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Burden and Management of Type 2 Diabetes Mellitus in Rural United States

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Abstract

In the United States (US), rural areas have a higher burden of type 2 diabetes mellitus (T2DM) compared to urban areas. However, there is limited information on risk factors and interventions that improve the primary prevention and management of T2DM in rural areas. To synthesize current knowledge on T2DM in rural areas and to guide healthcare providers and policy makers, we reviewed five scientific databases and the gray literature over the last decade (2010 to 2020). We described classification systems for rurality and the T2DM burden based on rurality and region (West, South, Midwest, and Northeast). We highlighted risk factors for T2DM in rural compared to urban areas, and summarized interventions to screen and manage T2DM based on opportunistic screening, T2DM self-management, community-based initiatives, as well as interventions targeting comorbidities and T2DM. Several studies identified the co-existence of T2DM and depression/psychological symptoms, which could reduce adherence to non-pharmacologic and pharmacologic management of T2DM. We highlighted the role of technology in education and counseling of patients with geographic and financial barriers to accessing care, which is exacerbated by the SARS-CoV-2 coronavirus disease-19 (COVID-19) pandemic. We identified knowledge gaps and next steps in improving T2DM care in rural areas. There is an urgent need for interventions tailored to rural areas given that rural Americans currently experience a disproportionate burden of T2DM and are encumbered by its associated morbidity, mortality, and loss in economic productivity.

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AUTHOR CONTRIBUTIONS

All authors contributed to the conception, design, and development of the manuscript. The initial draft was written by SBD, and was critically revised by MMM and AV. All authors reviewed and approved the submitted draft.

CONFLICT of INTEREST DISCLOSURE

None of the authors reports any conflict of interest.

DATA AVAILABILITY

There were no original data or datasets used in this manuscript. All cited literature is publicly available.

Keywords

type 2 diabetes mellitus; rural health; urban-rural disparities; primary prevention

INTRODUCTION

In the United States (US), approximately 34 million people have diabetes mellitus, with striking health disparities in rural, compared to urban, areas.¹ Of these 34 million people, approximately 32 million have type 2 diabetes mellitus (T2DM). Compared to urban populations, rural populations have a 16% higher prevalence of T2DM, a 20% higher T2DM-related hospital mortality, and a smaller improvement in overall T2DM-related mortality rates from 1999 to 2016.¹⁻⁵ Despite the many studies on T2DM, none of the published reports compared T2DM incidence in urban and rural areas. In 2017, the cost of managing diabetes mellitus (type 1 and type 2 diabetes, combined) was \$327 billion, which was 26% higher than costs five years prior, and largely resulted from medical expenses and reduced productivity.⁶ Most of these costs was attributed to T2DM. The reasons for rural-urban inequalities for T2DM are largely unknown but represent a major public health problem for the 60 million Americans living in rural areas.

Over the last four decades, the US burden of diabetes mellitus has changed. Based on self-reported diabetes mellitus status (type 1 and type 2, combined) from the US National Health Interview Survey, the incidence of age-adjusted diagnosed diabetes mellitus plateaued from 1980 to 1990, increased from 1990 to 2007, and decreased annually by 3.1% to reach an annual incidence rate of 6.0% in 2017. This decrease was driven by non-Hispanic whites.⁷ The national prevalence of diabetes mellitus (type 1 and type 2, combined) mirrored national trends in incident diabetes mellitus, except for the period from 2009 to 2017, during which, the prevalence plateaued rather than declined.⁷ Despite the somewhat reassuring plateau in temporal trends of the national prevalence and incidence of diabetes mellitus, there are notable temporal disparities when analyzed by subgroup (gender, race/ethnicity, and region).^{8,9} For example, men had a higher age-adjusted prevalence of diabetes mellitus compared to women, although the incidence rates were comparable. From 2007 to 2018, the age-adjusted prevalence of diabetes mellitus based on race/ethnicity ranged from 7.5% (non-Hispanic whites) to 14.7% (American Indians/Alaska Natives), whereas age-adjusted incidence ranged from 5.0% (non-Hispanic whites) to 9.7% (Hispanics).⁹ In the US, Hispanic populations face a disproportionate burden of T2DM attributed to genetic factors (e.g., higher susceptibility to obesity and insulin resistance), sociocultural factors (e.g., lower income) reduced access to healthcare, among other factors.¹⁰

In comparison to information on the national prevalence and incidence of diabetes mellitus (type 1 and type 2, combined) by gender and race/ethnicity, less information is available for the epidemiology of diabetes mellitus by region and rurality. In 2016, among adults 20 years or older, the prevalence of age-adjusted diabetes mellitus across US counties ranged from 1.5% to 33%, and annual age-adjusted incidence ranged from 1.2 to 46.2 per 1000 persons.⁹ Despite these data, to our knowledge, no studies have synthesized the multi-dimensional perspectives of rurality and T2DM. To address this knowledge gap, we conducted a

literature review study¹¹ to obtain a multi-dimensional perspective on rurality and T2DM including rural-urban classification systems, risk factors for T2DM, comorbidities associated with T2DM, interventions to reduce the rural burden of T2DM, and knowledge gaps to guide future research. This study highlights the effort required to fulfill the Health People 2020 goal of improving the “quality of life for all persons who have, or are at risk for” T2DM diabetes.¹² We did not focus on type 1 diabetes mellitus because its epidemiology, genetics, and pathophysiology differ from T2DM and may be less amenable to primary prevention interventions compared to T2DM. However, the human and healthcare burden of type 1 diabetes mellitus is important and should be reviewed in a separate study.

MATERIALS and METHODS

This study was classified as a literature review, based on the proposed analytic framework.¹¹ The search strategy was designed by the study investigators in consultation with an academic librarian at Mayo Clinic, Rochester, MN. We searched CINAHL, Embase, MEDLINE, Scopus, and Web of Science databases and the gray literature using a combination of database index terms and key words ‘diabetes mellitus’, ‘rural’, ‘nonmetropolitan’, ‘United States’, and their variants. We focused on articles from the last decade to emphasize the contemporary burden of risk factors for T2DM as well as interventions/strategies and, thereby, maximize relevance to healthcare providers. Thus, we limited our search to English language articles published from 2010 to June 5, 2020 (date of literature search). We included full-length original and review articles, and excluded other article types (conference abstracts, editorials, brief reports, letters to the editor, and theses). Our search generated 1016 articles; duplicate articles were excluded and 431 unique articles were exported to EndNote®, a reference management software package.¹³ To identify articles in the gray literature, we used Google® to search government resources (site: .gov) as well as broader organizational and educational websites for T2DM in rural populations. The search string ‘rural AND type 2 diabetes’ was used and weblinks on the first five pages of results were reviewed.

One investigator (SBD) screened the titles and/or abstracts of the unique articles (n=431) and identified 122 articles for full-text review. We included articles on the primary prevention and management of T2DM in US rural populations. From these articles, we summarized definitions of rurality, described the burden of T2DM in rural areas, compared risk factors for T2DM in rural and urban areas, and discussed interventions to reduce the burden of T2DM in rural areas. We also identified knowledge gaps to reduce urban-rural disparities for the primary prevention of T2DM. This work is relevant to healthcare providers and policy makers who deliver or design care for rural populations.

This article summarizes published studies and did not require Institution Ethics approval.

RESULTS

Major Classification Systems for Rurality

Defining rurality is nuanced, and depends on the context, as briefly summarized below and in Table 1.

The *2010 US Census Bureau* system classifies geographic areas into urban and rural based on population density.¹⁴ Census tracts and/or census blocks are classified as urbanized areas, urban clusters, and rural areas, the latter encompassing non-urban areas. *Frontier and Remote Area (FAR) codes* identify remote and sparsely populated areas that are predominant in the Great Plains and Intermountain West.¹⁵ FAR codes are characterized by population size and geographic remoteness, and are particularly relevant when describing the availability of health services, food, and publicly available social services.

The *2013 Office of Management and Budget* system classifies counties as metropolitan statistical areas or nonmetropolitan statistical areas based on population density and commuting.¹⁶ Nonmetropolitan areas are outside of metropolitan area boundaries and are subdivided into micropolitan and noncore areas. Metropolitan areas are generally considered urban, and nonmetropolitan areas are generally considered rural. To increase granularity of the 2013 Office of Management and Budget classification system and to study health differences across the urban-rural continuum, the *National Center for Health Statistics (NCHS)* developed a six-level system to classify rurality at the county level.¹⁷ The NCHS system has four levels of metropolitan counties (large central metropolitan, large fringe metropolitan, medium metropolitan and small metropolitan) and two levels of nonmetropolitan counties (micropolitan and noncore) (Figure 1).

The *Rural-urban continuum code (RUCC)* provides granularity beyond the NCHS system by distinguishing metropolitan counties by the metropolitan area population (three levels) and nonmetropolitan counties by the degree of urbanization and adjacency to a metropolitan area (six levels).¹⁸ In this classification system, each county is assigned one of nine codes. The advantage of the RUCC over the NCHS is that counties can be divided into finer residential groups to study the influence of population density and metropolitan influence on health outcomes.¹⁸ The RUCC will be updated in mid-2023.¹⁸ *Rural-Urban Commuting Area (RUCA) codes* characterize census tracts based on US Census Bureau definitions (for urbanized areas and urbanized clusters)¹⁴ in combination with work commuting information.¹⁹ In addition to RUCA codes, a ZIP code based RUCA approximation was also developed and is publicly available.¹⁹ *Urban Influence Codes* divide counties and county equivalents into 12 groups (Table 1).²⁰ Similar to most classification systems, this allows for granular gradation of the rural-urban continuum to study the design and delivery of health services.

Of these seven rural classification systems, the system used depends on the economic, health, or policy issue under consideration. Although an increased rural-urban granularity may reveal health disparities, it is challenging to obtain and use such granular information. With individual rural-urban mobility, possibly living and working in areas of different rurality, it is difficult to attribute area-level characteristics to individual health outcomes. Finally, health policy decisions may not be made at the level where health disparities are identified, making it challenging to increase health resources or implement change if the proposed changes align differently from political priorities.

Urban-Rural Disparities in Diabetes-related Mortality

The US Census Bureau delineates the US into four census regions: Northeast (9 states), Midwest (12 states), South (16 states and District of Columbia) and the West (13 states).^{14,21} From 1999 to 2016, the crude diabetes (type 1 and type 2, combined)-related mortality rate across US regions differed by rurality.^{5,14} Using the NCHS system for county-level rurality, in 1999, the Midwest showed lower diabetes-related mortality in noncore counties (i.e., most rural; 24.6 deaths per 100,000) compared to central metropolitan counties (i.e., most urban; 28.1 deaths per 100,000). However, by 2016, urban counties showed marked improvement in diabetes-related mortality rates (21.8 deaths per 100,000) whereas there was little reduction in rural counties (23.9 deaths per 100,000). This resulted in a higher mortality burden in rural counties.⁵ The South showed a similar trend: from 1999 to 2016, mortality in central metropolitan counties reduced from 29 deaths per 100,000 to 21 deaths per 100,000. However, over the same time period, mortality in noncore (rural) regions was unchanged from 29.3 deaths per 100,000 to 28.6 deaths per 100,000.⁵ The differences were less pronounced in the Northeast and West.

Across US regions, there are urban-rural disparities in diabetes-related hospital mortality. Analysis from the Nationwide Inpatient Sample, from 2009 to 2015, showed 29% higher odds of mortality in noncore vs. large central metropolitan counties in the South (odds ratio, 95% confidence interval 1.29 [1.25–1.33]), Midwest (1.23 [1.18–1.28]) and West (1.10 [1.02–1.17]), but not Northeast.⁴ The reasons for the urban-rural disparities are incompletely understood.

Risk Factors for T2DM in Rural Areas

The higher overall mortality in rural versus urban areas may be a reflection of the higher incidence in rural versus urban areas. However, there are no published reports comparing the incidence rates of T2DM in rural and urban areas, due to paucity in data. Most data are self-reported and/or do not distinguish type 1 from type 2 diabetes mellitus, precluding an analysis of the incidence of T2DM in rural and urban areas. Importantly, as lifestyle changes can avert or delay T2DM,²² T2DM prevention strategies optimized for rural populations could reduce the T2DM burden and, thereby, urban-rural health disparities. Several studies have focused on comparing risk factors in rural and urban areas.

Traditional metabolic risk factors—Risk factors for T2DM across the general population include age ≥ 45 years, family history of diabetes, overweight or obesity, inadequate physical activity, hypertension, and dyslipidemia.^{22,23} The Centers for Disease Control and Prevention (CDC) has comprehensive data on risk factors for T2DM in rural populations. In 2013, CDC data showed that the prevalence of five optimal lifestyle factors (sufficient sleep, nonsmoking, normal body weight, nondrinking/moderate alcohol, and physical activity), most of which are linked to a higher risk of T2DM, was lower in rural than urban populations (27% vs. 32%).²⁴ The analysis of National Health Interview Survey data from 2008 to 2017 also showed that the age-standardized prevalence of meeting physical activity guidelines (150 minutes per week of vigorous- and light or moderate intensity leisure-time physical activity) differed among adults in urban and rural areas.²⁵

Similar to physical activity, there were urban-rural differences in the prevalence of obesity.²⁶ Using 2016 Behavioral Risk Factor Surveillance System (BRFSS) data, there was a higher unadjusted obesity prevalence in nonmetropolitan areas (34.2%) than metropolitan areas (28.7%).²⁶ The nonmetropolitan-metropolitan difference was 5.6% (South; 36.6% vs. 31.0%), 5.4% (Northeast; 31.8% vs. 26.4%), 3.7% (Midwest; 34.2% vs. 30.5%), and 2.9% (West; 28.6% vs. 25.7%). The higher frequency of inadequate physical activity and obesity in rural compared to urban areas is concerning given their association with higher risk of T2DM.

Other studies have examined the association of diet and risk of T2DM. The analysis of 2009 BRFSS data showed that rural compared to non-rural adults were less likely to consume at least five daily servings of fruits and vegetables.²⁷ Using 2012 BRFSS data that included adults aged ≥ 65 years, rural compared to urban areas were characterized by higher obesity rates and lower fruit consumption.²⁸ Among urban adults, there was an inverse association between obesity and fruit consumption, an association not observed among rural adults.²⁸ In addition, among 96 American Indian families living in rural areas, the higher intake of processed meat (top vs. lowest quintile of consumption) was associated with a 1.6-fold higher risk of incident T2DM.²⁷ However, the association between dietary choices and T2DM is nuanced and may vary by region and availability of affordable healthful food nutrition.

Novel Rural-enriched Risk Factors—In addition to traditional metabolic risk factors, there is growing interest in the association between novel rural-enriched factors and risk of T2DM. Exposure to pesticides, organic pollutants, and fertilizers is associated with a higher risk of T2DM.^{29–32} Although the use of these organic chemicals may be higher in rural than urban populations,³³ the association between these factors and T2DM risk in rural populations has not been examined directly. It is unknown if exposure to these risk factors is associated with higher risk of T2DM in rural populations, and if they increase risk beyond traditional risk factors.

T2DM Risk Prediction Scores for Rural Areas

There are several risk prediction scores for T2DM; the vast majority were developed in Europe and have not been examined in US rural populations.^{34,35} Most of these risk prediction scores incorporate traditional risk factors, as described in an earlier section. Many risk prediction scores incorporate biomarkers such as cholesterol and triglycerides, which may limit people in rural areas with geographic and financial barriers for laboratory testing.^{34,35} As a result, there is emerging interest in the use of non-invasive (i.e., non-laboratory) T2DM risk scores to possibly overcome geographic and financial barriers for risk prediction. Also, rural-enriched factors have not been incorporated into risk prediction scores, and it is unknown if they improve risk prediction beyond traditional risk factors. The paucity of T2DM risk prediction scores validated and optimized in rural populations may limit the ability of healthcare providers to determine T2DM risk and provide preventive counseling in these areas.

Comorbidities and Other Factors Associated with T2DM

A meta-analysis of 102 prospective studies (n ~700,000 participants) showed that diabetes mellitus (type 1 and type 2, combined) is associated with a 1.5–2 fold higher risk of cardiovascular events and accounted for approximately 10% of vascular deaths.³⁶ Effective management of T2DM requires non-pharmacologic and pharmacologic interventions to mitigate the risk of cardiovascular events. However, adherence to these interventions may be influenced by comorbidities and social factors. For example, among veterans with T2DM and depression, medication non-adherence (<80% medication possession ratio for T2DM medications) was higher among rural compared with urban Hispanic patients, but lower among rural compared with urban non-Hispanic whites and non-Hispanic blacks.³⁷ This and other studies showed that people with T2DM and concomitant depressive symptoms, high psychosocial stress of having T2DM, or low social supports, have lower adherence to lifestyle and pharmacologic management of T2DM.^{38–42} Further, perceptions of the neighborhood can affect management of comorbidities. A study of 250 Latino adults with T2DM in a rural agricultural community (San Joaquin Valley, California) showed that neighborhood perceptions (e.g., crime, access to exercise facilities, transportation) were independently associated with higher body mass index and blood pressure, after adjusting for demographics and comorbidities.⁴³ In addition, the workplace can be a significant barrier to effective self-management. Rural areas tend to have employment directed toward services, trades, and government organizations. People with T2DM working in rural compared to urban areas may have inadequate food choices, reduced ability to regulate timing of meals and medications, and lower flexibility in work schedules to meet with healthcare providers.⁴⁴ These factors can affect the management of T2DM and associated comorbidities.

Screening and Management of T2DM in Rural Areas

Residents of rural areas, compared to urban counterparts, receive inadequate diabetes education and care (e.g., dilated eye examination).^{45,46} Two systematic reviews of factors that influence T2DM self-management in rural communities showed that personal factors (e.g., cost of medications), cultural factors (e.g., lack of culturally competent guidelines/recommendations), and infrastructure (e.g., transportation, distance to health facilities) were important barriers to self-management.^{47,48} Various strategies have been implemented to try to improve the screening and management of T2DM in rural areas, as briefly described below.

Opportunistic Screening—The availability of healthcare services is essential to the screening and management of T2DM. A cross-sectional study of health providers in the ‘diabetes belt’ Appalachian region (including 410 counties in West Virginia and 12 other states) showed that most health facilities did not have adequate diabetes specialists: less than 15% had an endocrinologist, only 37% had a certified diabetes educator, and some facilities reported inadequate funding.^{49,50} While rural areas may have limited access to a primary care provider, providers have leveraged opportunistic nontargeted screening for prediabetes and T2DM. At the Northern Navajo Medical Center, a rural Indian Health Service emergency department in Shiprock, New Mexico, providers screened people presenting to the emergency department. Of 924 people tested for T2DM, 26.2% (n=242) had undiagnosed prediabetes and 2.6% (n=24) had undiagnosed T2DM.⁵¹ Similarly, diabetes

screening and education at a local festival (Pioneer Day) in Loachapoka, Alabama, allowed for the increased detection of previously undiagnosed prediabetes and T2DM.⁵²

T2DM Self-Management—In-person and telehealth interventions with clear goal-setting (e.g., for diet, physical activity, blood pressure) have been associated with improvement in T2DM self-management.⁴⁷ There have been nine studies of in-person interventions including group classes (n=7 studies), group and individual classes (n=1 study), and in-home education with a nurse (n=1 study) of duration ranging from 8 weeks to 12 months. Six studies on telehealth interventions used videoconference sessions of varying duration (6 months to 3 years); of these, one study offered videoconference and secure messaging to a nurse care manager.⁴⁷ These studies compared the intervention to usual care, but there were no studies comparing the effectiveness of different interventions.

Community-based Initiatives—Community-based initiatives may be effective in improving T2DM management. In a rural county in South Carolina, adults with diabetes were given access to a federally qualified health center-based farmers' market and personal financial incentives. Over the 22-week intervention and pre/post evaluation, adults with diabetes increased their consumption of fruits and vegetables.⁵³ Similarly, other lifestyle improvement programs based on recommendations from the American Diabetes Association and YMCA (28 sessions over a 12-month period) were associated with improvement in body-mass index, hemoglobin A1c, and medication adherence.⁵⁴ In another study, participants randomized to a 3-month community health worker intervention vs. usual care showed improvement in adherence to self-management recommendations.⁵⁵

Interventions Targeting Comorbidities and T2DM—Given the frequent co-existence of T2DM and depression/psychological symptoms, studies have evaluated whether the treatment of depression/psychological symptoms improves T2DM management. The ACTIVE (Appalachians Coming Together to Increase Vital Exercise) program enrolled 50 adults with T2DM and depression in a single-arm intervention of aerobic activity (150 minutes per week) and cognitive behavioral therapy (10 sessions). After the 12-week intervention period, there was an improvement in major depressive disorder symptoms, hemoglobin A1c (lowered by 0.4%), and fasting glucose (lowered by 4.7 mg/dL), although the hemoglobin A1c changes were not sustained at 3-months following the intervention.⁵⁶ Similarly, among 129 rural African-American women in the EMPOWER study, women were randomized to telephone-based peer-support (intervention) or mail-based educational material (control) arms to manage diabetes-related distress. The intervention was associated with greater improvement in hemoglobin A1c and medication adherence compared to those with worsened/unchanged diabetes distress.⁵⁷ The COMRADE study randomized 139 rural adults to 16 sessions of severity-tailored cognitive behavioral therapy plus lifestyle counseling compared with usual care.⁵⁸ The intervention was associated with improvement in depressive symptoms, self-care behaviors, medication adherence, and a non-significant decrease in hemoglobin A1c (−0.92 vs. −0.31; p=0.06).⁵⁸

While these studies highlight the importance of *treating* depression/psychological symptoms, it is also important to *screen* for these comorbidities. One study showed adults may not have received adequate treatment for depression, which in turn, may have affected

the non-pharmacologic and pharmacologic management of T2DM.⁵⁹ Additional studies are required to evaluate novel strategies to treat comorbidities and improve T2DM self-management. Ultimately, engaging a patient in shared decision making may improve decisional outcomes and, possibly, clinical outcomes.⁶⁰

Role of Technology in Managing T2DM

As many rural patients experience geographic barriers to access healthcare, there has been a growing interest to use technology-based interventions to improve T2DM management.^{61–65} These studies showed that telemedicine interventions can improve T2DM knowledge,⁶² reduce waist circumference,⁶² lower body mass index,⁶² and lower hemoglobin A1c.⁶⁵ In the ENHANCED randomized controlled trial, a dietician nutritionist-led telemedicine program resulted in improvement in diabetes care measures (hemoglobin A1c <8%, blood pressure <140/90 mmHg, tobacco cessation, statin use, and aspirin use appropriate) compared to the control arm.⁶³ Importantly, studies have shown that telemedicine delivery of a T2DM prevention program was non-inferior to an in-person program, suggesting that telemedicine could become an important mechanism to deliver care in areas with reduced access to providers.^{64,66} These results require replication in other cohorts, but are reassuring for providers and facilities implementing telemedicine based care for rural patients.

T2DM Primary Prevention Initiatives in Rural Areas

Several studies examined interventions to improve risk factors for T2DM among rural populations.^{67–70} In a study in rural North Carolina, African-American adults at high-risk of T2DM participated in a community-based ‘Power to Prevent’ T2DM prevention program. Individuals were defined as high-risk based on the 7-item risk calculator from the American Diabetes Association. This program was associated with an improvement in knowledge on diabetes and lifestyle, but not in blood glucose, weight, or blood pressure.⁶⁸ Similarly, other community programs involving diabetes education,⁶⁸ nutrition education with behavioral coaching,⁷⁰ and faith-based programs at local churches,⁶⁹ have shown success in improving risk factors associated with T2DM. Future work is required to evaluate if these programs reduce incident T2DM and if the health benefits are sustained after completion of the program.

Guidelines and T2DM in Rural Areas

The American Diabetes Association identified telemedicine as an effective strategy to manage T2DM among rural patients.⁷¹ The American Heart Association and American Stroke Association released a *Call to Action* highlighting the growing burden of cardiovascular disease in rural areas.⁷² This *Call to Action* highlights the burden of risk factors, including T2DM, and the urgent need for strategies to improve rural health. Adults across rural populations vary by age, race/ethnic composition, desire to incorporate technology for T2DM self-management, and preference for individual vs. group interventions. The success of interventions will also rely on their cultural competence, as shown for T2DM self-management programs.^{73–78}

Knowledge Gaps and Next Steps

Improving the health of rural populations, an important minority group, is a priority for national organizations including the CDC and the National Institutes of Health.^{9,79–81} At present, there is sparse information on the incidence rates of T2DM in rural compared to urban areas. In addition, the determinants of the high burden of T2DM in rural areas have not been well studied. Based on publicly reported information, there are very few clinical trials of interventions to improve T2DM primary prevention in rural areas.

Future studies on rural areas should evaluate the incidence rates and temporal trends of T2DM and its major determinants at the individual level (e.g., obesity, dietary lifestyle, physical activity) and community level (e.g., access to healthful food, community programs, health services) by gender, sex, and race/ethnicity. In this study, we focused on T2DM given its link to metabolic risk factors (e.g., obesity, metabolic syndrome) and vascular (micro- and macro-) complications; however, these topics should be reviewed in separate studies. To guide health disparities research, the National Institute on Minority Health and Health Disparities (NIMHD) developed a research framework that outlines levels of influence (individual, interpersonal, community, and societal) and domains of influence (biological, behavioral, physical/built environment, sociocultural environment, and health care system) to improve health outcomes at the individual, family/organizational, community, and population levels.⁸⁰ There is an urgent need for systematic efforts to assess these levels and domains of influence to develop targeted interventions to improve health outcomes (Figure 2). This is particularly relevant as a recent report showed rural areas lag urban areas in their progress toward reducing mortality from T2DM and other conditions.⁸²

CONCLUSIONS

In the US, the burden of T2DM is higher in rural compared to urban areas. The rural burden of T2DM varies by gender, race/ethnicity, region, infrastructure, and access to health services. Given the diversity of rural populations, it will be challenging and unrealistic to design a single strategy for widespread implementation. Instead, culturally competent tailored strategies will be more effective in improving the primary prevention of T2DM. Recognizing this, the Federal Office of Rural Health Policy, Health Resources & Services Administration (US Department of Health and Human Services) funds at least 10 rural health research center and policy initiatives that focus on the burden and local needs of people.⁸³ A concerted effort is required to engage patients, providers, and governmental and non-governmental stakeholders, design patient-centered approaches to reduce the burden of T2DM in rural areas, and achieve the Health People 2020 goal for diabetes.¹²

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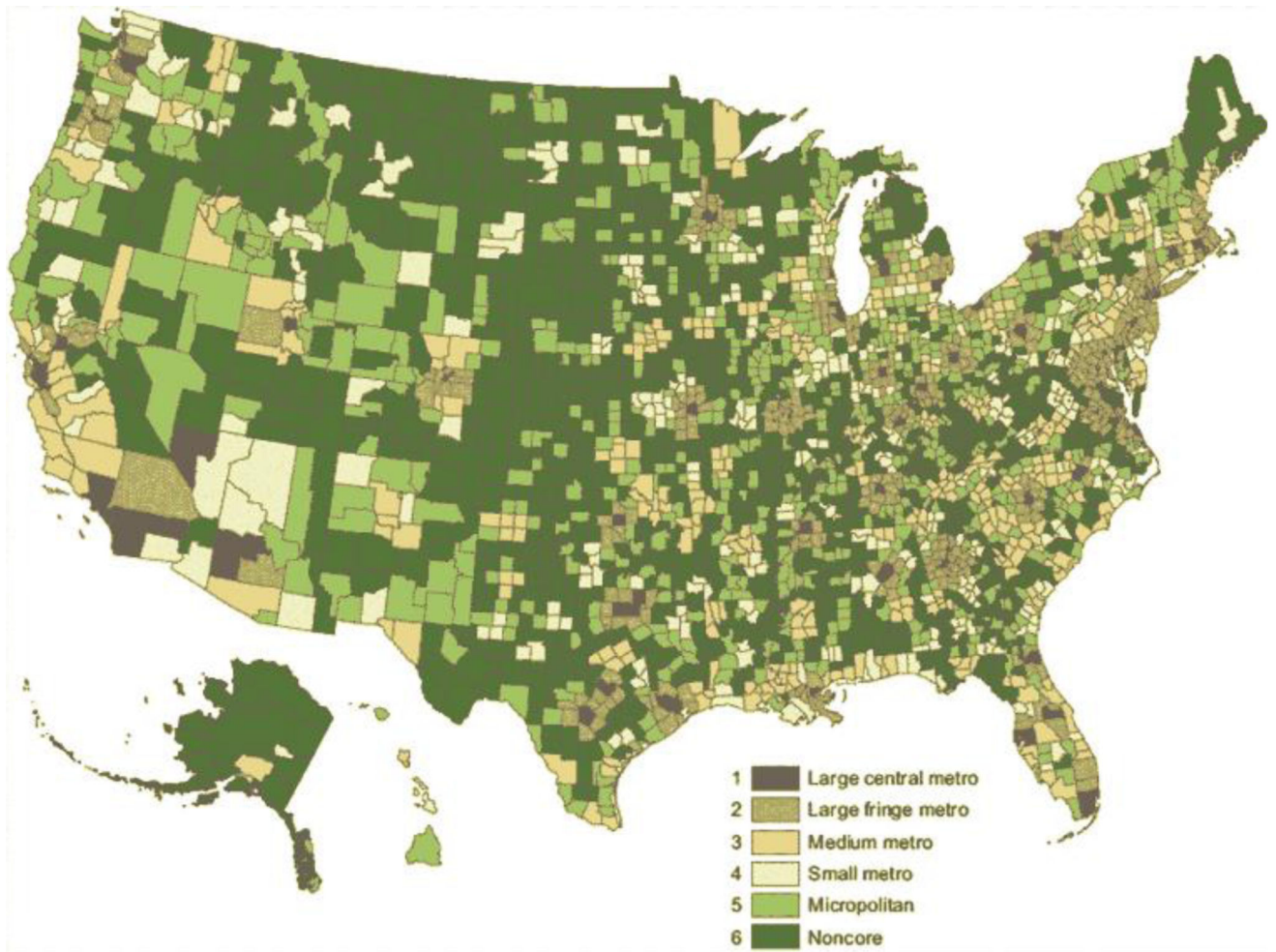


Figure 1. Distribution of counties using the 2013 National Center for Health Statistics (NCHS) system for urban-rural classification at the county level. The six-level system comprises metropolitan counties (large central metro, large fringe metro, medium metro, and small metro) and nonmetropolitan counties (micropolitan and noncore). Reproduced from publicly available report.¹⁷

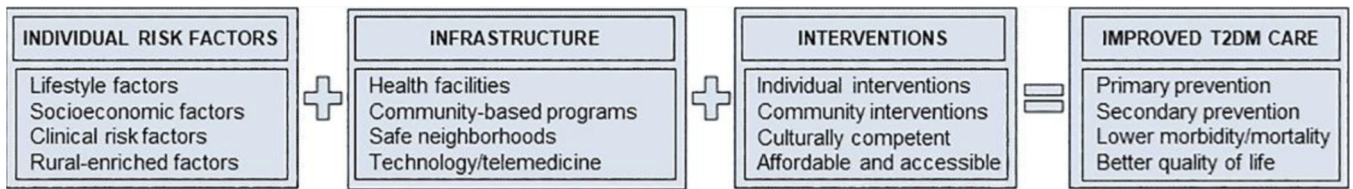


Figure 2. Schematic outlining importance of individual risk factors, infrastructure, and tailored interventions to improve type 2 diabetes mellitus (T2DM) care in rural population.

Table 1.

US rural-urban classification systems

Source	Description of rural and urban areas
2010 US Census Bureau ^{14,84}	<p>Urban: territory, population, and housing units located within UAs[†] (population 50,000) and UCs[‡] (2,500 population <50,000)</p> <p>Rural: all non-urban areas</p>
USDA Economic Research Service ¹⁵	<p>Frontier and Remote Area (FAR) codes</p> <p>‘Frontier and remote’ describes territory characterized by combination of low population size and high geographic remoteness. Based on 2010 US census, four codes are defined in relation to the time it takes to travel by car to the edges of nearby UAs.</p> <ul style="list-style-type: none"> i. Level one FAR approximates remoteness from UAs of 50,000 people ii. Level two FAR approximates remoteness from UAs of 25,000 people iii. Level three FAR approximates remoteness from UAs of 10,000 people iv. Level four FAR shows remoteness from UA of 2,500 people
Office of Management and Budget (OMB) ¹⁶	<p>County-level designation based on population density and commuting:</p> <p>Metropolitan statistical areas:</p> <ul style="list-style-type: none"> i. contain a core urban area with one or more UAs (population 50,000), and ii. adjacent counties with high degree of social and economic integration to the core UAs, measured by labor-force commuting <p>Nonmetropolitan areas outside of the boundaries of metropolitan areas and subdivided in to:</p> <ul style="list-style-type: none"> i. micropolitan statistical areas centered on UCs (10,000 population <50,000) ii. noncore areas not included in micropolitan and micropolitan areas <p>Metropolitan areas are generally considered urban, and nonmetropolitan areas are generally considered rural.</p>
National Center for Health Statistics (Centers for Disease Control and Prevention) ¹⁷	<p>County-level designation</p> <p>Metropolitan counties</p> <ul style="list-style-type: none"> i. Large central metropolitan: counties in metropolitan statistical areas (MSA) of 1 million population that: <ul style="list-style-type: none"> • contain the entire population of the largest principal city of the MSA, or • are completely contained within the largest principal city of the MSA, or • contain at least 250,000 residents of any principal city in the MSA ii. Large fringe metropolitan: counties in MSAs of 1 million population that do not qualify as large central metro counties iii. Medium metropolitan: counties in MSAs of 250,000–999,999 population iv. Small metropolitan: counties in MSAs of <250,000 population <p>Nonmetropolitan counties</p> <ul style="list-style-type: none"> i. Micropolitan: counties in micropolitan statistical areas ii. Noncore: nonmetropolitan counties that do not qualify as micropolitan
United States Department of Agriculture (USDA) Economic Research Service ¹⁸	<p>Rural-urban continuum codes (RUCC) based on OMB codes, and developed in 2013.</p> <p>Metropolitan counties:</p> <ul style="list-style-type: none"> i. counties in metropolitan areas with population 1 million ii. counties in metropolitan areas with population 250,000 – 1 million iii. counties in metropolitan areas with population <250,000 <p>Nonmetropolitan counties:</p> <ul style="list-style-type: none"> i. urban population 20,000, adjacent to a metropolitan area ii. urban population 20,000, not adjacent to a metropolitan area iii. urban population 2,500 – 19,999, adjacent to a metropolitan area iv. urban population 2,500 – 19,999, not adjacent to a metropolitan area v. completely rural or <2,500 urban population, adjacent to a metropolitan area vi. completely rural or <2,500 urban population, not adjacent to a metropolitan area <p>Unknown-Alaska/Hawaii State/not official USDA Rural-Urban Continuum code</p> <p>Unknown/not official USDA Rural-Urban Continuum code</p>

Source	Description of rural and urban areas
<p>Health Resources and Services Administration's (HRSA's) Office of Rural Health Policy; USDA's Economic Research Service; WWAMI Rural Health Research Center¹⁹</p>	<p>Rural-Urban Commuting Area (RUCA) codes are an alternative to the county-level classification system. RUCA codes classify US census tracts using measures of population density, urbanization, and daily commuting.</p> <p>Metropolitan area core: primary flow within a UA</p> <p>Metropolitan area high commuting: primary flow 30% or more to a UA</p> <p>Metropolitan area low commuting: primary flow 10% to 30% to a UA</p> <p>Metropolitan area core: primary flow within a UC of 10,000 to 50,000 (large UC)</p> <p>Metropolitan high commuting: primary flow 30% or more to a large UC</p> <p>Metropolitan low commuting: primary flow 10% to 30% to a large UC</p> <p>Small town core: primary flow within a UC of 2,500 to 9,000 (small UC)</p> <p>Small town low commuting: primary flow 30% or more to a small UC</p> <p>Small town low commuting: primary flow 10% to 30% to a small UC</p> <p>Rural areas: primary flow to a tract outside a UA or UC</p> <p>Sub-codes present within each category, as described.¹⁹</p>
<p>USDA Economic Research Service²⁰</p>	<p>Urban Influence Codes</p> <p>Metropolitan counties</p> <ul style="list-style-type: none"> i. In large metropolitan area of 1 million population ii. In small metropolitan area of <1 million population <p>Nonmetropolitan counties</p> <ul style="list-style-type: none"> i. Metropolitan area adjacent to large metropolitan area ii. Noncore adjacent to large metropolitan area iii. Metropolitan area adjacent to small metropolitan area iv. Noncore adjacent to small metropolitan area and contains a town of 2,500 population v. Noncore adjacent to small metropolitan area and contains a town of <2,500 population vi. Metropolitan area not adjacent to a metro area vii. Noncore adjacent to micro area and contains a town of at least 2,500 residents viii. Noncore adjacent to micro area and does not contain a town of at least 2,500 residents ix. Noncore adjacent to metro or micro area and contains a town of at least 2,500 residents x. Noncore not adjacent to metro or micro area and does not contain a town of at least 2,500 residents

¹⁹ US: United States;

²⁰ UA: urbanized area;

²¹ UC: urban cluster