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Differences in Diabetes Care Practices between Rural and Urban Adults in the United States in 2017

By

Susan (Siqi) Ma

Degree to be awarded: Masters of Public Health (MPH)

Department: Global Health/Epidemiology

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B.S. Biochemistry, 2016

Washington and Lee University

Faculty Thesis Advisors: Shivani A. Patel, MPH, PhD & K.M. Venkat Narayan, MD, MSc, MBA

An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health
in Global Health/Epidemiology

2019

Abstract

Differences in Diabetes Care Practices Between Rural and Urban Adults in the United States in 2017

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Aims: There is evidence of disparities in diabetes-related health outcomes between those living in rural and urban counties of the U.S. This may in part be related to urban-rural disparities in the receipt of diabetes care practices. Our study examined differences in diabetes care practices across the urban-rural continuum in U.S. adults with diabetes for the year 2017.

Methods: Data were from the 2017 Behavioral Risk Factor Surveillance System telephone survey of 14,455 non-institutionalized adults with self-reported diagnosed diabetes with information on diabetes care and residence. Two types of diabetes care practices were considered: engagement with health care and self-management behaviors. Engagement practices included biannual health professional visits, biannual HbA1c tests, and an annual foot exam. Self-management indicators included diabetes education, daily glucose self-monitoring, daily foot checks, and monthly exercise. Place of residence was classified based on the respondent's landline telephone number. Respondents in any a metropolitan statistical area (MSA) were considered urban, while respondents outside an MSA were considered rural. We estimated the prevalence of each care practice across the urban-rural continuum. We also conducted multiple logistic regression to estimate the association between residence (ref= urban) and each care practice, adjusting for race/ethnicity, sex, education, income, and age. Measures were stratified by race to account for potential effect modification.

Results: Compared to those living inside the center city of a metropolitan area, rural respondents had lower proportions of engagement in diabetes education (52.0% vs 59.5%) and annual foot exams (76.8% vs 79.9%). Despite differences in prevalence, adjusted and unadjusted analyses indicated no significant associations between place of residence and likelihood of optimal diabetes practices, besides among rural black adults, who had a significantly lower likelihood of participating in all diabetes care practices (OR= 0.46, p=0.009) and all self-management practices (OR=0.46, p=0.004).

Conclusion: Rural adults did not exhibit a significantly different likelihood of participation in any individual diabetes care practice indicators compared to urban adults. Black adults were the only group to exhibit significant rural disadvantage with respect to diabetes care, suggesting that race intersects with rurality in influencing healthcare access and behaviors.

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Chapter I: Background/Literature Review

Diabetes is an immense public health issue in the United States. There are approximately 30.3 million individuals living with diabetes in the U.S. (9.4% of the total population), 23.8% of them undiagnosed (1). The overall prevalence of diabetes has been rising annually since 1994, with growing overweight and obesity rates in the U.S. (3,4). Because the course of diabetes affects numerous systems in the body, those with diabetes have an increased risk for mental health and disease complications. These include stroke, obstructive sleep apnea, depression, metabolic conditions, major cardiovascular diseases, kidney disease, and other chronic and non-chronic conditions (1,5,6). Medical expenditures also impose an economic burden at the individual and government-level, with an estimated cost of $245 billion in medical expenditures for those with diagnosed diabetes in 2012 (2). Among those with diabetes, type II diabetes represents a majority of total diabetes cases (95%) (1).

The burden of diabetes, including increased mortality rates, greater risk for complications, high medical expenditures, and low-quality care and poor management, is largely affected by social determinants on an individual and geographic level. Individual-level factors correlated with increased prevalence of diabetes, mortality, complications, and low quality and access to care, include having low-income and education (7), high BMI (4), no insurance coverage (8), being a female (5, 9, 10, 11), being non-Hispanic Black, Hispanic (12, 13) or South Asian (14), having one or more serious mental illnesses (15), and being an older adult (8). Additionally, living in rural areas of the U.S., Southern regions, and U.S. territories are place-based factors associated with increased complications and prevalence of diabetes (16, 17, 18), lower access in essential diabetes care (19, 20, 21), and increased mortality rate due to diabetes (22). Those in rural regions, specifically, face compounded multilevel barriers in the management of their diabetes, including engaging with preventative practices, such as seeing health professionals for their diabetes and self-management behaviors including lifestyle changes, self-monitoring of blood glucose levels, and performing self-checks for feet sores or irritations. Barriers range from environmental factors including poor access to clinics, hospitals and other health resources, down to individual-level ones such as lower levels of education and health literacy, cultural norms, and core beliefs (19). Thus, there is a basis for place-based disparities for those living with diabetes in rural regions in the U.S. However, the extent to which these individuals are engaging in preventative practices, compared to those living in more urban regions, has not been well characterized comprehensively in a nationally representative study since 2007, despite recent initiatives by Healthy People 2020 and ADA to improve the prevalence of engagement among those living with diabetes (23). Therefore, this study seeks to analyze urban-rural differences in preventative behaviors relating to engagement in health care and self-management nationally and by sociodemographic subgroups using the Behavioral Risk Factor Surveillance System (BRFSS) survey for 2017.

Rurality – Exposure

Evidence points to place of residence as an important factor in developing diabetes, diabetes-related complications, and poor health outcomes, including mortality (1,18, 24, 22). Previous studies identified rurality, or living in a rural region, as a determinant for poorer diabetes health outcomes and lower rates of access for important care practices and procedures (18, 19, 22, 25, 26). Moreover, differences in the prevalence of diabetes between urban and rural regions of the U.S. are estimated to be as high as 17% in rural compared to urban regions (22). Studies have attributed this to a low supply of health practitioners in rural regions, high poverty rates, unemployment rates, and difficulty in accessing affordable and quality care among those living in rural areas (27, 28). In fact, the Rural Healthy People 2020, a supplement to the Healthy People 2020 initiative, has indicated access to health care as their number one priority and diabetes as the third priority (24). Improvement in diabetes outcomes and health care access among rural regions has become a national goal. However, results are inconclusive, as some studies pointed to rurality as a determinant of better management of diabetes or to no difference between rural and urban regions in diabetes care practices at all (23,29).

Defining what constitutes “rural” and “urban” is often complex. The United States Department of Agriculture (USDA) defines rural as any region outside of an urban area, where urban areas include cities or towns with a population greater than 50,000, as well as any urbanized areas contiguous and adjacent to a city or town having a population of 50,000 or more (20). By this definition, approximately 46 million Americans, or 14% of the U.S. population, live in rural regions. However, this definition of rural combines regions with highly variable economic and sociodemographic characteristics. For example, while some rural regions have undergone high economic development with diverse industries, others are reliant on singular trades such as agriculture. Additionally, population characteristics in these regions may vary across race/ethnicity, income level, and so on (19,24).

In this study, the definition of rurality follows the USDA definition. This classification assigns each county in the U.S. into one of five categories: 1) in the city center of a metropolitan statistical area (MSA), 2) outside city center but inside county containing MSA, 3) in suburbs of an MSA, and 4) outside an MSA, where an MSA is an area with a population of 50,000 or more. Additionally, place of residence was also considered as binary, where the regions within an MSA are labeled as urban, and outside an MSA as rural. Although this classification does not directly take into account all of the complexity involved in characterizing rurality, it is widely used in health research (16,17,18,31,18) and has been adopted by the National Center for Health Statistics (32).

Engagement in health care

For those living with diabetes, quality and consistency of care is crucial in maintaining health and avoiding long-term complications. Diabetes care is multifaceted and involves more than glycemic control. This is due to the complex progression of diabetes to various systems of the body: it is the leading cause of blindness, kidney failure, lower-limb amputations, and depression (1). Thus, individuals living with diabetes require engagement with health professionals on a regular basis to maintain stable health (33). The Healthy People 2020 initiative has set goals for engaging with health professionals to manage the course of their diabetes. The initiative has set standards to increase the proportion of adults who have foot examinations, dental examinations, dilated eye examinations, and glycosylated hemoglobin measurements by a health professional (34).

Indicators for engagement in health care in this study will help provide useful information on the progress of urban and rural individuals living with diabetes in engaging with health professionals to manage their diabetes. Through this information, barriers and disparities in engagement can be identified and addressed through interventions and policy. Current research reports a lower proportion of adults in rural areas engaging with health professionals for their diabetes compared to those in urban areas. For example, a cross-sectional study in two clinics in Alabama (N=551) found that

83.5% of urban patients had an optimal number of A1c measurements, compared to 79.5% of rural patients. Additionally, 25.7% of urban patients had a regular foot exam, compared to 9.0% of rural patients (35). However, there are mixed findings regarding differences in urban-rural engagement with health professionals. A similar study conducted comparing BRFSS and the Medical Expenditures Panel Survey (MEPS) datasets examining engagement in care between urban and rural (BRFSS 2001-2002, N= 441,351 and MEPS 2001-2002, N=48,428) found that although rural individuals were significantly less likely to receive an annual feet check (BRFSS: aOR=0.85, MEPS: aOR=0.89), rural residents in both datasets were more likely to get an HbA1c test (BRFSS: aOR=1.02, MEPS: aOR=1.12) (26). Additionally, a study conducted using the BRFSS 2007 (N=52,817) found no statistically significant difference between urban and rural individuals in receiving HbA1c examinations as well as visiting a health professional for their diabetes (23). Therefore, the results remain inconclusive of how urban and rural individuals currently compare in engagement in health care practices.

Diabetes Self-management

Diabetes self-management covers many preventative behaviors that an individual can perform on him/herself. They include practices and lifestyle behaviors such as self-monitoring blood glucose, exercising, eating a diet low in saturated fats, taking courses on self-management, and so on (36). With the complexity of these practices, it is difficult to distinguish which are the most efficacious. Thus, ongoing research has presented various evidence-based guidelines for self-care in diabetes. For example, diabetes self-management education programs (DSME) have proven to be a critical tool for those who have diabetes or are at risk for diabetes (20,37,38). These programs provide a resource for those with diabetes on decision-making, problem-solving, and different ways for these individuals or their close family and friends to care for them (20). In this study, participants are evaluated on four indicators of effective self-management including taking a course on diabetes self-management, performing feet self-checks, self-monitoring blood glucose, and regularly exercising. Two of the four indicators were selected from the Healthy People 2020 initiative on improving health outcomes among those with diabetes. These call for an increase in the proportion of those diagnosed with diabetes who receive formal diabetes education and an increase in the proportion of those who perform daily self-monitoring of blood glucose (34).

Statistics from BRFSS 2008 indicate that overall, 56.8% of adults with diagnosed diabetes have received diabetes education and 64% self-monitored their blood glucose daily (20). Previous studies have also indicated urban-rural differences in the prevalence of these practices. One study conducted on 10,570 veterans with type 2 diabetes found rural veterans to have received significantly less diabetes education (p=0.002) compared to veterans from urban regions (39). Many similar studies found a significant association between living in an urban area and a higher likelihood of receiving diabetes education (25,26). However, the difference between urban and rural individuals on the practice of self-monitoring blood glucose remains unclear. A study conducted using the BRFSS 2017 found that rural individuals with diabetes were significantly more likely to self-perform glucose testing at least once daily (aOR=1.14) To these two indicators, we also added the practice of self-checking feet for sores or irritations and exercising regularly. Because diabetes can cause nerve damage, known as diabetic neuropathy, blisters and sores may go unnoticed and lead to infections which, without proper treatment or early detection, can lead to amputation (40). In fact, diabetes is one of the main causes of lower body amputations in the U.S. (1,41). Thus, self-care of feet is an essential practice for those with diabetes and a behavior to be examined in this study. In the literature, those residing in rural regions appear to have a higher proportion of those who self-check their feet as a self-management practice. A study conducted to analyze U.S. veterans with type 2 diabetes found that those residing in rural regions had higher proportions of those who performed daily feet checks (OR=1.36) (39). Another study conducted using BRFSS also found significantly higher odds of daily foot checks among rural populations compared to urban (OR=1.42) (23). In this study, we would like to see if this trend of higher prevalence of daily foot checks among rural individuals living with diabetes still pervades.

Additionally, lifestyle changes such as physical activity and nutrition are essential in glycemic control (42). However, since nutrition is more difficult to characterize, physical activity will be examined as an indicator of self-management. Literature has cited various barriers to exercise among those with diabetes, including latent factors such as psychological distress, social support, and self-efficacy (43). Additionally, a lack of knowledge and rationale for participating in these lifestyle changes and practices exist as barriers for those with diabetes to achieve glycemic control and avoid complications (28). However, there has not been literature citing the differences in physical activity between urban and rural individuals living with diabetes, despite its known long-term benefits in glycemic control and reducing the risk of complications. Therefore, the self-management factor in this study includes an indicator for physical activity as well as individual preventative behaviors in reducing the risk of complications due to diabetes.

Objectives

Our study seeks to describe and analyze place-based disparities for indicators in engagement in health care and self-management behaviors among adults diagnosed with diabetes. More specifically, we seek to estimate urban-rural differences across evidence-based preventative practices which reduce the risk of complications and mortality among those living with diabetes. The results of this study may be used to inform public policy and interventions through its description of current trends in these practices and help to target vulnerable populations within the urban-rural spectrum.

Previous research has reported on some of the indicators described above. However, there is need for a current and comprehensive measure of the frequencies and urban/rural differences in these practices among those with diabetes.

Chapter II. Manuscript

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Aims: There is evidence of disparities in diabetes-related health outcomes between those living in rural and urban counties of the U.S. This may in part be related to urban-rural disparities in the receipt of diabetes care practices. Our study examined differences in diabetes care practices across the urban-rural continuum in U.S. adults with diabetes for the year 2017.

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Results: Compared to those living inside the center city of a metropolitan area, rural respondents had lower proportions of engagement in diabetes education (52.0% vs 59.5%) and annual foot exams (76.8% vs 79.9%). Despite differences in prevalence, adjusted and unadjusted analyses indicated no significant associations between place of residence and likelihood of optimal diabetes practices, besides among Black rural individuals, who had a significantly lower likelihood of participating in all diabetes care practices (OR= 0.46, p=0.009) and all self-management practices (OR=0.46, p=0.004).

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Introduction

Diabetes is an immense public health issue in the United States. There are approximately 30.3 million individuals living with diabetes in the U.S. (9.4% of the total population), 23.8% of them undiagnosed (1). The overall prevalence of diabetes has been rising annually since 1994, with growing overweight and obesity rates in the U.S. (3,4). Because the course of diabetes affects numerous systems in the body, those with diabetes have an increased risk for mental health and disease complications. These include stroke, obstructive sleep apnea, depression, metabolic conditions, major cardiovascular diseases, kidney disease, and other chronic and non-chronic conditions (1,5,6). Medical expenditures also impose an economic burden at the individual and government-level, with an estimated cost of $245 billion in medical expenditures for those with diagnosed diabetes in 2012 (2). Among those with diabetes, type II diabetes represents a majority of total diabetes cases (95%) (1).

The burden of diabetes, including increased mortality rates, greater risk for complications, high medical expenditures, and low-quality care and poor management, is heavily affected by social determinants on an individual and community level. Individual-level factors correlated with increased prevalence of diabetes, mortality, complications, and quality and access to care, include having low-income and education (7), high BMI (4), no insurance coverage (8), being a female (5, 9, 10, 11), being non-Hispanic Black, Hispanic (12, 13) or South Asian (14), having one or more serious mental illnesses (15), and being an older adult (8). Additionally, community level factors such as area of residence also impact diabetes. Residing in rural areas of the U.S., Southern regions, and U.S. territories is associated with increased complications and prevalence of diabetes (16, 17, 18), lower access and usage overall in essential diabetes care (19, 20, 21), and increased mortality rate due to diabetes (22). Those in rural regions, specifically, face compounded multilevel barriers in the management of their diabetes, including engaging with preventative practices, such as seeing health professionals for their diabetes and self-management behaviors including lifestyle changes, self-monitoring of blood glucose levels, and performing self-checks for feet sores or irritations. Barriers range from health systems factors including poor access to clinics, hospitals and other health resources, down to individual-level ones such as lower levels of education and health literacy, cultural norms, and core beliefs (19). Thus, there is a basis for place-based disparities for those living with diabetes in rural regions in the U.S.

However, the extent to which these individuals are engaging in preventative practices, compared to those living in more urban regions, has not been well characterized comprehensively in a nationally representative study since 2007, despite recent initiatives by Healthy People 2020 and ADA to increase the proportion of engagement among those living with diabetes (23). Therefore, this study seeks to analyze urban-rural differences in preventative behaviors relating to engagement in health care and self-management nationally and by sociodemographic subgroups using the Behavioral Risk Factor Surveillance System (BRFSS) survey for 2017.

Methods

Data source

Conducted by the Centers of Disease Control (CDC), the Behavioral Risk Factor Surveillance System (BRFSS) is the largest telephone survey administered in the United States. It gathers self-reported data on health-related behaviors and chronic conditions across the 50 states, including the District of Columbia, Puerto Rico, Guam, and the U.S. Virgin Islands through state and local health departments on U.S. non-institutionalized persons. Surveys are administered annually and are cross-sectional and nationally representative. Previous studies have confirmed the validity of questions from the BRFSS on diabetes diagnosis and health care behaviors (44).

Sample selection

We sought to examine the care behaviors of American adults with diabetes in the most current data available. Respondents ages 18 years or older with prior diagnosed diabetes were eligible to be in this study. Specifically, if participants answered “Yes” to the question, “(Ever told) you have diabetes?”, they were included in the analytic sample.

Those who answered “No,” “Don’t know/Not sure,” were diagnosed with diabetes during pregnancy only, had a diagnosis of prediabetes but not overt diabetes, or refused to answer the question were excluded from the analytic sample. Of the 450,012 total respondents in the 2017 survey, 60,440 (13.4%) met the diagnosed diabetes criteria. We also excluded from analysis respondents who were missing information on residential location (n=28,182), diabetes related behaviors (n=17,803) and key demographic covariates (included in the number of missing observations for residence and diabetes care behaviors). For a more detailed description of sample selection, see Figure 6. The final analytic sample consisted of 14,455 participants with no missing data for any variables of interest. This sample consisted of largely older, married, white, female, and higher educated and higher income adults compared to the excluded sample (Table 2, Appendix). Description of study covariates and missingness across the full eligible sample is available in Table 2 of the Appendix.

Diabetes care outcomes

The outcomes of interest in this study included a total of seven indicators, three describing engagement in health care and four describing self-management of diabetes. Four of the seven indicators were selected based on Healthy People 2020 diabetes care objectives. These include biannual HbA1c examinations, annual foot exam, diabetes education, and conducting daily glucose self-monitoring. Other indicators were added based on recommendations from the American Diabetes Association (ADA) clinical practice guidelines and standards of care to supplement the research question and specifically evaluate place-based disparities in a greater number of essential diabetes care practices (33, 45). All indicators were dichotomized as being achieved/optimal or not being achieved/suboptimal. Answers such as “Don’t know/Not sure” or “Refused” were treated as missing, because they do not provide sufficient information to describe whether a care practice was adopted.

Under the engagement in health care category, Healthy People 2020 indicators used were biannual glycosylated hemoglobin examinations by a health professional and annual foot examinations by a health professional. The survey items for these indicators are "about how many times in the past 12 months has a health professional checked your feet for any sores or irritations" and "about how many times in the past 12 months has a doctor, nurse, or other health professional checked you for A-one-C", respectively. Healthy People 2020 objectives identify the optimal number of foot exams by a health professional to be at least once in the last 12 months. Thus, a new variable was coded 0 if the study participant answered "None," indicating they have not had their feet checked by a health professional in the last 12 months, 1 if a participant answered one or more feet checks by a health professional. Additionally, the standard practice for checking glycosylated hemoglobin by a health professional for individuals with diabetes is at least twice a year, according to Healthy People 2020. This variable was also dichotomized as 0, if participants answered one or less A1c tests and if they had "never heard of 'A one C' test," and 1 if participants reported two or more A1c tests by a health professional. An additional indicator was added under engagement in health care as a general insight into diabetes health visits in the sample and asks, "about how many times in the past 12 months have you seen a doctor, nurse, or other health professional for your diabetes?" According to the ADA Clinical Practice guidelines, the recommended number of times for those living with diabetes to visit a health professional is two to four times per year (33). Since it is a range, the decided cutoff was two times for this analysis. This variable was categorized as 0 for those who indicated less than two visits and 1 for those who indicated two or more visits.

For diabetes self-management, indicators were also dichotomized according to either Healthy People 2020 standards or care guidelines from the ADA. The Healthy People 2020 indicators include receipt of diabetes self-management of education and daily blood glucose monitoring. Indicators added based on ADA recommendations and guidelines were daily self-foot checks and monthly physical activity or exercise (41). For a more detailed explanation of outcome indicators chosen for analysis, see Table 1 in the Appendix.

Urban-rural residence

Urban-rural residence, measured as a 4-level continuum and as binary, was the primary exposure of interest for this analysis. BRFSS 2017 uses the respondent's landline telephone number to categorize urban-rural residence into four distinct groups according to its proximity to a metropolitan statistical area (MSA), specifically: 1) in the center city of an MSA, 2) outside center city of an MSA but inside county containing center city, 3) inside a suburban county of the MSA, 4) and not in an MSA. Additionally, urbanicity was also dichotomized to urban and rural to calculate measures of association, where rural is defined as those who do not live in an MSA and urban as all other participants who live in or near an MSA. In this case, urban was used as a reference to calculate measures of association.

Covariates

Through previous research findings, sex, marital status, education, income, age at time of survey, age at diabetes diagnosis, health insurance status, and race/ethnicity were included as covariates of interest in the initial full model. Race/ethnicity was categorized into three groups, Non-Hispanic Black, Other (including American Indian or Alaskan Native, Non-Hispanic Asian, Native Hawaiian or Pacific Islander, Hispanic, Non-Hispanic Multiracial, and Hispanic), and Non-Hispanic White (reference). Education was categorized into three groups: less than high school (reference), high school graduate, and some college or more. Additionally, income level was grouped into four categories: <25k (reference), 25k-35k, 35k-50k, and 50k+. Lastly, age was categorized into 18-44, 45-64, and 65+ years (reference).

Statistical Analyses

All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC, USA). This analysis utilized strata, cluster, and weight variables provided by the BRFSS to account for complex survey design. Descriptive analyses were conducted using SAS survey procedures, specifically "proc surveyfreq," which accounts for the sampling frame. Demographic characteristics including sex, marital status, education level, income level, age, health insurance status, and race/ethnicity are described in Table 1. Frequencies and distributions for these variables were evaluated in the final sample to determine ample sample size and normality. Proportions of those attaining standards in engagement in health care and self-management were calculated.

Additionally, multiple logistic regression using SAS software survey procedures were used to calculate adjusted and unadjusted bivariate comparisons of urban versus rural for each indicator outcome. Collinearity among the covariates was not detected, using a conditional indices value of 30 as a threshold, therefore all covariates were included in the adjusted models. Interaction assessment was also conducted to assess potential effect modification of the exposure of interest by other covariates. We conducted a type 3 test first to determine if significant interaction was present. The test indicated significant interaction (p=0.02), thus, a backward elimination was then used to elucidate significant interaction variables. Lastly, an analysis of potential confounders was performed. After the assessments, the final model included urban-rural status as the primary exposure, interaction terms for urbanicity with race/ethnicity variables, and covariates including sex, education, income level, and age. Dummy variables were created for all covariates in the final model, except for sex (dichotomous).

Results

Our study sample consisted of 14,455 non-institutionalized adults with diagnosed diabetes. Of these participants, 4,725 live in the center city of a metropolitan statistical area (MSA), or a region with over 50,000 residents. Additionally, 2,357 live outside the center city, but in a county containing an MSA, 2,891 live inside a suburban area of an MSA, and 4,482 live in a rural region, or outside of an MSA. Table 1 describes the demographic makeup of these respondents for the survey year 2017. Compared with those excluded in the analysis, respondents included in this study were mostly white, older (45+), married, female, had a college education, and had some health insurance coverage (Table 2, Appendix). There were notable differences in the demographic characteristics of the sample across the urban-rural spectrum (Table 1). Compared to urban regions, a larger proportion of those in rural regions had lower education levels. Approximately a fifth of those residing in rural regions reported their highest education level as high school or less, versus only 10.4% to 12.6% across the spectrum of urban regions. Rural participants were also more economically disadvantaged, with the highest proportion in the lowest income bracket (41.0%) compared to those in urban regions

(29.0%-34.0%). Additionally, rural regions were more racially homogeneous, with a white population of 80% compared to those in the center city of an MSA (a category of urban) with black and other adults making up approximately 40% of the population.

Proportions for reaching optimal standards in individual indicators for engagement in health care were fairly similar in magnitude across place of residence (Table 2a). For example, there appears to be minimal difference across the urban-rural spectrum for attending health professional visits twice a year and for biannual HbA1c examinations. However, rural residents had the lowest proportion of attending annual foot examinations at 76.8%. Similarly, there were few urban/rural differences for optimal engagement with self-management practices and across indicators. Across indicators, the proportion of those who have taken diabetes self-management education courses was lowest. Only about half of rural respondents (52.0%) reported they have taken a course on diabetes management, whereas for those inside the city center of an MSA, approximately 59.5% had diabetes education.

Similarly, indicators of disease management indicated areas of rural disadvantage and advantage. Engaging in monthly physical activity was also lowest among rural respondents. However, the proportion of rural respondents who engaged in daily self-monitoring of blood glucose was highest among rural residents at 62.9% compared to urban residents at an estimated 61.3% to 62.5.%. Additionally, rural respondents also had the highest proportion of daily self-foot-checks (64.2%) compared to that of urban (58.2% to 61.5%). Therefore, on average, there does not appear to be large differences between urban and rural respondents across these individual indicators.

Table 2b shows proportions of those engaging with health professionals and adopting self-management behaviors across places of residence. A notable trend is consistently lower proportions among rural respondents compared to that of most urban regions for all diabetes care practices and for the two specific care categories. Approximately 55.2% of rural respondents engaged optimally with all three engagement practices, compared to 59.2% at the upper range of urban regions. This trend is also present for optimal engagement with all diabetes care practices, where 11.2% of rural individuals indicated optimal engagement with all seven practices, compared to a higher proportion of urban respondents at 11.5 to 13.3%. However, rural residents surpassed those living inside a county of an MSA for complying with self-management standards. Across care engagement and self-management practices, proportions reaching optimal standards for self-management practices were much lower (15.7% to 17.8%) across all places of residence compared to that of engagement practices (55.2% to 59.2%).

Figure 1 depicts the percentage of the sample in reaching all engagement in care standards for this study across the urban-rural spectrum. Rural respondents fell behind their urban counterparts in engaging optimally in all engagement in health care practices by a close margin. In Figure 2, it appears rural respondents surpassed those who live inside a county containing a metropolitan region but fell behind those living in the center city and suburbs in achieving optimal self-management practices, also by a fairly narrow margin.

Table 3a displays adjusted stratified and non-stratified odds ratios (OR), comparing urban and rural regions for indicators of diabetes engagement and self-management practices. Urban was used as reference for comparison. After adjusting for sex, education, income, age, and race/ethnicity, the estimated odds of meeting standards for biannual health visits and HbA1c testing were, on average, higher for rural regions compared to urban among black (OR=1.51 and OR=1.25) and other (OR=1.62 and OR=1.83) but lower among white (OR=0.9 and OR=0.98). However, these associations were not statistically significant in both stratified and non-stratified ORs across all race/ethnicity groups. The pattern in OR point estimates, however, suggested that black and other adults living in rural regions had lower odds of receiving an annual foot exam compared to those in urban regions (OR=0.61, 95% CI: 0.27, 1.38 and 0.60, 95% CI: 0.24, 1.54). Point estimates for non-stratified ORs also depicted a lower odds of annual foot exam for rural adults compared to urban (OR=0.89, 95% CI: 0.72, 1.09). However, the odds of receiving an annual foot exam was higher for rural compared to urban among whites (OR=1.65, 95% CI: 0.65, 4.21). Overall, the associations between urban-rural status and engagement with health care indicators depict no difference between urban and rural populations because there is not significant evidence in these results. Among self-management practice indicators, rural respondents had lower odds of engaging with diabetes education and daily self-monitoring blood glucose in the total sample and among black and white adults compared to urban respondents, whereas rural respondents in the other race category were more likely to engage with these practices compared to urban. However, the only significant OR was attaining optimal daily self-monitoring blood glucose among others, where rural individuals had 2.61 times higher odds of participating. For performing daily foot checks and exercising monthly, those living in rural regions had higher odds of engagement compared to urban across whites and others, as well as in non-stratified measures for these indicators. In fact, this finding was significant for daily self-foot checks for the total sample and among whites. Among black adults, rural individuals had lower odds of engaging with both daily self-foot checks and monthly exercise practices. Statistically significant associations between practices and place of residence were only ones in which rural residents had higher odds of optimal engagement with a practice. There was evidence for significance at alpha=0.05 among the total population and white adults for daily self-foot checks (OR=1.25, 95% CI: 1.05, 1.49 and OR=1.24, 95% CI: 1.03, 1.48) and among other adults for daily self-monitoring of glucose (OR=2.61, 95% CI: 1.16, 5.90).

Figures 3, 4, and 5 display graphs of adjusted odds ratios of optimal participation with all engagement in health care practices, all self-management practices, and all practices combined comparing urban and rural respondents across race/ethnicity, using urban as reference. Among black adults, the odds of optimal participation with all care categories and all self-management practices tended to be significantly lower among rural respondents compared to urban. This relationship contrasts with others, who tended to have higher odds and less precise confidence around optimal engagement with all care categories among urban compared to rural. White participants tended to show little to no difference in engagement with all practices and in each care category.

Discussion

In 2017, individuals with diagnosed diabetes living in rural regions of the United States fell behind those living in urban regions in overall rates of participation in engagement in health care and all care practices, on average. Rural respondents also had lower proportions than those in urban in having optimal participation in annual foot exams, diabetes education, and monthly physical activity. However, they also surpassed urban respondents in daily self-monitoring of blood glucose and self-foot-checks.

Half of the current Healthy People 2020 (34) targets evaluated in this study were unsurpassed by both urban and rural respondents. The targets were to increase the proportion of the adult population diagnosed with diabetes to the following levels: annual foot exams to 74.8%, biannual HbA1c testing to 71.1%, diabetes education to 62.5%, and daily self-monitoring blood glucose to 70.4%. Goals for two of these targets were unmet, both under the self-management category. These include diabetes education and daily self-monitoring of blood glucose. Rural residents had the lowest proportions for receiving diabetes education (52.0%) and highest for daily glucose self-monitoring (78.4%). On the other hand, the goals of receiving annual foot exams and biannual HbA1c tests were largely surpassed by both urban and rural populations. Participation in annual foot exams across the urban-rural spectrum ranged from 76.8% to 80.7%, which surpassed the HP2020 goal of 74.8%, and participation in biannual HbA1c tests ranged from 76.0% to 79.6%, surpassing the target of 71.1%.

Previous literature has also reported a pronounced disparity in diabetes education between those living in centers of large cities and those living outside of these cities. Studies examining the prevalence of diabetes education in nationally representative datasets in 2001-2002 and 2007 comparing urban and rural individuals found a significantly lower likelihood of those living in rural regions to participate in diabetes education (23,25,26). Diabetes self-management education (DSME) is intended to encourage patient participation in preventative practices and behaviors, focusing on decision-making, problem-solving, and self-care, which has been shown to promote glycemic control and reduce the risk of complications in persons living with diabetes (46). Though there have been some efforts to promote DSME in rural regions during recent years, reports indicate that, still, 62% of nonmetropolitan counties did not have a single DSME program in 2016 (20). Lack of funding and resource limitations in rural regions in the staffing and infrastructure necessary to build and expand DSME programs are persistent barriers. There is also other evidence for persisting characteristics of those living in rural regions in this study, such as lower levels of education, attributing from the high proportion of those with a high school education or less, and a high proportion of those with low income, as perhaps the root of many diabetes care disparities. Evidence also suggests factors such as insurance status, employment rate, and the number of persons with diabetes diagnoses to be associated with lower engagement and development of DSME programs in rural regions (20). However, insurance status did not differ significantly between urban and rural residents in this study. In fact, the proportion of those with some insurance coverage in this sample was the highest among rural residents compared to urban regions, perhaps due to the selection of our sample. Therefore, there must be other factors that explain the effect of insurance status among rural residents in its association with lower levels of diabetes education.

Irrespective of statistical significance differences, there were some notable differences in diabetes care practices between rural and urban individuals living with diabetes. While proportions of rural respondents fell behind urban respondents in a few diabetes care practices such as receiving annual foot exams, diabetes education, and physical activity, they exceeded those in urban regions in other practices such as daily glucose self-monitoring and foot checks, which agrees with previous studies (23,26). Additionally, across all race/ethnicity groups, odds ratios comparing urban and rural respondents in their care practices vary between a higher likelihood of achieving diabetes care practices for urban and rural by each indicator. Across white persons in the sample, there were no significant differences besides daily foot checks, where rural residents were more likely to participate than urban ones. Among others, rural respondents had significantly higher odds of daily self-monitoring of blood glucose levels and monthly exercise.

Higher odds of participating in certain practices among rural populations may be due to the declining mortality rates due to diabetes and a greater effort in prevention. For example, the National Diabetes Prevention Program (NDPP) which began in 2010 has partnered with public and private organizations around the U.S. to develop and provide interventions to change the lifestyles and reduce medicine dependency of those with prediabetes (CDC). Results from an evaluation of this program from 2012-2016 showed that participants from this program were able to increase physical activity and experience weight loss, and thus reduce their diabetes risk (47). These intervention programs, aimed at prevention, coupled with improvements in access to health care with the passage of the Affordable Care Act, allowing for greater expansion of health services and affordability, may likely have played large roles in both decreasing the number of individuals living with diabetes and ensured equitable access to preventative services in rural regions of the U.S. (48). Therefore, though some studies indicate gaps in diabetes care among rural individuals, the landscape of prevention and care may have been somewhat efficacious in recent years in decreasing diabetes prevalence in rural regions and breaking down barriers to accessing necessary health resources for diabetes care among rural populations.

The data for this study has also indicated diabetes care to be lacking in a comprehensive manner among rural respondents in this sample. Only 11.2% of those living in rural regions were able to achieve all care practices analyzed in this study, compared to 11.5% to 13.3% in other regions. Rural regions also have the lowest proportion of participating in comprehensive engagement practices, even though they exceed those living in urban regions on some individual practices. Additionally, among black adults, the odds of participating in all diabetes care practices and all self-management practices was significantly lower among rural respondents. Perhaps there is a greater level of disparity between rural and urban individuals among black adults with diabetes in the United States compared to other races. Our findings suggest that it may be more difficult for rural individuals with diabetes to engage with a number of care practices altogether. Perhaps they are only able to participate and engage with practices they feel are most important or convenient for them. Current evidence suggests there are many individual and environmental barriers to an individual's ability to self-manage their diabetes. Individual barriers such as knowledge and health literacy and environmental barriers such as social support, socioeconomic factors, and distance to health site may all be viable hurdles to engaging and receiving comprehensive care. Thus, these barriers managing diabetes among rural populations must be further examined in order to evaluate effective interventions to improve diabetes care among rural populations.

Limitations

Several limitations must be taken into account in the interpretation of results from this study. Data from BRFSS are strictly self-reported, thus it is susceptible to biases such as misclassification and subjective recall. Additionally, objective measures of diabetes status and care practices were not used in this dataset. BRFSS also limits surveys to non-institutionalized populations, including the homeless or those in nursing homes. Thus, our results cannot be generalized to these populations. This dataset also does not distinguish the type of diabetes in its surveys, even though the pathology of type 1 and type 2 diabetes is dissimilar. Type 2 diabetes also accounts for 95% of U.S. populations with diabetes, while only 5% are type 1. In addition to inherent limitations from the dataset, a major limitation is the selectiveness of our final study sample, which consisted of only 24% of the original sample of those with diagnosed diabetes. The exclusion of those with any missing data may contribute to selection of participants with certain characteristics and reported health behaviors in this study. In fact, in our missingness analysis (Table 2, Appendix), we found our study sample to have, on average, a greater proportion of older, white, married females, who have higher levels of education, somewhat higher income, and greater insurance coverage, compared to the sample of those with missing data. For diabetes care outcomes, there was a greater proportion of those in the study sample who indicated optimal engagement in annual foot exams, biannual HbA1c exams, and diabetes education compared to the sample with missingness. Moreover, urban-rural characterizations were only assigned to those with landline telephones, which may explain this variable as having the highest level of missingness of all the variables of interest (Table 3, Appendix). This may also disproportionately favor older individuals who are more able to afford a landline. Therefore, especially if there were differential missingness by residence, our results may be biased.

Additionally, while this study reports on several important diabetes care practices, they are limited by the scope of the data used, which did not include other care practices, such as annual eye exams, or other clinically-based guideline diabetes care practices which may shed light on further disparities between urban and rural populations. Additionally, specific differences in urban/rural characterizations were not fully examined in our study. The characterization of urban as “within center city of an MSA” was weighed most heavily upon, but disparities within other characterizations of urban including “outside center city, but inside county containing MSA” and “inside suburban county of MSA" must be further examined. Lastly, the race/ethnicity variable used in this study grouped many race/ethnicities into the "other" variable, while research has indicated Hispanic populations in the U.S. to have greater vulnerability to disparities in diabetes care practices. Our results indicated the "other" group to have the highest level of disparity between urban and rural, with urban falling behind those living in rural regions in diabetes care practices. A more detailed examination into urban/rural differences across the different race/ethnicities represented in the "other" category will help to identify those disparities and lead to more specialized interventions and policies.

Conclusion

In conclusion, the differences between urban and rural regions in self-care and engagement with health professionals in this study are inconclusive. On one hand, there appears to be little difference between proportions and odds of urban and rural individuals in individual diabetes care practices. Lower engagement in the six diabetes self-care practices studied is evident among rural individuals in our study. However, data representative of the total rural and urban population, not just those with landlines, are needed to validly assess the extent of these disparities. Despite some inconsistencies, these results are able to provide insights to inform specific areas of future research and interventions. From the HP2020 standards and ADA recommendations examined, this study can provide benchmarks to achieving those standards. Specifically, ones for biannual HbA1c testing, annual foot exams, diabetes education, and daily self-monitoring of blood glucose levels, which have specific prevalence standards. Our results indicate that there may have been improvements in diabetes care among rural individuals in the U.S. over recent years in specific practices. Whether this can be attributed to certain policies, interventions, or lifestyle shifts needs to be further examined. Additionally, research into policies and interventions aimed at improving access and engagement among rural populations to more comprehensive diabetes care may be necessary to determine which if certain care indicators are more efficacious in improve diabetes outcomes or, if a range of different practices taken together is better.

References

1. Centers for Disease Control and Prevention. *National Diabetes Statistics Report: Estimates of Diabetes and Its Burden in the United States, 2017*; U.S. Department of Health and Human Services: Atlanta, GA, USA, 2017.
2. Economic Costs of Diabetes in the U.S. in 2012. *Diabetes Care*. 2013;36(4):1033–1046.
3. CDC's Division of Diabetes Translation. (2015). Maps of trends in diagnosed diabetes and obesity. Centers for Disease Control, National Surveillance System, https://www.cdc.gov/diabetes/statistics/slides/maps_diabetes_trends.pdf (PDF, 461 KB). Accessed March 22, 2019.
4. Leung MYM, Carlsson N, Colditz GA, et al. The Burden of Obesity on Diabetes in the United States: Medical Expenditure Panel Survey, 2008–2012. *Value Health*. 2017;20(1):77–84.
5. Chima CC, Salemi JL, Wang M, et al. Multimorbidity is associated with increased rates of depression in patients hospitalized with diabetes mellitus in the United States. *Journal of Diabetes and its Complications.* 2017;31(11):1571–1579.
6. Reutrakul S, Mokhlesi B. Obstructive Sleep Apnea and Diabetes. *Chest*. 2017;152(5):1070–1086.
7. Liese AD, Lamichhane AP, Garzia SCA, et al. Neighborhood characteristics, food deserts, rurality, and type 2 diabetes in youth: Findings from a case-control study. Health & Place. 2018;50:81–88.
8. Kim Y-M, Delen D. Critical assessment of health disparities across subpopulation groups through a social determinants of health perspective: The case of type 2 diabetes patients. Informatics for Health and Social Care. 2018;43(2):172–185.

9. Maffi P, Secchi A. The Burden of Diabetes: Emerging Data. Management of Diabetic Retinopathy. 2017;60:1–5.
10. Endocrinology TLD&. Sex disparities in diabetes: bridging the gap. The Lancet Diabetes & Endocrinology. 2017;5(11):839.
11. Al-Salameh A, Chanson P, Bucher S, et al. Cardiovascular Disease in Type 2 Diabetes: A Review of Sex-Related Differences in Predisposition and Prevention. Mayo Clin. Proc. 2019;94(2):287–308.
12. Saydah S, Imperatore G, Cheng Y, et al. Disparities in Diabetes Deaths Among Children and Adolescents - United States, 2000-2014. MMWR Morb. Mortal. Wkly. Rep. 2017;66(19):502–505.
13. Mayberry LS, Bergner EM, Chakkalakal RJ, et al. Self-Care Disparities Among Adults with Type 2 Diabetes in the USA. Curr. Diab. Rep. 2016;16(11):113.
14. Vijayakumar V, Mavathur R, Sharma MNK. Ethnic Disparity and Increased Prevalence of Type 2 Diabetes Among South Asians: Aetiology and Future Implications for Diabetes Prevention and Management. Curr Diabetes Rev. 2018;14(6):518–522.
15. Liu J, Brown J, Morton S, et al. Disparities in diabetes and hypertension care for individuals with serious mental illness. Am J Manag Care. 2017;23(5):304–308.
16. Hale NL, Bennett KJ, Probst JC. Diabetes Care and Outcomes: Disparities Across Rural America. J Community Health. 2010;35(4):365–374.
17. O'Connor A, Wellenius G. Rural–urban disparities in the prevalence of diabetes and coronary heart disease. Public Health. 2012;126(10):813–820.
18. Towne SD, Bolin J, Ferdinand A, et al. Assessing Diabetes and Factors Associated with Foregoing Medical Care among Persons with Diabetes:

Disparities Facing American Indian/Alaska Native, Black, Hispanic, Low Income, and Southern Adults in the U.S. (2011-2015). *Int J Environ Res Public Health.* 2017;14(5).

19. Grant JS, Steadman LA. Barriers to Diabetes Self-Management Among Rural Individuals in the Workplace. *Workplace Health Saf.* 2016;64(6):243–248.
20. Rutledge SA, Masalovich S, Blacher RJ, et al. Diabetes Self-Management Education Programs in Nonmetropolitan Counties — United States, 2016. MMWR Surveill Summ. 2017;66(10):1–6.
21. Ogilvie RP, Patel SA, Narayan KMV, et al. Are the U.S. territories lagging behind in diabetes care practices? *Primary Care Diabetes*. 2018;12(5):432–437.
22. Callaghan T, Ferdinand AO, Akinlotan MA, et al. The Changing Landscape of Diabetes Mortality in the United States Across Region and Rurality, 1999-2016. *The Journal of Rural Health* [electronic article]. 0(0). (http://onlinelibrary.wiley.com/doi/abs/10.1111/jrh.12354). (Accessed March 24, 2019)
23. Strom JL, Lynch CP, Egede LE. Rural/Urban Variations in Diabetes Self-Care and Quality of Care in a National Sample of US Adults With Diabetes. *Diabetes Educ.* 2011;37(2):254–262.
24. Bolin JN, Bellamy GR, Ferdinand AO, et al. Rural Healthy People 2020: New Decade, Same Challenges. *The Journal of Rural Health.* 2015;31(3):326–333.
25. Brown-Guion SY, Youngerman SM, Hernandez-Tejada MA, et al. Racial/Ethnic, Regional, and Rural/Urban Differences in Receipt of Diabetes Education. *Diabetes Educ.* 2013;39(3):327–334.

26. Krishna S, Gillespie KN, McBride TM. Diabetes burden and access to preventive care in the rural United States. *J Rural Health.* 2010;26(1):3–11.

27. Sina M, Graffy J, Simmons D. Associations between barriers to self-care and diabetes complications among patients with type 2 diabetes. *Diabetes Research and Clinical Practice*. 2018;141:126–131.

28. Ahola AJ, Groop P-H. Barriers to self-management of diabetes. *Diabetic Medicine.* 2013;30(4):413–420.

29. Weingarten JP, Brittman S, Hu W, et al. The state of diabetes care provided to Medicare beneficiaries living in rural America. *J Rural Health.* 2006;22(4):351–358.

30. Cromartie J. Rural America at a Glance. *United States Department of Agriculture* 2017 Edition. :6.

31. Lutfiyya MN, McCullough JE, Mitchell L, et al. Adequacy of diabetes care for older U.S. rural adults: a cross-sectional population based study using 2009 BRFSS data. *BMC Public Health*. 2011;11:940.

32. Data Access - Urban Rural Classification Scheme for Counties. 2019;(https://www.cdc.gov/nchs/data_access/urban_rural.htm). (Accessed April 15, 2019)

33. Association AD. Standards of Medical Care for Patients With Diabetes Mellitus. *Diabetes Care.* 2003;26(suppl 1):s33–s50.

34. Diabetes | Healthy People 2020. (https://www.healthypeople.gov/2020/topics-objectives/topic/diabetes/objectives). (Accessed March 24, 2019)

35. Andrus MR, Kelley KW, Murphey LM, et al. A Comparison of Diabetes Care in Rural and Urban Medical Clinics in Alabama. *Journal of Community Health*. 2004;29(1):29–44.

36. Toobert DJ, Hampson SE, Glasgow RE. The summary of diabetes self-care activities measure: results from 7 studies and a revised scale. *Diabetes Care.* 2000;23(7):943–950.

37. Haas L, Maryniuk M, Beck J, et al. National Standards for Diabetes Self-Management Education and Support. *Diabetes Care.* 2014;37(Supplement 1):S144–S153.

38. He X, Li J, Wang B, et al. Diabetes self-management education reduces risk of all-cause mortality in type 2 diabetes patients: a systematic review and meta-analysis. *Endocrine.* 2017;55(3):712–731.

39. Lynch CP, Strom JL, Egede LE. Disparities in diabetes self-management and quality of care in rural versus urban veterans. *Journal of Diabetes and its Complications*. 2011;25(6):387–392.

40. Diabetes and Foot Problems | NIDDK. National Institute of Diabetes and Digestive and Kidney Diseases. (https://www.niddk.nih.gov/health-information/diabetes/overview/preventing-problems/foot-problems). (Accessed March 25, 2019)

41. Bonner T, Foster M, Spears-Lanoix E. Type 2 diabetes–related foot care knowledge and foot self-care practice interventions in the United States: a systematic review of the literature. *Diabet Foot Ankle* [electronic article]. 2016;7.

42. Koenigsberg MR, Corliss J. Diabetes Self-Management: Facilitating Lifestyle Change. *Am Fam Physician*. 2017;96(6):362–370.

43. Walker RJ, Gebregziabher M, Martin-Harris B, et al. Understanding the influence of psychological and socioeconomic factors on diabetes self-care using structured equation modeling. *Patient Educ Couns*. 2015;98(1):34–40.

44. Li C, Balluz LS, Ford ES, et al. A comparison of prevalence estimates for selected health indicators and chronic diseases or conditions from the Behavioral Risk Factor Surveillance System, the National Health Interview Survey, and the National Health and Nutrition Examination Survey, 2007–2008. *Preventive Medicine.* 2012;54(6):381–387.

45. Association AD. Physical Activity/Exercise and Diabetes Mellitus. *Diabetes Care*. 2003;26(suppl 1):s73–s77.

46. Powers MA, Bardsley J, Cypress M, et al. Diabetes Self-management Education and Support in Type 2 Diabetes: A Joint Position Statement of the American Diabetes Association, the American Association of Diabetes Educators, and the Academy of Nutrition and Dietetics. *Clin Diabetes.* 2016;34(2):70–80.

47. Ely EK, Gruss SM, Luman ET, et al. A National Effort to Prevent Type 2 Diabetes: Participant-Level Evaluation of CDC's National Diabetes Prevention Program. *Diabetes Care.* 2017;40(10):1331–1341.

48. Nowinski Konchak J, Moran MR, O'Brien MJ, et al. The State of Diabetes Prevention Policy in the USA Following the Affordable Care Act. *Curr Diab Rep.* 2016;16(6):55.

49. (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4761684/). (Accessed March 21, 2019)

Tables

Table 1. Demographic Characteristics of U.S. Adults with Diagnosed Diabetes across the Urban-Rural Spectrum (in Percentages)

	Urban-rural spectrum (N=14,455)			
	In the center city of an MSA (n=4,725)	Outside center city, but inside county containing MSA (n=2,357)	Inside suburban county of MSA (n=2,891)	Not in MSA (rural, n=4,482)
Sex				
Female	53.4	53.4	53.1	53.5
Male	46.6	46.6	46.9	46.5
Marital status				
Not Married	47.6	37.4	39.6	40.5
Married	52.4	62.6	60.4	59.5
Education level				
< High school	12.6	11.2	10.4	20.8
High school graduate	30.2	30.2	35.1	36.9
Some college or more	57.2	58.6	54.5	42.3
Income level				
25k and under	34.0	30.4	29.0	41.0
25k – 35k	14.5	11.2	12.3	17.9
35k- 50k	15.6	15.2	14.8	15.4
50k+	35.9	43.2	43.8	25.7
Age				
18-44	6.8	3.6	7.7	4.2
45-64	35.8	38.4	43.9	42.3
65+	57.5	57.9	48.5	53.5
Health insurance status				
Some coverage	95.7	96.7	95.0	97.0
No coverage	4.3	3.3	5.0	3.0
Race				
Black	23.7	10.3	15.2	10.1
White	59.2	77.5	75.5	80.0
Other	17.1	12.3	9.3	9.9

Table 2a. Engagement in Health Care and Self-Management Behaviors Across Urban-Rural Continuum Among Adults with Diabetes (in Percentages with 95% Confidence Intervals)

	Engagement with healthcare			Self-management behaviors			
Region	Biannual Health professional visits	Biannual HbA1c testing	Annual foot exam	Diabetes education	Daily self-monitoring blood glucose	Daily self- foot checks	Monthly physical activity
Urban							
Inside city center of MSA (n=4725)	75.1 (72.8, 77.5)	76.0 (72.8, 79.1)	79.8 (77.7, 81.8)	59.5 (56.3, 62.7)	61.3 (57.5, 65.0)	58.8 (55.3, 62.3)	62.1 (59.2, 65.0)
Inside county of MSA (n=2357)	75.7 (72.9, 78.6)	79.6 (76.8, 82.4)	79.4 (76.8, 82.0)	55.4 (52.0, 58.8)	62.5 (59.4, 65.7)	58.2 (54.8, 61.6)	59.1 (55.6, 62.5)
Inside suburbs of MSA (n=2891)	74.8 (71.8, 77.8)	77.7 (74.7, 80.6)	80.7 (78.3, 83.2)	56.2 (53.0, 59.4)	62.1 (59.1, 65.1)	61.5 (58.4, 64.2)	58.5 (55.5, 61.6)
Rural							
Outside MSA (n=4482)	75.4 (71.7, 79.1)	78.4 (75.2, 81.7)	76.8 (73.6, 80.0)	52.0 (47.3, 56.7)	62.9 (58.7, 67.1)	64.2 (60.5, 67.9)	57.0 (52.6, 61.3)

Table 2b. All Practices Taken Together, Including All Engagement in Health Care and Self-Management Practices Across Urban-Rural Continuum Among Adults with Diabetes (in Percentages with 95% Confidence Intervals)

	All seven recommended diabetes care practices	All three engagement practices	All four self-management practices
Urban			
Inside city center of MSA (n=4,725)	13.3 (11.3, 15.3)	55.7 (52.7, 58.72)	17.8 (15.6, 19.9)
Inside county of MSA (n=2,357)	11.5 (9.5, 13.6)	57.3 (43.5, 52.2)	15.4 (13.1, 17.8)
Inside suburbs of MSA (n=2,891)	12.3 (10.6, 14.1)	59.2 (56.0, 62.5)	17.6 (15.2, 20.0)
Rural			
Outside MSA (n=4,482)	11.2 (9.4, 13.0)	55.2 (51.0, 59.4)	15.7 (13.6, 17.8)

Table 3a. Logistic Regression of Engagement in Health Care and Self-Management Indicators by Urban-Rural Status Among Adults with Diabetes, Stratified and Non-Stratified[a]

		Engagement practices			Self-management practices			
		Biannual Health professional visits	Biannual HbA1c testing	Annual foot exam	Diabetes education	Daily self-monitoring blood glucose	Daily self-foot checks	Monthly physical activity
All	Rural	1.00 (0.81, 1.23)	1.09 (0.87, 1.37)	0.89 (0.72, 1.09)	0.87 (0.72, 1.05)	0.99 (0.82, 1.20)	1.25* (1.05, 1.49)	1.01 (0.82, 1.24)
	Urban	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
White	Rural	0.90 (0.74, 1.10)	0.98 (0.78, 1.24)	1.65 (0.65, 4.21)	0.91 (0.76, 1.08)	0.92 (0.78, 1.09)	1.24* (1.03, 1.48)	1.01 (0.85, 1.20)
	Urban	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Black	Rural	1.51 (0.83, 2.74)	1.25 (0.73, 2.15)	0.61 (0.27, 1.38)	0.57 (0.32, 2.76)	0.71 (0.43, 1.15)	0.87 (0.50, 1.50)	0.86 (0.46, 1.62)
	Urban	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Other	Rural	1.62 (0.70, 3.75)	1.83 (0.62, 5.42)	0.60 (0.24, 1.54)	1.02 (0.37, 2.76)	2.61* (1.16, 5.90)	1.88 (0.67, 5.16)	1.24 (0.37, 4.10)
	Urban	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.

[a] Multiple logistic regression models adjusted for age, sex, race/ethnicity, education, and income. Odds ratios stratified by race/ethnicity (black, other, white). Reference is those living in urban regions

*Statistically significant at $p<0.05$

Table 3b. Logistic Regression of All Diabetes Care, Engagement in Health Care, and Self-Management Indicators Among Adults with Diabetes, Unstratified Odds Ratios[a]

		All Diabetes Care Practices, Odds Ratio (95% CI)	All Engagement in Health Care Practices, Odds Ratio (95% CI)	All Self-Management Practices, Odds Ratio (95% CI)
Unadjusted	Rural	0.877 (0.71, 1.09)	0.93 (0.77, 1.12)	0.90 (0.74, 1.10)
	Urban	Ref.	Ref.	Ref.
Adjusted	Rural	0.98 (0.79, 1.20)	0.94 (0.78, 1.14)	1.00 (0.83, 1.20)
	Urban	Ref.	Ref.	Ref.

[a] Multiple logistic regression models adjusted for age, sex, race/ethnicity, education, and income.

*Statistically significant at $p<0.05$

Figures

Figure 1. Proportion of Adults with Diabetes Participating at Optimal Standards for All Engagement in Health Care Indicators Across Urban-Rural Spectrum

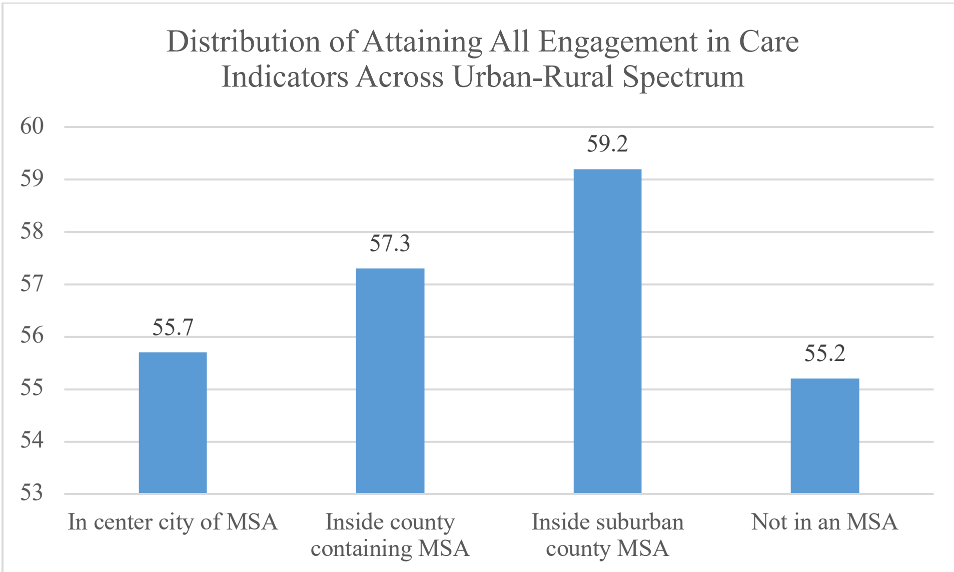


Figure 2. Proportion of Adults with Diabetes Participating at Optimal Standards for All Self-Management Indicators Across Urban-Rural Spectrum

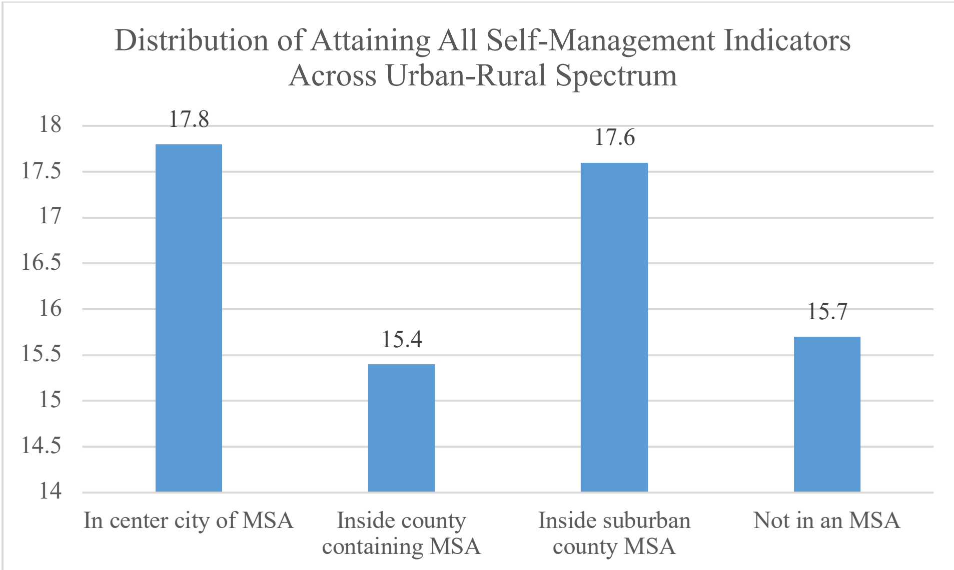
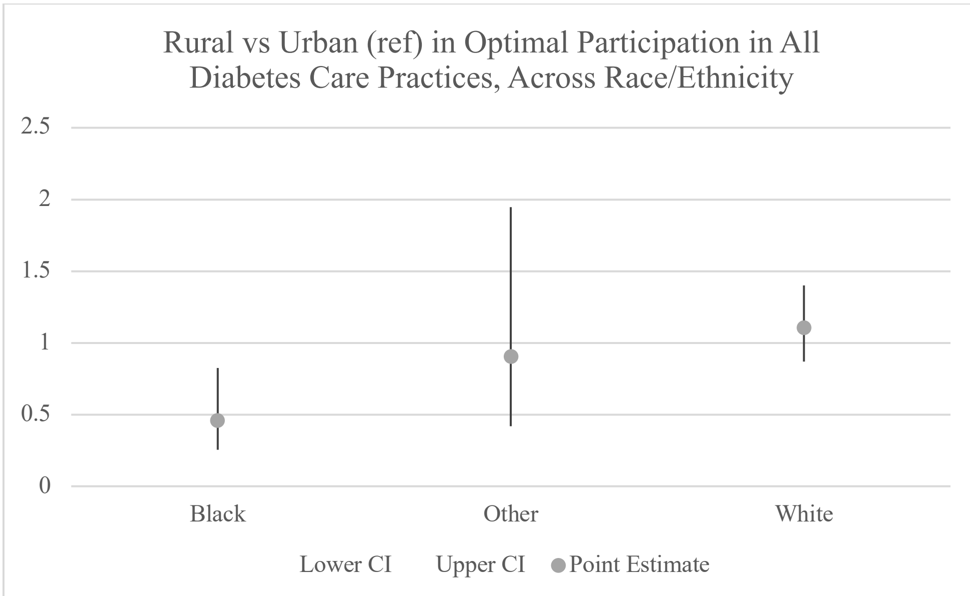
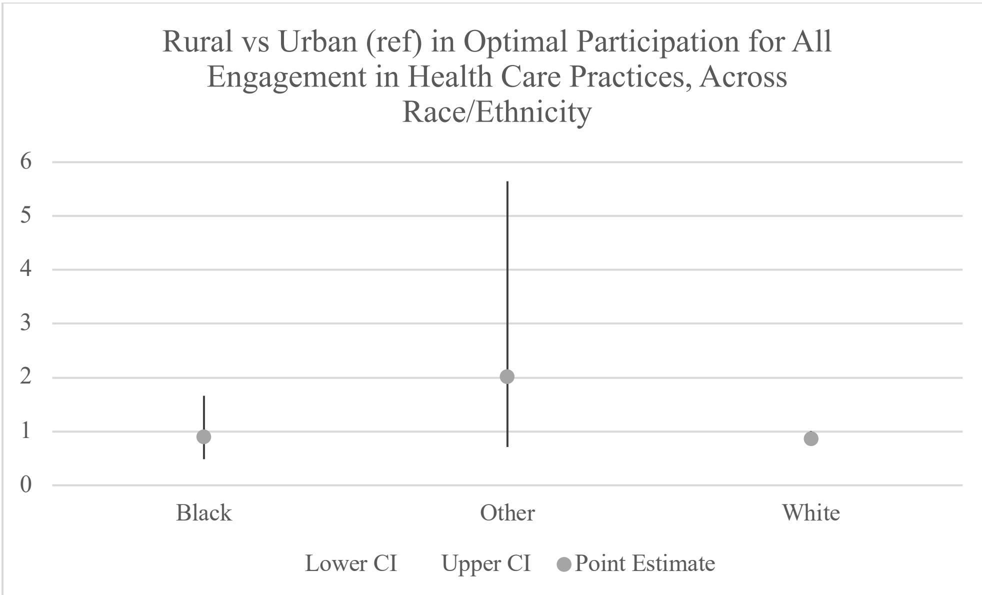


Figure 3. Adjusted Odds Ratios and 95% Confidence Intervals Stratified by Race/Ethnicity Comparing Urban and Rural in Attaining Optimal Standards in All Diabetes Care Indicators[a]



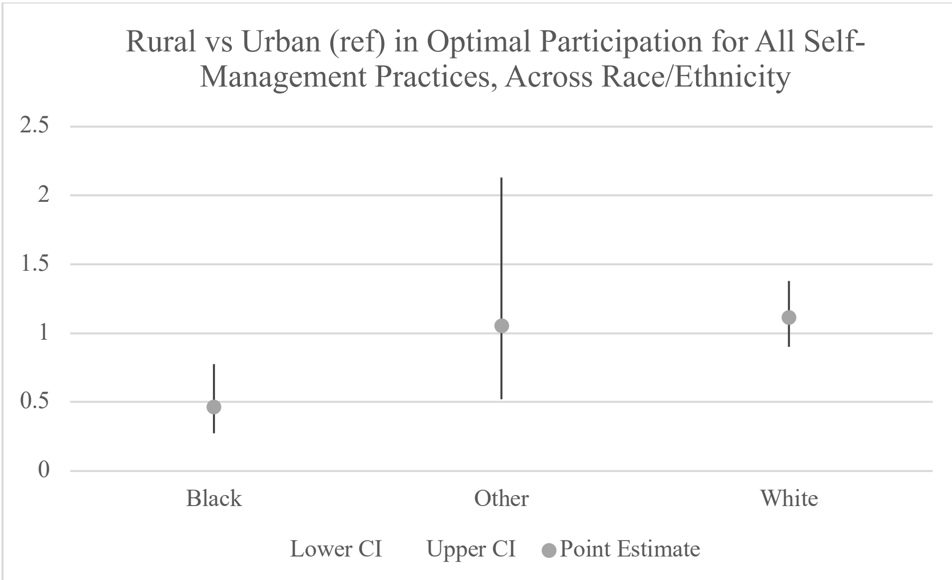
[a] Multiple logistic regression models adjusted for age, sex, race/ethnicity, education, and income. Odds ratios stratified by race/ethnicity (black, other, white). Reference is those living in urban regions

Figure 4. Adjusted Odds Ratios and 95% Confidence Intervals Stratified by Race/Ethnicity Comparing Urban and Rural in Attaining Optimal Standards in All Engagement in Health Care Indicators[a]



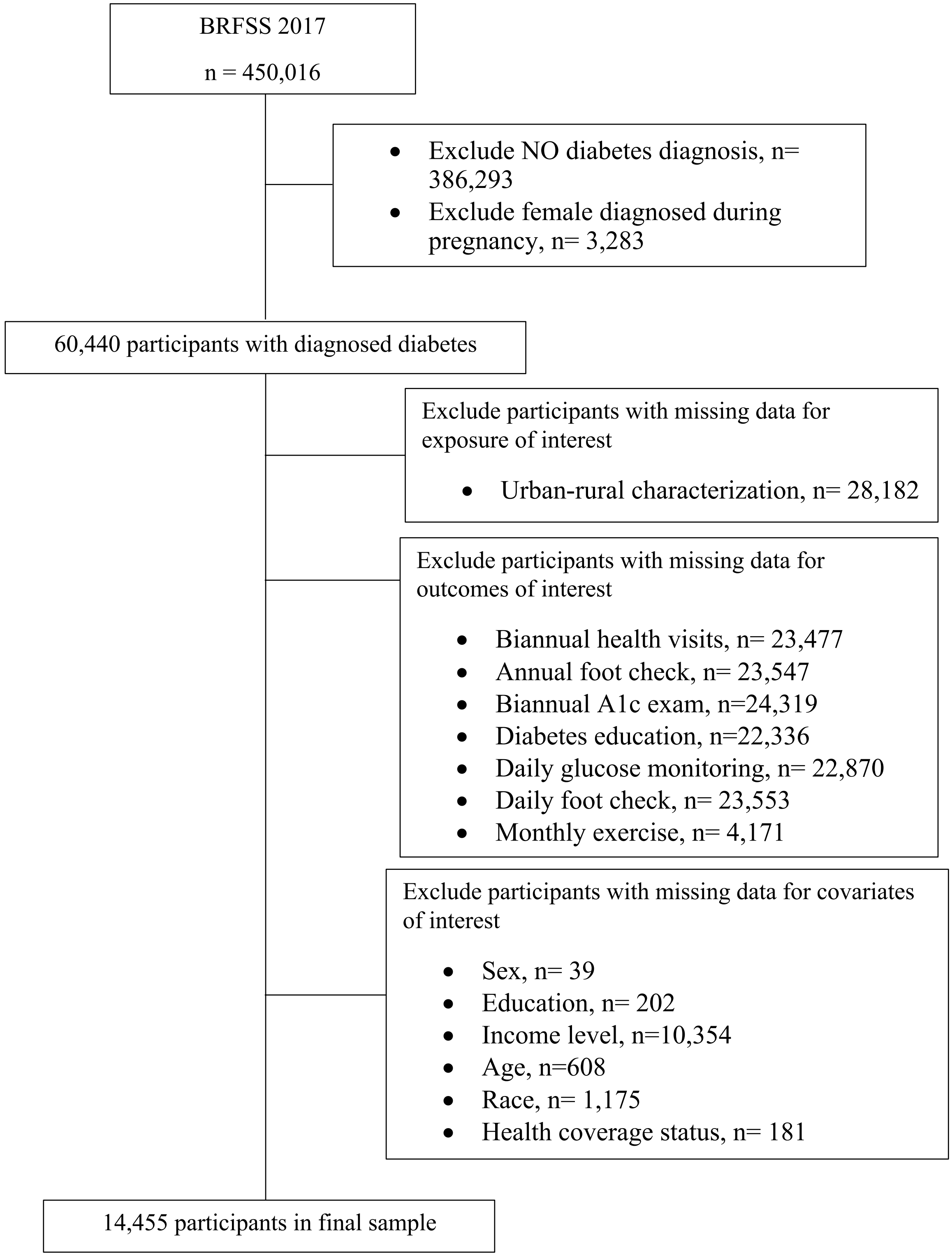
[a] Multiple logistic regression models adjusted for age, sex, race/ethnicity, education, and income. Odds ratios stratified by race/ethnicity (black, other, white). Reference is those living in urban regions

Figure 5. Adjusted Odds Ratios and 95% Confidence Intervals Stratified by Race/Ethnicity Comparing Urban and Rural in Attaining Optimal Standards in All Self-Management Indicators[a]



[a] Multiple logistic regression models adjusted for age, sex, race/ethnicity, education, and income. Odds ratios stratified by race/ethnicity (black, other, white). Reference is those living in urban regions

Figure 6. Flow Chart for Exclusion Criteria from BRFSS 2017



Chapter III: Summary, Public Health Implications, and Future Directions

Summary: Despite past evidence of urban-rural disparities in diabetes care practices, our study found no statistically significant differences between urban and rural respondents living with diabetes in indicators of how they engaged with care and were able to self-manage to prevent complications. This may be due to the efficacy of recent policies and interventions aimed at improving access to care and diabetes prevention. The finding may also be an artifact of the sampling methodology, which only included adults with landlines who are, on average, more advantaged. However, diabetes education and annual foot exams were exceptions, with rural regions falling behind the standard set by Healthy People 2020. We also found the overall prevalence of self-management indicators and all care indicators taken together to be consistently lower among rural compared to that of urban regions.

Public Health Implications: Our study concludes that disparities in diabetes care practices between urban and rural populations living with diabetes have minimized, or, are not as bleak as previously believed. The results also provide a benchmark for goals set by Healthy People 2020 and the American Diabetes Association on the progress of certain care practices among rural populations.

Possible Future Directions: Our results also indicate a need for further interventions and policies aimed at improving access and engagement in diabetes education across rural populations with diabetes. Furthermore, an examination into barriers preventing rural populations with diabetes to accept or access diabetes care practices comprehensively is necessary for rural populations to adopt a greater range of personal practices to reduce their risk of complications.

Appendix

Table 1. Summary Table of Diabetes Care Indicators

Indicator	**Survey item**	**Coding**	**Justification**
Engagement			
Biannual health visit	"About how many times in the past 12 months have you see a doctor, nurse, or other health professional for your diabetes?"	Dichotomous (0/1): "None" or <2 coded as 0 (standard not met), ≥2 coded as 1 (standard met)	American Diabetes Association Clinical Practice recommendation: those with diabetes should see their doctor ≥2/year
Biannual HbA1c exam	"About how many times in the past 12 months has a doctor, nurse, or health practitioner checked you for A1c?"	Dichotomous (0/1): "None", <2, or "Never heard of 'A one C' test" coded as 0, ≥2 coded as 1	Healthy People 2020 (HP2020) objective D11: increase proportion of adults with diabetes who have an HbA1c measurement ≥2/year
Annual foot exam	"How many times in past 12 months has health professional checked your feet for any sores or irritations"	Dichotomous (0/1): "None" or <1 coded as 0, ≥1 coded as 1	HP2020 objective D9: increase proportion of adults with diabetes who have a foot exam ≥ 1/year
Self-management			
Diabetes education	"Have you ever taken a course or class in how to manage your diabetes yourself?"	Dichotomous (0/1): if "No" then coded as 0, if "Yes" then coded as 1	HP2020 objective D14: increase proportion of persons with diabetes who receive formal diabetes education
Daily glucose self-monitoring	"How often do you check blood for glucose or sugar?"	Dichotomous (0/1): "None" or <7 times/week, <30 times/month, <99 times/year coded as 0, ≥1/day, ≥ 7/week, ≥30/month coded as 1	HP2020 objective D13: increase proportion of persons with diabetes who perform self-blood glucose monitoring ≥ 1/day
Daily foot checks	"About how often do you check feet for sores or irritations?"	Dichotomous (0/1): "None" or <7 times/week, <30 times/month, <99 times/year coded as 0, ≥1/day, ≥ 7/week, ≥30/month coded as 1	ADA foot care recommendation: check feet every day for red spots, swelling, and blisters
Monthly physical activity	"During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?"	Dichotomous (0/1): if "No" then coded as 0, if "Yes" then coded as 1	ADA Standards of care for patients with diabetes: Regular exercise, adapted to the presence of complications for all patients with diabetes

Table 2. Demographic Characteristics and Outcome Proportions of Sample with Missing Data (n=45,958) Compared to Study Sample (n=14,455) among respondents with diagnosed diabetes

	n (weighted %) missing data[a] (N=60,440)	Sample excluded from analysis due to missing[a] data (n=45,985)	Analyzed sample (n=14,455)
Urban-rural characterization	28,182 (74.8)		
In center city of MSA		37.2	35.7
In county containing MSA		24.2	21.7
In suburb of MSA		18.0	21.9
Not in MSA		20.6	20.7
Dichotomous urban-rural	28,182 (74.8)	79.4	79.3
Number of health visits	23,477 (50.1)	74.4	75.2
Number of foot checks	23,547 (50.4)	74.0	79.3
Number of HbA1c exams	24,319 (52.2)	73.3	77.6
Ever taken diabetes education	22,336 (47.9)	51.5	56.3
Times self-check glucose	22,870 (49.1)	61.2	62.1
Times self-check feet	23,553 (50.5)	59.7	60.4
Exercise monthly	4,171 (10.2)	60.3	59.6
Sex	39 (0.1)		
Female		49.2	53.4
Male		50.8	46.6
Marital status	281 (0.6)		
Not Married		48.1	42.2
Married		51.9	57.8
Education level	202 (0.4)		
< High school		23.3	13.5
High school graduate		30.4	32.7
Some college or more		46.3	53.8
Income level, $	10,354 (20.3)		
25k and under		42.8	33.6
25k – 35k		11.9	14.0
35k- 50k		13.2	15.2
50k+		32.1	37.1
Age, years	608 (1.3)		
18-44		13.5	5.8
45-64		45.5	39.5
65+		41.0	54.8
Health insurance status	181 (0.4)		
Some coverage		91.7	96.1
No coverage		8.3	3.9
Race	1,175 (2.4)		
Black		15.4	16.1
White		55.8	71.0
Other		28.8	12.9

[a]Missing data includes “missing,” “don’t know/not sure,” and “refused to answer” responses. For the FEETCHK2 variable, those who responded “no feet” were also characterized as missing.