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SYMPOSIUM

The Association between Driving Distance and Glycemic Control in Rural Areas

Janice C. Zgibor, R.Ph., Ph.D., M.P.H.,[1] Laura B. Gieraltowski, Ph.D., M.P.H.,[2] Evelyn O. Talbott, Dr.P.H., M.P.H.,[1] Anthony Fabio, Ph.D., M.P.H.,[1] Ravi K. Sharma, Ph.D.,[3] and Hassan Karimi, Ph.D.[4]

Abstract

Background:

In order to optimize care and improve outcomes in people with diabetes, adequate access to health care facilities and resources for self-management is required.

Methods:

Data on 3369 individuals with type 2 diabetes who received education at 7 diabetes centers were collected prospectively between June 2005 and January 2007. The driving distances of subjects who were in good control [hemoglobin A1c (A1C) ≤7.0%] were compared with the driving distances of those who were not (A1C >7.0%). The association between A1C and improvement in A1C with travel burden was tested.

Results:

The mean distance subjects traveled to visit their center was 13.3 miles. The results indicated that residing more than 10 miles from the diabetes management center [odds ratio (OR) = 1.91, $p < .0001$], being younger (OR = 0.99, $p = .00015$), and having a longer duration of diabetes (OR = 1.03, $p = .0007$) were significant contributors to a A1C >7% adjusted for individual- and community-level factors. In addition, those who lived within 10 miles of their center were 2.5 times more likely to have improved their A1C values between their first and last office visits.

Conclusion:

Health care providers should be aware of travel burden as a potential barrier to glycemic control. In the future, it may be useful to minimize driving distance for individuals with diabetes, perhaps by improved public transportation, more diabetes center locations in rural areas, telemedicine, or home visits.

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Author Affiliations: [1]Department of Epidemiology, University of Pittsburgh, Pittsburgh, Pennsylvania; [2]Centers for Disease Control and Prevention, Atlanta, Georgia; [3]Department of Behavioral and Community Health Sciences, University of Pittsburgh, Pittsburgh, Pennsylvania; and [4]Department of Information Sciences, University of Pittsburgh, Pittsburgh, Pennsylvania

Abbreviations: (BMI) body mass index, (DBP) diastolic blood pressure, (A1C) hemoglobin A1c, (LDL) low-density lipoprotein, (OR) odds ratio, (SBP) systolic blood pressure, (SES) socioeconomic status

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Corresponding Author: Janice C. Zgibor, R.Ph., Ph.D., A529 Crabtree Hall, 130 DeSoto St., Pittsburgh, PA 15213; email address edcjan@pitt.edu

Introduction

Diabetes is a group of diseases marked by high levels of blood glucose resulting from defects in insulin production, insulin action, or both. Diabetes is a major public health challenge because of its enormous impact on the affected individual, their families, and the health care system. Currently, 25.8 million people are affected by diabetes, with an annual cost of $218 billion.[1,2] Diabetes can lead to serious complications and premature death; however, people with diabetes can take steps to control the disease and lower the risk of complications.[3] Research demonstrates that diabetes-related mortality and morbidity can be prevented or delayed by controlling risk factors, which include hemoglobin A1c (A1C), blood pressure, and lipid levels.[4]

Certain environmental aspects play an important role in the primary prevention and treatment of chronic diseases such as diabetes. Studies demonstrate that an individual's surroundings or community factors, including access to health care, diet, physical activity, housing, income, and environmental exposures, contribute to diabetes prevalence.[5] While there are many ways to define community, geographic location is one important way to understand the context in which people live. In the past, there was not a valid method for defining and analyzing geographic areas that make up a community where chronic diseases and their risk factors may cluster.

Good glycemic control, in the sense of a "target" for risk-factor treatment, is an important goal of diabetes care.[3] The standard assessment for glycemic control is A1C, which reflects average glucose over the preceding 2–3 months. Accepted "target levels" of A1C for those with diabetes is less than 7%,[3] although evidence may challenge this lower limit.[6] One tool in managing diabetes and risk factors for complications is adequate access to providers with expertise in diabetes and specialty services, including diabetes self-management education. While specialty services are effective at improving short-term behavioral and physiologic outcomes for people with diabetes, patients in rural areas may have limited access to these services,[7] causing them to rely almost exclusively on primary care providers for their diabetes care.

As diabetes is preventable and can be controlled with intervention, it is important to understand the impact of rural geography on outcomes. From a provider perspective, busy rural primary care practices often lack organizational support and computerized tracking systems to initiate practical interventions to improve diabetes care.[8] From a patient perspective, driving distance may influence access to required services, which puts those in rural areas at a significant disadvantage. Therefore, the objective of this study was to examine the association between travel burden and glycemic control and to determine if travel burden also influenced improvement in glycemic control.

Methods

Study Population

Data on individuals with type 2 diabetes were collected from seven diabetes management centers in Southwestern Pennsylvania using an electronic data management system. Individual-level data such as home street addresses, demographics, laboratory test data, medications, health indicators, comorbid conditions, and complications were entered into this data system from June 2005 to January 2007. All individuals were 18 years and older ($n = 3369$) and diagnosed by their physician with diabetes prior to be being referred to the diabetes center.

Measurement of Travel Burden and Definitions of Outcomes

The home addresses of the subjects and the location of diabetes centers they attended were geocoded to the street address level using ArcGIS software (ESRI, Redlands, CA). The ESRI street centerline datasets for each county in the study area were used to geocode the location. The driving distance from each subject's house to the diabetes centers was calculated using the network analyst tool within the software. The tool distances how far the subjects lived from the centers. The travel distance was dichotomized into living 10 miles or less and greater than 10 miles from the diabetes center they visited. A 10-mile distance was chosen based on previously conducted studies and based on recommendations from the Rural Health Association.[9–11] Using network analyst, an origin–destination cost matrix was created for the homes of subjects to each diabetes center they visited. The parameters for the original destination cost matrix were specified, and paths from each home to the particular center they visited were created.

Laboratory values from the patients who were entered into the electronic system were used to define the risk factors. The first laboratory values that were entered for each patient were used in a cross-sectional analysis. Patients were classified as uncontrolled if they had A1C level >7.0% or controlled if the A1C level was ≤7%. Body mass index (BMI) was calculated as [weight in kilograms/height in meters^2]. Individuals with a BMI ≥25 kg/m^2 were classified as overweight and those with a BMI ≥30 kg/m^2 as obese. Individuals were categorized as having hypercholesterolemia if they had a low-density lipoprotein (LDL) cholesterol >100 mg/dl and/or reported taking cholesterol-lowering medications. Patients were considered to have hypertension if they had a systolic blood pressure (SBP) ≥ 130mm Hg, a diastolic blood pressure (DBP) ≥80 mm Hg, and/or if they reported taking antihypertensive medication. Medications were recorded in the database according to patient report.

Statistical Analysis

Univariate analysis was conducted to find significant differences between glycemic control and population characteristics. Generalized estimating equations logistic regression was performed to estimate odds ratios (ORs) of having uncontrolled diabetes and the association with the distance to diabetes management centers. Each of the risk factors, including age, gender, race, duration of diabetes, and BMI, was modeled separately for each marker of travel burden (distance as a continuous variable and as a dichotomous variable). Since individual-level socioeconomic status (SES) information was not available, census tract information[12] was used in the model to control for these factors. The percentage of residents living below the poverty level, percentage of residents reporting black as their race, median household income, and percentage of residents with a high school education or greater for each census tract were also considered in the regression models. Descriptive analysis was conducted to calculate the mean and percentages of laboratory values, age, gender, duration of diabetes, comorbidities, and complications of diabetes.

To investigate improvement in A1C values over time and the association with travel burden, the differences between the first visit A1C and last visit A1C value was calculated. Chi squares, *t*-tests, and logistic regression were used to determine the associations between improvement in A1C levels and travel burden, adjusting for individual- and community-level factors.

Results

Description of the Population

The analysis included 3369 individuals with diabetes from seven diabetes centers in Southwestern Pennsylvania (**Table 1**). They were predominantly older (mean age = 67.9 years), male (57.6%), and Caucasian (94.6%). Fifty percent (n = 1704) of individuals were categorized as having uncontrolled diabetes (A1C >7.0). Seventy-two

Table 1.
Population Characteristics of Type 2 Diabetes Patients in Rural Southwestern Pennsylvania[a]

	Uncontrolled n = 1704	Controlled n = 1665	Total n = 3369	p value
Gender (% male)	738 (43.4)	688 (41.3)	1943 (57.6)	0.24
Age (years)	66.7 (15.7)	69.1 (15.9)	67.9 (15.9)	<0.0001
Ethnicity (% Caucasian)	1439 (94.9)	1474 (94.3)	2913 (94.6)	0.56
Duration of diabetes (years)	6.1 (5.2)	5.4 (3.6)	5.8 (4.5)	0.0004
BMI (kg/m^2)	32.8 (8.1)	32.9 (8.1)	32.9 (8.1)	0.99
A1C (%)	8.6 (1.6)	6.1(0.5)	7.4 (1.7)	<0.0001
SBP (mmHg)	135.7 (18.2)	135.2 (18.2)	135.4 (18.2)	0.44
DBP (mmHg)	78.3 (10.4)	77.9 (10.4)	78.1 (10.4)	0.27
High-density lipoprotein cholesterol (mg/dl)	39.8 (11.4)	40.7 (11.7)	40.3 (11.6)	0.04
LDL cholesterol (mg/dl)	104.6 (33.7)	104.6 (34.0)	104.6 (33.9)	0.99
Triglycerides (mg/dl)	183.9 (114.6)	178.6 (110.9)	181.3 (112.9)	0.17
Percentage living below poverty level	13.1 (7.9)	13.6 (9.3)	13.4 (8.6)	0.09
Median income ($)	29,434.0 (6709.2)	29,572.0 (7402.2)	29,502.4 (7095.5)	0.57
Miles traveled to diabetes center	14.9 (16.4)	11.7 (15.3)	13.3 (15.9)	<0.0001
Subjects within 10 miles of diabetes center	830 (48.7)	1037 (51.3)	1867 (55.4)	<0.0001

[a] Data are n (%) or mean (standard deviation).

percent of the individuals had hypertension (mean SBP = 135.4; mean DBP = 78.1), 52.7% had hyperlipidemia (mean LDL = 104.6 mg/dl), 68.7% were overweight (mean BMI = 32.9 kg/m^2), and 46.4% were obese. The mean duration of diabetes was 5.8 years, and those with uncontrolled glycemia had significantly longer diabetes duration than those who were in control (6.1 and 5.4 years, respectively). The mean distance subjects traveled to visit their diabetes management center was 13.3 miles (range 0.06–85.1 miles). Overall, 55% of the subjects lived less than 10 miles from their diabetes center. Those with uncontrolled diabetes traveled farther to their diabetes center (14.9 versus 11.7 miles), with 51.3% of patients living within 10 miles of the diabetes center compared with 48.7%.

Generalized Estimating Equation Regression

The associations between the distance subjects traveled to their diabetes management centers and the glycemic control are presented in **Table 2**. The associations were adjusted for individual-level factors such as age, duration of diabetes, race, and gender. Because individual-level SES variables were unavailable, census tract information,[12] as previously described, was included in the model adjustment.

The results indicated that residing more than 10 miles from the diabetes management center (OR = 1.91, $p < .0001$), being younger (OR = 0.99, p = .00015), and having a longer duration of diabetes (OR = 1.03, p = .0007) were significant contributors to the model. Those who lived more than 10 miles from their diabetes management center were 91% more likely to have A1C levels greater than 7.0% compared with those who lived less than 10 miles from their center, adjusted for individual-level factors such as age, sex, race, duration of diabetes, and BMI as well as community-level factors such as percentage of residents with a high school degree or higher, median household income, and percentage of residents living below the poverty level.

Table 2.
Adjusted Odds Ratios and 95% Confidence Intervals for Likelihood of Having Uncontrolled Diabetes (A1C > 7%) Associated with Travel Burden (Dichotomous)

Parameter	OR	95% confidence interval	p value
Diabetes center >10 miles	1.91	1.59, 2.30	<0.0001
Age (years)	0.99	0.98, 0.99	0.00015
Gender (male)	1.12	0.94, 1.34	0.22
Race (white)	1.05	0.69, 1.59	0.80
Diabetes duration (years)	1.03	1.01, 1.06	0.0007
BMI (kg/m^2)	0.99	0.98, 1.01	0.83
Percentage with high school degree[12]	0.99	0.97, 1.01	0.31
Median income (2000 U.S. dollars)[12]	0.99	0.99, 1.00	0.11
Percentage living below poverty level[12]	0.97	0.95, 0.99	0.03
Percentage black (county)[12]	1.01	0.99, 1.03	0.19

The association between the numbers of miles from the diabetes center as a continuous variable and glycemic control was also modeled. The results indicated that greater driving distance from diabetes center (OR = 1.02, $p < .0001$), being younger (OR= 0.99, p = .007), having a longer duration of diabetes (OR = 1.03, p = .004), and living in a census tract with a higher percentage of residents living below the poverty level (OR = 0.98, p = .05) were significant contributors to the model. Therefore, for every mile the subjects lived from their diabetes management center, they were 2% more likely to have A1C levels greater than 7.0%, adjusted for individual- and community-level factors.

The results of longitudinal analyses are presented in **Table 3**. Those with only one visit to the diabetes management center were removed from this particular analysis (n = 230). The mean time between visits was 0.36 years (range = 0.3–1.7 years). There was a significant difference between travel burden and the number of visits to the center (p = .0003). Those who lived less than 10 miles from their center had a mean of 2.0 office visits,

Table 3.
Change in A1C Values Stratified by Travel Burden

	Center ≤10 miles (n = 1737)	Center >10 miles (n = 1402)	Total (n = 3139)	p value
Difference between first and last A1C values	—	—	—	<0.0001
Mean (standard deviation)	-0.19 (1.0)	0.12 (1.1)	-0.01 (1.09)	—
Improved A1C values	—	—	—	<0.0001
n (%)	1719 (91.9)	1276 (85.1)	2967 (88.2)	—

while those who lived greater than 10 miles from the center had a mean of 1.6 visits. There was also significant difference between travel burden and change in A1C values over time ($p < .0001$). Individuals who resided less than 10 miles from their diabetes center had a mean decrease in A1C values of 0.19%. Those who lived greater than 10 miles from their diabetes center had a mean increase in A1C values of 0.12. Furthermore, 85.1% of those living more than 10 miles from their center were able to improve their A1C values between their first and last visits, while 91.9% were able to improve their A1C values ($p < .0001$) if they lived less than or equal to 10 miles from the center.

The association between living less than or greater than 10 miles from the diabetes center and improvement in A1C values over time was also modeled (**Table 4**). The results indicated that those living within 10 miles of their diabetes management center (OR = 2.48, $p < .0001$), being older (OR = 1.01, $p = .004$), having a shorter duration of diabetes (OR =0.95, $p = .0001$), and having more office visits (OR = 1.47, $p < .0001$) were significant contributors to the model. Therefore, those who lived less than 10 miles from their diabetes management center were 2.48 times more likely to have improved their A1C values between their first and last center visits, after adjusting for individual- and community-level factors. Additionally, those who lived less than 10 miles from their center had a significantly shorter time between visits to the center compared with those who lived 10 or more miles from the center (0.26 years and 0.43 years, respectively).

Table 4.
Odds Ratios and 95% Confidence Intervals of Having Improved A1C Values Associated with Travel Burden

Parameter	OR	95% confidence interval	*p* value
Diabetes center ≤10 miles	2.48	1.65, 3.71	<0.0001
Age (years)	1.01	1.00, 1.02	0.004
Gender (male)	1.01	0.73, 1.41	0.94
Race (white)	1.74	0.91, 3.33	0.09
Diabetes duration (years)	0.95	0.93, 0.98	0.001
BMI (kg/m^2)	1.00	0.98, 1.02	0.83
Percentage with high school degree[12]	0.99	0.95, 1.03	0.57
Median income (2000 U.S. dollars)[12]	1.00	0.99, 1.00	0.63
Percentage living below poverty level[12]	1.00	0.95, 1.05	0.99
Percentage black (County)[12]	0.99	0.96, 1.03	0.86
Number of center visits	1.47	1.38, 1.57	<0.0001

A subanalysis of those who reported health insurance information ($n = 2116$) indicated that type of insurance coverage was not significantly associated with glycemic control and travel burden in this study (data not shown).

Discussion

Results from this study indicated that the distance patients live from their diabetes management center has an effect on glycemic control, as there was a clear association between travel burden and glycemic control among individuals with type 2 diabetes. Those who lived more than 10 miles from their diabetes management center were 91% more likely to have a A1C >7.0% compared with those who lived less than 10 miles from their center, after multivariate adjustment. In addition, those who lived 10 miles or less from their diabetes management center were twice as likely to improve their A1C values between their first and last office visits.

Patients in this study reside in rural areas of Southwestern Pennsylvania and may use less medical care than those living in urban areas.[13] This may be dependent on a number of factors. Rural areas are frequently characterized by poorly developed and fragile economic infrastructures, resulting in fewer available *per capita* hospital beds, doctors, nurses, and other health care services.[10] In addition to socioeconomic hardships, rural residents face substantial physical barriers, including a lack of public transportation, difficult terrain, and long distances to services.[11,14] Further, patient-specific factors such as age, race, ethnicity, and perceptions of quality, as well as extrinsic factors such as insurance coverage and health care costs may contribute.[13] In this study, age and duration of diabetes were significantly associated with travel burden and glycemic control. A subanalysis of those who reported health insurance information indicated that insurance coverage may not contribute to glycemic control and travel burden. However, these results are only hypothesis generating, as there may be a reporting bias since only two of seven centers reported insurance information. Another potential factor related to health care utilization is travel time and distance.[15,16] Research suggests that health care utilization is adversely affected by long travel times. One study found that patients may forgo free care if it is greater than 20 miles away.[16] Several state health departments have proposed a standard in which rural residents should not have to travel more than 30 minutes to see a physician.[13] Travel distance in this study ranged from approximately 1 to 85 miles, supporting this hypothesis.

Our current framework of the rural–urban hierarchy of care is one in which rural areas are very dependent on urban areas for health care, in particular, specialty care, which is integral for diabetes. In this "hub-and-spoke" model, rural patients must travel long distances for their care. Further, rural residents have fewer overall visits and see fewer medical specialists and more generalists for their care than their urban counterparts.[17] Strauss and colleagues[17] examined the relationship between glycemic control and the driving distance from a patient's home to the site of primary care. The authors found that driving distance was significantly associated with glycemic control in their population of older rural subjects. Each 22 miles of driving distance was associated with a 0.25% increase in A1C. Although our study focused on subjects who visited diabetes management centers, and Strauss and colleagues[17] focused on primary care offices, the results support the associations between the travel burden and glycemic control in those with diabetes.

The findings of this study expand on those of Littenberg and associates,[18] where the role of travel burden as a barrier to the use of insulin in adults with diabetes was assessed. The researchers recruited 781 adults receiving primary care for type 2 diabetes. Travel burden was estimated as the shortest driving distance from the patient's home to the site of primary care. The researchers found that driving distance was significantly associated with insulin use, where adults with type 2 diabetes living farther from their source of primary care were significantly less likely to use insulin. The researchers hypothesized that this might be because patients and physicians are concerned about the potential risks associated with using insulin and are reluctant to use it if they feel that the patient lives too far away from care for rescue in the event of hypoglycemia. Although our study focused on glycemic control and travel burden, and Littenberg and associates[18] focused on insulin use, these results strengthen the associations found between the travel burden and glycemic control hypothesis in those with diabetes. Our study also supports the independent association of travel burden with improved glycemic control, as the relationship remained significant after adjusting for patient- and community-level characteristics, including number of visits to the diabetes center.

There were some limitations in the current study. Because the study was conducted in rural Southwestern Pennsylvania, the population was mostly white and older, reflecting the characteristics of the general population; therefore, these results may not be generalized to urban or more diverse populations. Also, driving distance from the subject's home to the diabetes center may not be a perfect measurement of travel burden. Some subjects may take public transportation or have a friend or family member to drive them to the diabetes center; however, we did not have individual-level data to assess this. Further, data on phone contacts and visits to other providers were not available, limiting the conclusions that can be drawn from these analyses. Individual-level data on income and education were also not available; therefore, census data[12] were used in the multivariate analysis and may not reflect individual level SES. Future analysis would benefit from this individual-level data.

Conclusion

This study is unique to the literature because it is the only study, to our knowledge, that examines the association between diabetes outcomes and diabetes management services that the subjects actually received. Having data on number of visits, time between visits, and laboratory values is very distinctive and enabled us to find relationships between glycemic control and travel burden to a care site. Furthermore, results from this study demonstrate that travel burden may be a potential barrier to diabetes management. In the future, it may be useful to minimize driving distance for individuals with diabetes, perhaps by improved public transportation, adding more diabetes center locations in rural areas, telemedicine, or home visits. This study also demonstrates the need for more strategically located health care centers in rural areas. Information on where the majority of residents live, road connectivity, and geography allows for the deliberate placement of needed health care locations. Additional research should focus on more effective ways to connect diabetes care providers and patients in rural areas.

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