomes less than $25,000 per year. With respect to health behaviors, rural residents who were prediabetic in the baseline were more likely to be current smokers and to be obese than urban residents who were prediabetic. In terms of the characteristics of counties themselves, rural counties were the poorest and had the highest percentage of population aged over 65. Urban counties were more likely to be designated as primary care health professional shortage areas[5] than rural counties. The designation might not characterize an actual shortage but might still allow for federal program support for the area (Monnat and Pickett 2011).

For those who were non-diabetic in the baseline, rural residents were the least likely to have completed four-year college degrees, be employed, and have household incomes over $74,999 per year compared to individuals in urban counties. They were more likely to report smoking currently and less likely to manage their weight than their counterparts. In terms of the characteristics of counties, rural counties had the highest percentages of seniors, lowest index for quality of health care, and highest percentages of households classified as poor.

Table 1: Descriptive Statistics along the Urban-Rural Continuum (percentages in each category)

	Prediabetic in baseline (N=873)			Non-diabetic in baseline (N=3,466)		
	Large (n=442)	Med/ small (n=255)	Rural (n=176)	Large (n=1,740)	Med/ small (n=1,087)	Rural (n=639)
Being diabetic	28.5	33.3	34.7	34.2	33.2	34.4
Individual characteristics						
Age						
51-64	33.7	29.4	30.1	42.1	42.3	39.6
65-74	40.3	37.7	43.2	36.0	34.2	38.7
75+	26.0	32.9	26.7	21.9	23.5	21.8
Female	57.9	60.0	56.8	58.7	58.6	57.8
Race/Ethnicity						
NHW	63.1	73.3	76.7	79.8	83.6	89.4
NHB	25.1	15.3	18.2	11.3	6.8	6.7
Hispanic	7.7	8.2	2.8	6.8	8.2	2.8
NHO	4.1	3.1	2.3	2.1	1.4	1.1
Educational attainment						
Less than HS	18.3	24.3	25.6	13.3	17.2	17.2
High school	31.9	34.5	43.8	30.8	32.8	43.8
Some college	25.3	24.7	15.3	24.5	23.7	20.2
4 years college+	24.4	16.5	15.3	31.4	26.3	18.8
Married	64.3	65.9	72.2	70.9	73.1	76.8
Employed	32.4	32.9	35.8	41.9	39.3	38.5
Has Medicare	64.5	67.8	69.9	56.3	58.0	6.0
HH Income						
<$25,000	28.1	29.0	29.6	20.4	25.9	26.8
$25,000 to $74,999	48.0	47.8	50.6	43.4	45.0	49.6
≥$75,000	24.0	23.1	19.9	36.2	29.2	23.6
Smoking history						
Never smoked	13.1	13.7	14.8	12.9	12.1	13.6
Former smoker	40.5	39.2	34.7	45.8	44.2	39.1
Current smoker	46.4	47.1	50.6	41.3	43.7	47.3
Overweight	39.1	41.2	37.5	41.1	41.3	41.8
Obese	38.5	37.3	42.1	23.3	25.2	27.4

	Prediabetic in baseline (N=873)			Non-diabetic in baseline (N=3,466)		
	Large	Med/ small	Rural	Large	Med/ small	Rural
	(n=442)	(n=255)	(n=176)	(n=1,740)	(n=1,087)	(n=639)
Physically active	31.0	31.4	22.2	37.5	37.0	29.9
Visit doctor	96.8	96.1	97.2	95.8	92.6	94.1
County characteristics						
Quality of health care (index)	1.9	1.9	1.9	1.9	1.9	1.9
HPSA	45.7	46.3	10.2	42.5	39.7	19.6
Population loss	12.9	18.4	4.0	12.0	11.5	8.5
Percentage of seniors	12.2	12.9	13.4	12.1	13.4	14.6
Poor county	6.6	14.5	34.1	3.9	12.1	20.3

NHW = non-Hispanic Whites; NHB = non-Hispanic Blacks; NHO = non-Hispanic other races; HPSA = Health Professional Shortage Area

THE EMPIRICAL MODEL

To examine the differences in transitions between stages of type 2 diabetes, we estimated the following logistic equation:

$$Y_{ijt} = \alpha + \beta_1 R_{ijt-1} + \beta_2 X_{ijt-1} + \beta_3 \gamma_{j2000} + \beta_4 \delta_{j2003\text{-}2005} + \varepsilon_{it}$$

where Y_{ijt} is equal to 1 when individual *i* living in a county *j* in the baseline had developed diabetes by the time of the follow-up *t*. In the model for the transition from prediabetes to diabetes, observations from middle- and older-aged Americans who had diabetes in the baseline were excluded from the sample. We also excluded the individuals who did not have diabetes in the baseline. The dependent variable is equal to 1 when a prediabetic individual at baseline goes on to develop diabetes at follow-up and is equal to 0 if a prediabetic individual remains prediabetic at follow-up. We did not observe the transition of any individual from prediabetic in the baseline to the normal stage in the follow-up. For the model of transition from being non-diabetic to being diabetic, we use an ordered multinomial logit, and the dependent variable is equal to 0 when the non-diabetic individual in the baseline remained normoglycemic in the follow-up, 1 when people who were not diabetic or prediabetic in the baseline went on to develop prediabetes in the follow-up, and 2 when people who were not prediabetic or diabetic in the baseline were classified as diabetic at follow-up.

To assess the effects of geographic variation on transitions into diabetes, we classified the county of residence into three types (R_{ijt-1}). The Rural-Urban Continuum Codes (RUCCs or Beale Codes) assigned in the baseline were used to categorize counties using a three-point graduated scale with 1 being the most urban and 3 being the most rural, according to the USDA-ERS (2003).[6] The regressions included controls for the four regions in the U.S. Census, with South as the reference category. Final variable selection was based on the research summarized above and assessments of multicollinearity and model fit.[7]

The regressions included the individual-level characteristics (X_{ijt-1}) and the county-level contextual variables that might have caused bias in the estimated coefficients. The individual demographic characteristics included the following race/ethnicity groups: non-Hispanic Whites (reference group), non-Hispanic Blacks, non-Hispanic other races, and Hispanics. Other demographic factors included gender (male = reference group) and dummy variables for age groups: 51-64 (reference category), 65-74, and 75 and over.

To examine the extent to which the urban-rural differences are explained by differences in individual-level characteristics and whether the socioeconomic status and health behaviors of individuals explain differences in transitions into diabetes from being prediabetic or from being non-diabetic between residents in large central/fringe counties and those in medium/small counties or rural counties, we included several individual-level variables in the baseline *t-1*. Educational attainment was measured using four categories: less than high school graduate, high school graduate (reference group), some college education, and four-year college graduate or above. Dichotomous variables for marital status (married = reference category), employment status (employed = reference category), and Medicare coverage (having Medicare coverage = reference category) were included as controls. Household income was classified into three categories: less than $25,000, between $25,000 and $74,999, and $75,000 and above (reference category). Health-related behaviors were measured using indicators of smoking, being overweight, being obese, being physically active, and visiting a doctor. Smoking status was classified into three categories: current smokers, former smokers, and people who never smoked (reference category). Being overweight and being obese were dichotomous variables determined by Body Mass Index (BMI). A BMI from 25 to <30 was classified as overweight, and a BMI of 30 or higher was classified as obese. A respondent was classified as physically active if the person reported exercising once per week or more

= 1 (reference category) vs. not = 0. We also controlled for whether the individual visited a doctor within the last two years or not.

Contextual variables represented by the vector γ_{j2000} proxy for county-level structural disadvantages. They included racial/ethnic composition, percent of population aged over 65, whether the county experienced population loss between 1990 and 2000, whether the county was a poor county, defined as having 20 percent or more of the population living below the poverty line, whether at least one area within the county was designated as a primary care health professional shortage area, and the index for the quality of medical care. To capture any systematic racism such as fewer resources in counties where the minority groups are more likely to live, we included the percent of non-Hispanic Blacks in 2000 and the percent of Hispanics in 2000. We included dichotomous variables indicating whether the county lost population between the 1990 and 2000 Censuses, and whether 20 percent or more of residents were poor.

One important contextual variable that may account in part for residential differences is the availability of health care services ($\delta_{j2003\text{-}2005}$). We referred to two sets of nationally accepted preventive service guidelines from the American Diabetes Association (ADA) and Healthy People 2020 to determine the threshold and generate the index of the quality of health care. The ADA provides the recommended frequency of each service, and Healthy People 2020 offered national goals (Table 2). We used the Dartmouth Atlas Data set in 2003-2005, which provides the average annual percentage of diabetics aged 65-75 who had the HbA1c test, eye exam, and blood lipids test in each U.S. county.

Table 2: Nationally Accepted Health Services Guidelines from the American Diabetes Association (ADA) and Healthy People 2020

	ADA	Healthy People 2020
HbA1c Test	Perform the A1c test at least 2 times a year in patients who are meeting treatment goals (and who have stable glycemic control) and quarterly in patients whose therapy has changed or who are not meeting glycemic goals.	≥71.1% of adults aged 18+ with diabetes will have an annual HbA1c test. ≥16.2% of adults aged 18+ with diagnosed diabetes will reduce an A1c value greater than 9%.

Eye Exam	Patients with type 2 diabetes should have an initial eye exam by an ophthalmologist or shortly after the diagnosis. Subsequent eye exams for type 2 diabetes patients should be repeated annually.	≥58.7% of adults aged 18+ with diabetes will have an annual eye exam.
Blood Lipid Test	In adult patients, test for lipid disorders at least annually. In adults with low-risk lipid values (LDL-C<100mg/dl) repeat lipid assessments every 2 years.	≥85.3% of adults aged 18+ with diabetes will have an annual blood lipid test. ≥58.3% of adults aged 18+ with diagnosed diabetes improve lipid control (LDL-C<100mg/dl).

We considered the county to offer high-quality diabetic care if each service variable exceeded the national goal for the services set by Healthy People 2020[8]. Our index takes a value between 0 to 3 where we added one point to the index if the average annual percentage of diabetic Medicare adults aged 65-75 receiving each service is above each threshold. For example, Champaign County in Illinois, where the average annual percent diabetic having an A1c test, an eye exam, and blood lipids tests are 84.55 percent (vs. national goal of 84.16 percent), 72.26 percent (vs. national goal of 71.05 percent), and 73.59 percent (vs. national goal of 78.92 percent), respectively, is assigned 2 points. Thus, larger values of the index imply higher quality of care for diabetic patients. A binary indicator for whether any part of the county was classified as a health care professional shortage area is used to measure health care infrastructure. Access to primary health care may facilitate preventive health interventions. Counties lacking these services may have higher transition rates to diabetes.

RESULTS

Transitions from Being Prediabetic to Being Diabetic

Table 3 presents four models estimating odds of reporting transitions from being prediabetic to being diabetic. Model 1 displays rurality differences controlling for U.S. Census regions of residence, individual race/ethnicity, dummy variables for age group, and sex. The results demonstrate that as the degree of rurality of the county increases, the probability of experiencing the transition to being diabetic increases. People who live in rural areas or medium/small metro counties are more likely to make the transition from prediabetes to diabetes than people who live in large central/fringe metro counties. We also observe that the average resident of rural counties has a greater likelihood of reporting the transition than the average resident in medium/small metro counties, and thus the differences in the transition from being prediabetic to being diabetic becomes greater with the degree of rurality. There are statistically significant differences in the race/ethnicity coefficients, suggesting that Black Americans who are prediabetic at baseline are more likely to go on to develop diabetes than Hispanics and White Americans are.

Individual-level socioeconomic status (SES) indicators including dummies for educational attainment, employment status, marital status, household income, and Medicare coverage are controlled for in Model 2. The addition of variables to control for individual SES does not lead to a remarkable change in magnitude of the county-type variables. Instead, the results demonstrate that the introduction of socioeconomic status variables mitigates the statistically significant racial/ethnic disparities in the transition.

Neither does the introduction of individual-level health behaviors in Model 3 result in a dramatic reduction in the magnitudes of the rurality variables. On the other hand, the introduction of health behavior variables makes the race/ethnicity coefficients lose their significance and attenuates differences in the transition from being prediabetic to being diabetic among Black Americans on average. The individual-level health conditions that affect the transition from prediabetes to diabetes the most are being overweight and being obese. People who were classified as obese in the baseline were 178 percent more likely to become diabetic than people who were not obese nor overweight. People who were overweight were 98 percent more likely to become diabetic than people who were not obese nor overweight.

Table 3: Logistic Model to Estimate the Transition from Being Prediabetic to Being Diabetic

	Pre-diabetes to diabetes (N=873)			
Odd ratios	(1)	(2)	(3)	(4)
Rurality (ref=Large central/fringe counties)				
Medium/small counties	1.41**	1.39**	1.37**	1.37*
	(0.25)	(0.25)	(0.25)	(0.25)
Rural counties	1.50**	1.49**	1.48*	1.47
	(0.31)	(0.31)	(0.31)	(0.35)
Race/Ethnicity (ref=NHW)				
Hispanics	1.31	1.24	1.11	0.98
	(0.39)	(0.39)	(0.36)	(0.32)
NHB	1.25**	1.20*	1.12	1.01
	(0.24)	(0.24)	(0.23)	(0.21)
Female	0.71**	0.70**	0.65**	0.65**
	(0.11)	(0.11)	(0.11)	(0.11)
Individual-level SES				
Educational Attainment (ref=High school)				
Less than HS		0.98	1.11	1.11
		(0.21)	(0.25)	(0.25)
Some college		1.15	1.25	1.26
		(0.23)	(0.26)	(0.26)
4-year college+		0.71	0.73	0.72
		(0.16)	(0.17)	(0.17)
Employed		0.88	0.92	0.94
		(0.16)	(0.17)	(0.18)
Married		1.00	0.99	0.97
		(0.19)	(0.19)	(0.19)
HH Income (ref=HH income>$74,999)				
HH Income: <$25,000		1.01	1.05	1.07
		(0.27)	(0.28)	(0.29)
HH Income: $25,000 to $74,999		0.95	0.99	1.03
		(0.19)	(0.21)	(0.22)
Has Medicare		1.03	1.07	1.06
		(0.30)	(0.32)	(0.32)
Individual-level Health Behaviors				
Overweight			1.98***	2.00***
			(0.46)	(0.46)
Being obese			2.78***	2.80***
			(0.65)	(0.66)
Smoking status (ref=Never smoked)				
Current smoker			1.55*	1.62*
			(0.39)	(0.41)
Former smoker			1.15	1.22
			(0.30)	(0.32)

	Pre-diabetes to diabetes (N=873)			
Odd ratios	(1)	(2)	(3)	(4)
Physically active			1.24	1.28
			(0.21)	(0.22)
Visit a doctor			0.99	1.06
			(0.42)	(0.45)
County-level contextual variables				
Quality of health care				-0.61*
				(0.16)
HPSA				1.25
				(0.25)
Population loss				0.87
				(0.23)
Percentage of seniors				0.24
				(0.55)
Poor county				1.04
				(0.26)
Model fit statistics				
Pseudo R-squared	0.33	0.38	0.63	0.67
AIC	1,071.40	1,081.76	1,067.14	1,071.13
BIC	1,128.67	1,177.20	1,191.21	1,119.06

NHW = non-Hispanic Whites; NHB = non-Hispanic Blacks; HPSA: Health Professional Shortage area

Notes: All models include controls for dummy variables for age groups: 51-64 (reference category), 65-74, and 75 and over, region of residence: Northeast, Midwest, West, and South (reference category), and non-Hispanic other races. Robust standard errors in parentheses. ***p<0.01, **p<0.05, and *p<0.1

Model 4 reveals that adding the county-level contextual features to the model further decreases the magnitude of the rurality coefficients. In particular, the finding suggests a reduced difference in the likelihood of the transition between the average residents in a large central/fringe metro county and the average individual living in medium/small metro county, and the medium/small metro county coefficient becomes marginally significant at the 10 percent level. The estimate for rural county is positive and insignificant for the transition from being prediabetic to being diabetic, in keeping with the expectation that this coefficient captures the partial effects of rurality on the development of diabetes. However, the magnitude of the estimate for rural county does not change much. Controlling for the contextual variables additionally decreases the magnitude of the coefficient for Black Americans. Hence, racial/ethnic differences in the transition are partially explained by differences in individual-level determinants and further explained by differences in county-level characteristics.

Adding county-level contextual variables to our analyses in Model 4 (Table 3) caused the effects of rurality to decrease and to become less statistically significant, which is not surprising because these county-level characteristics are related to rurality. The only county-level contextual variable that approached statistical significance was the quality of health care for diabetes. The result suggests that if the quality of health care for diabetics improves from the worst quality (index value of 0) to the best quality (value of 3), the likelihood of transitioning from prediabetes to diabetes falls by 1.83 percentage points (equal to the coefficient of -0.61*3 units of change in quality).

Transitions from Being Non-diabetic to Being Diabetic

Results of the regression analyses for the transition from being non-diabetic to being diabetic are presented in Table 4. From all four models, we find little evidence that there are effects of the county types on the direct transition from no diabetes to diabetes. Results of the model regressing the transition on the degree of rurality, U.S. Census regions of residence, race/ethnicity, sex, and age groups (Model 1) reveal statistically significant differences in racial and ethnic coefficients. Compared to a non-Hispanic White American, a Black American has about 197 percent (OR=2.97; [95%] CI=-1.50 to 0.67) greater odds of reporting the transition from being non-diabetic to being diabetic. We find that marriage plays an important role to reduce the odds of reporting the transitions to being diabetic from being non-diabetic. There is a significantly lower risk of the development of diabetes for a married person compared to a non-married person.

The introduction of county-level contextual variables in Model 4 leads to an additional change in the magnitude of the racial and ethnic coefficients. In particular, the addition of these variables to the model considerably reduces the magnitude of Black Americans (OR=2.10; [95%] CI=0.28 to 1.20) from being non-diabetic to being diabetic. Therefore, racial and ethnic differences in the transition from being non-diabetic to being diabetic are partially explained by differences in the socioeconomic status of minority groups living in certain neighborhoods and further explained by differences in county-level contextual features.

Table 4: Multinomial Logit Model to Estimate the Transition from Being Non-diabetic to Being Prediabetic and Diabetic

	No diabetes to prediabetes and diabetes (N=3,466)							
	(1)		(2)		(3)		(4)	
Odd ratios	Prediabetes	Diabetes	Prediabetes	Diabetes	Prediabetes	Diabetes	Prediabetes	Diabetes
Rurality (ref=Large central/fringe counties)								
Medium/small counties	0.95	1.07	0.93	1.05	0.93	1.03	0.91	0.96
	(0.09)	(0.18)	(0.09)	(0.19)	(0.10)	(0.18)	(0.10)	(0.18)
Rural counties	0.99	1.19	0.95	1.13	0.95	1.07	0.9	0.94
	(0.12)	(0.25)	(0.11)	(0.24)	(0.11)	(0.23)	(0.11)	(0.22)
Race/Ethnicity (ref=NHW)								
Hispanics	1.31	1.55	1.23	1.26	1.23	1.22	1.26	1.09
	(0.22)	(0.45)	(0.22)	(0.39)	(0.22)	(0.38)	(0.23)	(0.35)
NHB	1.77***	2.97***	1.68***	2.44***	1.62***	2.16***	1.70***	2.10***
	(0.12)	(0.63)	(0.24)	(0.54)	(0.23)	(0.48)	(0.26)	(0.49)
Female	1.11	0.76***	1.04	0.66***	1.12	0.66***	1.12	0.66***
	(0.09)	(0.11)	(0.09)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)
Individual-level SES								
Educational Attainment (ref=High school)								
Less than HS			0.86	1.25	0.82	1.21	0.82	1.19
			(0.13)	(0.28)	(0.11)	(0.28)	(0.11)	(0.27)
Some college			0.94	1.11	0.94	1.13	0.94	1.14
			(0.11)	(0.22)	(0.10)	(0.23)	(0.11)	(0.23)
4-year college+			0.77**	0.71	0.83	0.79	0.84	0.77
			(0.09)	(0.16)	(0.10)	(0.18)	(0.10)	(0.17)
Employed			0.80**	0.93	0.80**	0.90	0.81**	0.90

	No diabetes to prediabetes and diabetes (N=3,466)					
(1)	(2)		(3)		(4)	
	(0.08)	(0.18)	(0.09)	(0.17)	(0.09)	(0.18)
Married	0.93	0.61***	0.95	0.60***	0.96	0.59***
	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.11)
HH Income (ref=HH income>$74,999)						
HH Income: <$25,000	1.07	1.01	1.04	0.99	1.04	0.98
	(0.15)	(0.27)	(0.15)	(0.27)	(0.15)	(0.28)
HH Income: $25,000 to $74,999	0.93	1.27	0.91	1.27	0.90	1.27
	(0.10)	(0.26)	(0.10)	(0.26)	(0.10)	(0.26)
Has Medicare	0.96	1.07	0.95	1.00	0.96	1.03
	(0.19)	(0.38)	(0.18)	(0.34)	(0.19)	(0.35)
Individual-level Health Behaviors						
Overweight			1.39***	1.97***	1.38***	1.97***
			(0.14)	(0.43)	(0.14)	(0.43)
Being obese			1.54***	3.97***	1.52***	3.97***
			(0.18)	(0.88)	(0.18)	(0.87)
Smoking status (ref=Never smoked)						
Current smoker			0.64***	0.89	0.64***	0.89
			(0.09)	(0.22)	(0.09)	(0.22)
Former smoker			0.79*	0.80	0.78	0.80
			(0.10)	(0.20)	(0.10)	(0.20)
Physically active			0.87	0.82	0.86	0.82
			(0.08)	(0.14)	(0.08)	(0.14)
Visit a doctor			1.04	1.30	1.05	1.28
			(0.19)	(0.45)	(0.20)	(0.45)

	No diabetes to prediabetes and diabetes (N=3,466)				
	(1)	(2)	(3)	(4)	
County-level contextual variables					
Quality of health care (Index)				0.92	1.11
				(0.12)	(0.26)
HPSA				0.97	1.04
				(0.10)	(0.19)
Population loss				0.86	0.79
				(0.13)	(0.21)
Percentage of seniors				9.87**	2.80
				(10.66)	(5.89)
Poor county				1.02	1.62*
				(0.17)	(0.42)
Model fit statistics					
Pseudo R-squared	0.12	0.18	0.32	0.34	
AIC	5,096.57	5,097.64	5,046.68	5,057.64	
BIC	5,244.18	5,343.67	5,366.52	5,238.99	

NHW = non-Hispanic Whites; NHB = non-Hispanic Blacks; HPSA: Health Professional Shortage area
Notes: All models include controls for dummy variables for age groups: 51-64 (reference category), 65-74, and 75 and over, region of residence: Northeast, Midwest, West, and South (reference category), and non-Hispanic other races. Robust standard errors in parentheses. ***p<0.01, **p<0.05, and *p<0.10

For the transition from being non-diabetic to diabetic, one of the county-level proxies that captures structural disadvantage is an important predictor. Specifically, living in a poor county increases the odds of reporting the transition from being non-diabetic to being diabetic. An individual living in a county where 20 percent or more of the residents are poor has about 62 percent (OR=1.62; [95%] CI=-0.035 to 0.99) greater odds of reporting this transition.

DISCUSSION

Based on nationally representative data, we investigate the effects of racial, ethnic, and urban-rural differences on transitions from being non-diabetic and from being prediabetic to being diabetic. We find that the likelihood of reporting the transition from prediabetes to diabetes increases with the degree of rurality. The significant differences in the transition from being prediabetic to being diabetic between the residents of large central/fringe metro counties and the residents of rural counties become insignificant after controlling for individual-level characteristics and county-level contextual features. We also find that county-level proxies for structural disadvantage and individual-level correlates attenuate race/ethnicity and rurality disparities in the development of diabetes. Specifically, obesity and overweight are highly correlated with the transition to diabetes, and these two health outcomes are also related to race, ethnicity, and rural status (Zhang, Wang, and Huang 2009; Cohen et al. 2016). In addition, racial/ethnic differences in transitions into diabetes are partially explained by differences in individual-level factors and further explained by differences in disadvantaged conditions associated with rural counties. As also found in de Oliveira et al. (2020) and Dadgari et al. (2015), we find that marriage is protective against the development of diabetes.

Despite the strengths of this study, there are limitations. First, we explore differences in transitions into being diabetic among middle-aged and old-aged Americans living in three types of counties – large central/fringe metro counties, medium/small metro counties, and rural counties. Combining all of the non-metropolitan counties into the category of rural counties may ignore differences in transitions across different types of rural counties. Second, estimating our model requires us to start with a sample of individuals who do not have diabetes in the baseline, and as a consequence, we may underestimate racial, ethnic, and urban-rural differences in transitions into diabetes. For example, a higher proportion of rural residents have already developed diabetes by the baseline. By excluding them from the estimation, we are missing transitions into diabetes earlier in the life cycle, biasing the results. Third, residents of rural counties, Black Americans, and Hispanics were less likely to complete interviews and provide biomarker data than non-Hispanic White Americans and residents of urban counties. This nonrandom selection is also likely to result in an underestimate of racial, ethnic, and urban-rural differences in transitions into diabetes. Fourth, our analysis does not capture the behavior of rural residents who travel outside their community to seek health care when the availability and quality of local health care are limited (Cummings et al. 2013). Indeed, this may explain why we find that indicators for healthcare infrastructure have little effect on transitions to diabetes. Future research should use spatial mapping and analysis techniques to examine differences in transitions to being diabetic among rural individuals who travel versus do not travel to metropolitan counties to obtain medical care.

Taken together, the findings remind us that residents of rural counties have the greatest likelihood of reporting the transition from being prediabetic to being diabetic and show that county-level contextual variables are also important predictors of transitions into diabetes. Therefore, future public health efforts designed to reduce racial, ethnic, and urban-rural differences in transitions between stages of type 2 diabetes should examine detailed urban-rural classifications while controlling for individual characteristics, health behaviors, and county-level contextual correlates.

ENDNOTES

[1] Gestational diabetes is one of types of diabetes that consists of high blood glucose during pregnancy. However, it usually disappears after pregnancy. Mothers and their children may be at increased risk of developing type 2 diabetes later in life (Zhu and Zhang 2016).

[2] Minority populations experience different levels of diabetes prevalence. According to the Centers for Disease Control and Prevention (2020), non-Hispanic White Americans report the lowest rates (11.9 percent), followed by Hispanics (14.7 percent), non-Hispanic Asians (14.9 percent), and non-Hispanic Black Americans (16.4 percent).

[3] The USDA-ERS distinguished metropolitan counties by the population size of their metro area, and nonmetropolitan counties by adjacency of the county to a metro area and the urban population size.

[4] The number of missing covariates in the baseline are listed: geographic information (missing=1), educational attainment (missing=11), employment status (missing=2), insurance status (missing=5), physical activity status (missing=7), BMI (missing=61),

smoking history (missing=50), doctor visit (missing=1), and county-level contextual factors (missing=584, including missing for the quality of index =579).

[5] Health Professional Shortage Area (HPSA) designations are used to identify areas and population groups within the United States that are experiencing a shortage of health professionals. There are three categories of HPSA designation based on the health discipline that is experiencing a shortage: 1) primary medical; 2) dental; and 3) mental health. The primary factor used to determine a HPSA designation is the number of health professionals relative to the population with consideration of high need. See details: https://data.hrsa.gov/topics/health-workforce/shortage-areas

[6] We examined Urban Influence Codes (UICs) as well as the RUCCs. The classification into the three categories of the rural/urban continuum changed only trivially, and using the UICs would result in a loss of observations because county FIPS were missing in the data set.

[7] To detect multicollinearity, we calculated the variance inflation factors (VIFs) and the condition number in collinearity diagnostics. None of the VIFs were greater than 10, and the condition numbers were between 4.88 and 5.70 for the models we estimated. We used stepwise models to determine whether certain variables or blocks of variables were accounting for the attenuation of other predictors. There was no single variable that affected the attenuation of rural/urban residence in our models. Using the oglm stepwise selection procedure, we determined that heterogeneity was not an issue (Mood 2010; Kuha and Mills 2018). Details are available from the authors by request.

[8] Both ADA and Healthy People 2020 do not restrict their targets to middle-aged or older adults, and we classified the highest 25 percent for the HbA1c test, eye exam, and blood lipids test of diabetic Medicare adults aged 65-75 to set the threshold. The generated thresholds for each test are similar to the national goals, and we decided to use the national guideline to decide our thresholds.

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