Healthcare Travel Burden and Diabetes Management

BY

JAMES MCCOMBS
B.S., University of Illinois at Urbana-Champaign, 2009
M.P.H., University of Michigan at Ann Arbor, 2011

THESIS

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Defense Committee:
Mary Turyk, Chair and Advisor
Ben Gerber, Academic Internal Medicine and Geriatrics
Lisa Sharp, Pharmacy Systems, Outcomes and Policy

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LIST OF ABBREVIATIONS

A1C - Hemoglobin A1C

BMI – Body Mass Index

CI – Confidence Interval

GED – General Education Development

HMO – Health Maintenance Organization

LDL – Low-Density Lipoprotein

OR – Odds Ratio

PPO – Preferred Provider Organization

UIC – University of Illinois at Chicago

VHA – Veterans Health Administration

SUMMARY

In 2018, 10.5% of the United States population, approximately 34.2 million people, had diabetes, while 13.0% of adults age 18 years or older, about 34.1 million people, had diabetes (1). Diabetes is a complicated disease that requires ongoing care beyond managing blood glucose (A1C) (2). People with diabetes may need to manage changes in diet, physical activity, and medication use, as well as monitor their feet for injuries that may go unnoticed due to diabetic neuropathy (3). Yearly dilated eye exams are recommended to detect and manage diabetic retinopathy and diabetic macular edema (4). The propensity of diabetes to lead to other diseases, poorer health outcomes, high healthcare costs, greater disability, and work impediment make it critical that people with diabetes attain proper health care to manage their diabetes.

Transportation is necessary for ongoing healthcare access, so it is important to understand how travel burden affects health outcomes. Travel burden to health care is a subjective concept that can fluctuate due to multiple factors. Distance, travel time, geography, socioeconomic status, disability, and type of transportation used may affect patients' ability to travel to health care appointments.

This current research project will help us to understand the effect of self-reported urban travel burden on a group of low income, racial minority patients with diabetes. The study population for this investigation is drawn from a randomized trial of a diabetes intervention with two years of follow up data for 244 racial minorities with uncontrolled diabetes (A1C ≥ 8%) attending the University of Illinois Medical Center ambulatory network in Chicago (5). Travel burden was assessed by participants responding to the question, "On a scale of 1-4, how much trouble is it for you to get transportation to your primary care doctor at (UIC/Mile Square)." We hypothesized that greater travel burden is associated with high A1C levels (≥ 9%). The aims of this study are to:

1. Determine if self-reported travel burden to primary care provider is associated with A1C levels among the study population during the 2 years of follow up.

2. Determine if self-reported travel burden to primary care provider is associated with A1C levels among the study population with high A1C levels at baseline during the 2 years of follow up.

3. Assess effect modifiers of the association of travel burden with A1C levels.

With the inclusion of age and income covariates, this study found a statistically significant longitudinal relationship between self-reported travel burden and patients' success in achieving lower A1C levels among patients with high A1C levels at baseline. Models with age and income covariates found a significant difference between "no problem" and "a lot of trouble" travel burden. The effect of "little trouble" and "some trouble" did not differ significantly from "no trouble" travel burden in any models. Having low diabetes support from friends and family, low income, and being obese were each associated with travel burden having a stronger relationship with A1C levels. Our findings add to the literature by finding an association between self-reported travel burden and A1C levels for racial minorities with diabetes in an urban setting.

I. BACKGROUND

A. Diabetes Epidemiology

Diabetes occurs when the body's blood glucose level becomes consistently elevated (6). The hormone insulin allows blood glucose to enter the body's cells for use as energy. If the body does not produce enough insulin, or use the insulin well, the blood glucose will not reach the body's cells, resulting in an elevated blood glucose level. In type 1 diabetes a person's body does not produce insulin (7). In type 2 diabetes the body uses insulin improperly, which is referred to as insulin resistance (8). Subsequently, pancreatic beta cell dysfunction occurs leading to type 2 diabetes. Symptoms of diabetes include blurred vision, increased hunger, feeling tired, sores that do not heal, increased thirst and urination, and unexplained weight loss (9). Uncontrolled elevated blood glucose has been found to lead to heart disease, stroke, kidney disease, diabetic retinopathy and macular edema, dental disease, and diabetic neuropathy in extremities. Diabetes is associated with increased morbidity and mortality, mainly through cardiovascular disease (10). Diabetes increases the probability of defects in the vasculature, cellular and molecular mechanisms specific to insulin-resistant states, leading to vascular diseases including retinopathy and nephropathy, stroke, peripheral vascular disease, and coronary artery disease (11). Increases in all-cause mortality associated with diabetes have been found, with relative risk ranging from 1.15 to 3.15 (12). As of 2017, diabetes was the seventh leading cause of death in the United States (13).

In adults, about 90%–95% of diagnosed diabetes cases are type 2 (1). One of the major risk factors for type 2 diabetes is increased adiposity (14); 89% of adults with diabetes are overweight or obese, with 45.8% being obese, body mass index (BMI) of 30 to less than 40 kg/m^2 and 15.5% being severely obese, BMI of 40 kg/m^2 or higher (1). Being obese is associated with an increased risk of morbidities, some of which are shared with diabetes, including cardiovascular diseases, chronic kidney disease, nonalcoholic fatty liver disease, gastroesophageal reflux disease, cancer, as well as impairment of daily living activities (15). A meta-analysis of over 2 million people found obesity was associated with an increased mortality rate, with a hazard ratio of 1.18, and 95% confidence interval (CI) of 1.12–1.25 (16). Paradoxically, a meta-analysis of studies involving overweight and obese people with diabetes found mixed effects of weight on mortality (17). Being obese was found to reduce the risk of all-cause mortality in elderly people with diabetes with a hazard ratio of 0.69, and 95% CI of 0.63–0.75. This reduction in all-cause mortality was not present among non-elderly obese people with diabetes. Weight may not be as important of a mortality risk factor for obese people with diabetes who live to old age.

Additionally, the risk of developing type 2 diabetes is higher for people with older age, poor nutrition, and physical inactivity (14). In 2018, 10.5% of the United States population, approximately 34.2 million people, had diabetes (1). Over 13% of adults age 18 years or older, about 34.1 million people, had diabetes. The prevalence of diabetes among adults increases with age. Adults aged 65 years or older had the highest prevalence of diabetes, 26.8%. For adults age 18 and older, 14% of males had diabetes compared to 12% of females. While Non-Hispanic Whites had a diabetes prevalence of 11.9%, rates were elevated for Non-Hispanic Blacks (16.4%), Non-Hispanic Asians (14.9%), and Hispanics (14.7%). Diabetes prevalence varies with income as well. From 2009-2010, 43.8% of adults age 20 and over with a diabetes diagnosis had a family income < $35,000 compared to 13% of diagnoses being adults with a family income of $100,000 and higher (18). Additionally, low-income has been associated with increased diabetes-related death (19).

B. <u>Diabetes Management</u>

In 2017, costs of diabetes were estimated to be approximately $327 billion; $237 billion direct medical costs and $90 billion indirect costs due to disability, work loss, and premature death (20). Over a fifth of health care spending is for people with diagnosed diabetes.

Diabetes is a complicated disease that requires ongoing care beyond managing blood glucose (2). People with diabetes may need to manage changes in diet, physical activity, and medication use, as well as monitor their feet for injuries that may go unnoticed due to diabetic neuropathy (3). Yearly dilated eye exams are recommended to detect and manage diabetic retinopathy and diabetic macular edema (4). The propensity of diabetes to lead to other diseases, poorer health outcomes, high healthcare costs, greater disability, and work impediment make it critical that people with diabetes attain proper health care to manage their diabetes.

Diabetes management to keep blood glucose levels close to normal has been found to reduce the development of complications from diabetes (21). A glycated hemoglobin test (known as an A1C test) is used to assess diabetes management by providing the average blood glucose levels for the previous 2-3 months (22). The A1C test is also referred to as the hemoglobin A1C, HbA1c, or glycohemoglobin test. The structure in the red blood cell that carries oxygen to the cells is called hemoglobin. Glucose binds to the hemoglobin in red blood cells. The amount of glucose attached to hemoglobin is measured with an A1C test. A1C test results are reported as a percentage.

Using the A1C test, patients and healthcare providers can assess whether treatment plans are working and measure progress. Patients who are meeting treatment goals and have stable glycemic control should have the A1C test at least two times a year (2). Quarterly A1C tests should be performed for patients whose treatment has changed or who are not meeting glycemic goals. An A1C test level less than 5.7% is classified as normoglycemic. Prediabetes is considered A1C levels between 5.7% and 6.4%. An A1C level of 6.5% and higher is diagnosed as diabetes. An appropriate A1C goal for many diabetic, non-pregnant adults is 7%. Higher targets for A1C level, such as 8%, can be appropriate for patients with limited life expectancy, long-standing diabetes and difficulty achieving a lower target, severe hypoglycemia, or advanced diabetes complications.

For type 2 diabetes, if changes in diet, physical activity, and medications are not enough to manage blood glucose, insulin may be required (23). Type 1 diabetes requires insulin to be taken since the body no longer produces the hormone. Insulin comes in a variety of types which work at varying speeds (15 minutes to several hours) and durations (2 hours to 24 hours). Mixtures of two types of insulin are sometimes used to treat diabetes as well. Taking insulin correctly and at appropriate times is important to manage diabetes. Doctors can provide direction on when and how to take insulin and help patients figure out what insulin works best for them.

Patient financial barriers to diabetes management have been found to be significant obstacles to treatment (24). Providers have specifically identified the cost of home glucose monitoring and dilated eye examination as barriers to diabetes care (25). Diabetes care can also be a burden on employment. A study of employment among people with diabetes found diabetes decreased the likelihood of employment by 4.4% for females and 7.1% for males (26). Limitation to the kind or amount of paid work were experienced by 5.4% of males and 6% of females with diabetes. People with diabetes have reported needing to adapt their disease management to fit their work, resulting in suboptimal glycemic control (27). Additionally, people with diabetes expect little support from managers at work in managing their diabetes. Although rare, diabetes complications can also impair the ability to drive (28).

Obstacles to effective management of diabetes exist in patient barriers, and healthcare provider and healthcare system limitations (29). Patients' behavioral factors, psychosocial factors, and socioeconomic status can affect their diabetes management. Since diabetes requires ongoing care, patient engagement and communication with their health care provider is critical. Through shared decision-making, healthcare providers discussing treatment options and recommendations with patients, patients can be empowered to reach goals. For healthcare providers and systems, leveraging information technology can improve diabetes care by tracking A1C values and overall self-management performance, prescribing medication electronically to track medication adherence, and enabling participation in local patient databases to track and assess diabetes care achievements.

C. Transportation Burden

Transportation is necessary for ongoing healthcare access, so it is important to understand how transportation burden affects health outcomes. Transportation burden to reach a health care facility is a subjective concept that can fluctuate due to multiple factors. Distance, travel time, geography, socioeconomic status, disability, and type of transportation used may affect patients' ability to travel to health care appointments. The distance and the travel time required to reach the health care facilities are the most important transportation-related factors for health status and health outcomes (30) (31). Even if patients do not use their nearest health care facility, they likely use one nearby (32). For both rural and urban locations, studies have found a relationship between poorer health outcomes and how far a patient resides from health care (33). Even health-related quality of life has been found to be inversely associated with distance to health care facilities for kidney stone patients (34).

Patients have been found to perceive distance and time burdens as a barrier to health care use (33). Patients have reported travel burden to be the cause of missed medical appointments and medications being discontinued (35). Among the elderly, transportation difficulty has been identified as the third most common barrier to accessing health services, behind medical bills and having a doctor who is unresponsive to their concerns (36).

A systematic literature search of peer-review studies on transportation barriers found that transportation barriers are an important impediment to healthcare access, especially for the low income or under/uninsured populations (37). This review organized results into *measures of transportation barriers*, *transportation barriers and demographic differences*, and *measurement of the impact of transportation barriers*.

With respect to *measures of transportation barriers*, findings indicated that the absence of transportation or inaccessible transportation may result in missing regular health care, lower overall health care use, and missed health care appointments, with a greater effect for patients with lower economic means. The impact of urban and rural locations was mixed. While some studies found no difference in health care use and self-reported transportation barriers between adults living in urban and rural areas, other studies reported greater travel burdens for rural patients, including travel distance to health care and a greater burden of travel when measured by distance and time traveled. Using travel distance to health care providers as a measure of transportation barriers produced mixed results as well. Six studies found distance was a barrier to healthcare, while two studies found travel was not a barrier to health care utilization, with one study finding greater distance was associated with better health care access.

Findings for *transportation barriers and demographic differences* suggest that, controlling for socioeconomic status, racial minorities experience greater transportation burden to access health care. Additionally, children, the elderly, and veterans face distinctive barriers to health care unique to their population. Children rely on an adult for transportation to health care appointments, the elderly experience higher levels of disability and illness, and veterans may access health care through a federal health care system.

The *measuring the impact of transportation barriers* section found caregivers of children who missed appointments were more likely to identify transportation barriers as the primary reasons for missing appointments. Studies that explored transportation barriers and medication access found that transportation barriers were associated with decreased medication access. Transportation barriers were cited for patients stopping insulin use and associated with patients not being able to afford medications. An online survey of epilepsy.com members found that among members who could not drive, 45% reported that without transportation problems they would miss fewer doses of medication.

Additional studies support the conclusions of Syed et al. In a study of females using the Veterans Health Administration (VHA), longer drive times were associated with higher odds of dropping VHA care (38). The association between drive time and attrition was stronger among new patients. Overall, attrition among female veterans was found to be sensitive to longer drive time.

In two cancer studies, advanced cancer stage at diagnosis was associated with higher patient travel distance to health care (39) (40). Another cancer study found increased travel time to be associated with advanced cancer stage at diagnosis among low-income patients (41). These findings suggest transportation access as a barrier to early cancer screening. Earlier diagnosis can allow for less invasive treatments but also less treatment generally and reduced health care expenses. After cancer diagnosis, travel burden may affect the health care received. Increased travel burden was linked with lower likelihood of receiving radiation therapy for rectal cancer (42) as well as receiving salvage palliative chemotherapy for rectal cancer (43). A study of breast cancer patients found a decrease in health care visits with greater travel distance (44). An analysis of cancer clinical trial participants found participants from low-income areas had to travel a significantly longer distance to reach their cancer center (45) suggesting potentially worse outcomes for participants from low-income areas. Additionally, a study of travel time for cancer treatment found greater travel times for rural patients and care for certain cancers (46).

Lastly, in an analysis of 108 studies on travel burden and healthcare access, 77% of studies identified an association between patients living further from their healthcare facilities and poorer health outcomes than patients who resided closer to their healthcare facilities (33). This analysis included three studies that focused on people with diabetes. Included in this analysis, and the review by Syed et al., are two studies of rural subjects which found that greater driving distance from a primary care provider was associated with poorer glycemic control (47) (48). The third study found less insulin use as people with diabetes live farther from their primary care provider (49). These findings extend our knowledge of the importance of transportation burden in accessing health care to adverse impacts on diabetes management, particularly in rural populations. Literature is lacking on the impact of travel burden on glycemic control in urban populations.

There is a need for more research into transportation barriers in urban areas. Urban and rural areas may have different availability of public transportation and walkable streets and residents may have different barriers to access to health care based on their transportation options. Statistically significant differences have been found in commuting transportation behaviors between residents of rural and urban areas (50). Urban areas were more likely to have residents commute by biking and public transportation, and less likely to have residents walk to work. Additionally, low-income urban areas have a higher prevalence of residents walking, biking, and using public transportation for their commute (51).

Given the substantial burden of diabetes morbidity and mortality, particularly in low-income minority populations, and the importance of routine healthcare for management of diabetes to reduce morbidity and mortality it is imperative to understand and reduce barriers to healthcare access. The distance between a population's geographic region and health care facilities, and the travel time required to reach the health care services, have been identified as important transportation-related factors for health status and health outcomes. A few studies in rural populations have detected notable impacts of travel distance and poorer glycemic control in patients with diabetes. However, data is limited for urban populations that may have substantially different types of travel barriers. Thus, further research is needed to understand the effects of travel burden in urban areas on patients' ability to manage their diabetes. This current research project will help us explore the impact of urban travel burden on a group of low income, racial minorities with diabetes. We hypothesize that greater travel burden will be associated with high A1C levels (≥ 9%). The aims of this study are to:

1. Determine if self-reported travel burden to primary care provider is associated with A1C levels among the study population during the 2 years of follow up.
2. Determine if self-reported travel burden to primary care provider is associated with A1C levels among the study population with high A1C levels at baseline during the 2 years of follow up.
3. Assess effect modifiers of the association of travel burden with A1C levels.

II. STUDY POPULATION

The study population is drawn from a randomized trial of a diabetes intervention with two years of follow up data for 244 racial minorities with uncontrolled diabetes (A1C ≥ 8%) at the University of Illinois Medical Center ambulatory network in Chicago (5). The University of Illinois Medical Center serves a diverse, low income population through inpatient and outpatient healthcare services. Each year, roughly 8,000 African American or Latino patients receive diabetes care through outpatient services.

The goal of the source study was to assess the success of clinical pharmacists and community health workers on hemoglobin A1C, diabetes care behaviors (medication use, physical activity, and healthy eating), and LDL-cholesterol levels, blood pressure. This study used a crossover design. All participants had access to a pharmacist and were required to travel to a University of Illinois clinic for appointments. During the first year, participants were randomized to receive no additional support or support from a community health worker, such as performing telephone calls and home visits to provide education, encourage behavioral change and self-management, and reinforce pharmacist and provider recommendations. During the second year, community health worker support was switched to the group that did not receive community health worker support during year one. Community health workers were trained on a Center for Disease Control-funded curriculum.

Patients were eligible for the study if they met the following criteria:

- Were age 21 or above
- Received primary care at University of Illinois Medical Center
- Self-identified as African American/Black or Latino/Hispanic
- Had a history of type 2 diabetes
- Had an elevated A1C level 8% or higher in the past year (confirmed through electronic medical record)

- Had verbal fluency in English or Spanish

Patients were excluded from the study using the following criteria:

- Unable to verbalize comprehension of study or have evidence of impaired decision making
- Had a household member already participating in the study
- Lived outside of the Chicago area three or more months of the year
- Planned to move from the Chicago area within the next year
- Were pregnant or trying to become pregnant

Recruitment was carried out at four ambulatory sites. Research assistants received participant referrals through patients or staff. A study physician reviewed patients' medical records to screen A1C levels for eligibility. Eligible patients completed a written consent and a Health Insurance Portability and Accountability Act authorization. Data was collected at baseline, 6 months, 1 year, and 2 years. Questionnaires were completed in English or Spanish.

III. STUDY METHODS

Self-reported travel burden was assessed by participants responding to the question, "On a scale of 1-4, how much trouble is it for you to get transportation to your primary care doctor at (UIC/Mile Square)." Response options from 1-4 were reported on the scale of "no trouble, little trouble, some trouble, and a lot of trouble." Study participants completed this question during their baseline measurements only. A tabulation of travel burden and total number of data collection visits showed that a higher proportion of participants reporting "some trouble" or "a lot of trouble" with transportation to their primary care provider had only one or two data collection visits than participants reporting "little trouble" or "no trouble" with transportation (Table I). Among participants reporting "a lot of trouble", only 58% completed all four data collection visits compared to 73% to 76% for other of those reporting less travel burden.

Table I
TRAVEL BURDEN AND A1C LEVEL AT BASELINE BY NUMBER OF DATA COLLECTION VISITS DURING 2-YEAR STUDY[a]

		Number (percent) of Data Collection Visits			
Travel burden to primary care		**1**	**2**	**3**	**4**
	N=243	**19 (7.8)**	**24 (9.9)**	**21 (8.7)**	**179 (73.7)**
No trouble	**146 (60.1)**	8 (5.5)	15 (10.3)	12 (8.2)	111 (76)
Little trouble	**37 (15.2)**	4 (10.8)	1 (2.7)	5 (13.5)	27 (73)
Some trouble	**36 (14.8)**	2 (5.6)	5 (13.9)	2 (5.6)	27 (75)
A lot of trouble	**24 (9.9)**	5 (20.8)	3 (12.5)	2 (8.3)	14 (58.3)
High A1C at baseline**	**N=244**	**19 (7.8)**	**24 (9.8)**	**21 (8.6)**	**180 (73.8)**
No	**115 (47.1)**	11 (9.6)	10 (8.7)	12 (10.4)	82 (71.3)
Yes	**129 (52.9)**	8 (6.2)	14 (10.9)	9 (7)	98 (76)

[a]Data collection visits occurred at baseline, 6 months, 1 year, and 2 years

High A1C was defined as an A1C level of 9% or greater. Low A1C was defined as an A1C level less than 9%. This threshold was selected because the participants were enrolled based on an A1C ≥ 8% during the past year. The 9% threshold nearly provided an even division of the sample as well. At baseline, 47% of the study population had low A1C. The number of data collection visits was similar across A1C categories (Table I).

Descriptive statistics examined the distribution of dependent and independent variables. Variable categories with few responses were collapsed when appropriate. One participant with "Other" race was combined with "Hispanic/ Latino." Of seven income categories reported, 58% of respondents where in the lowest two. Other income categories with few responses were combined resulting in four income ranges being used in this analysis. Education levels of college and beyond were combined in one category. Self-reported health status was classified as "Excellent, Very Good, Good" and "Fair, Poor." Age categories were developed by dividing the sample into quartiles. Ages ranged from 24-89 years old. The amount of support the participants received from friends and family for dealing with diabetes was measured using a 5-point scale from "no support" to "a great deal of support." In total, 118 participants reported the highest level of support. The remaining participants were evenly spread across the lower four categories. For analysis, responses of 1 and 2 were combined into "low" support, responses of 3 and 4 were combined into "moderate" support, and responses of 5 became "high" support.

Bivariate analyses examined associations of A1C levels ("high" ≥ 9%, or "low" < 9%) and travel burden with participant characteristics at baseline, with statistical significance evaluated using logistic regression and Chi-square tests.

Multivariable longitudinal logistic regression modeling was used to assess the relationship between self-reported travel burden and A1C level across study time points. Longitudinal logistic regression modeling relates independent variables to a dichotomous dependent variable using multiple observations of subjects. Our analysis was performed using SAS 9.4 (SAS Institute, Cary, North Carolina).

Our longitudinal logistic regression modeling used the SAS procedure GLIMMIX with a compound symmetry covariance matrix and random intercept model. Multivariable modeling allows estimates of a predictor variable's effect to be adjusted for the effect of one or more additional variables. In our analysis, the dependent A1C level variable varied across study time points, but independent variables were only measured at baseline. We modeled the exposure variable, travel burden, as an ordinal variable to estimate the effect of a one-unit increase in travel burden category on A1C level. Additionally, we created contrast variables to assess the effect of each travel burden category compared to the lowest level of travel burden. Effect modification was assessed to investigate how levels of a third variable affect the travel burden and A1C level association.

We identified income as a confounding variable *a priori*. Low income is associated with poorer diabetes control (24) and increased diabetes-related deaths (19), as well as a greater impact of transportation barriers (37). Additional variables examined for confounding and effect modification included sex, age, health status, race/ethnicity, health insurance, education level, body mass index, randomization group, marital status, and diabetes support. Confounding was assessed as a change in the crude association by >10%. Effect modification was identified with interactions terms having p-values <.10. Analyses were performed on the complete data set (n=244) as well as a subset of participants who had high A1C at baseline (≥9%). Restricting the sample to participants with high A1C at baseline provided a subgroup of 129 participants who had the potential to attain low A1C (<9%) during the 2-year study period.

IV. RESULTS

A. Bivariate Analyses

Data was collected for 244 patients. Demographics of the full study sample are detailed in Table II. These demographic characteristics were potential confounders and effect modifiers in our analysis.

Bivariate analyses in Table II indicated which demographic variables may be associated with A1C levels and be potential confounders. Older age was significantly associated with A1C level (p-value=0.009). The association of A1C with education was of borderline significance (p-value=0.08). Bivariate analyses in Table III indicated which demographic variables race/ethnicity (p-value=0.02), education (p-value=0.01), and health status (p-value=0.02) may be associated with travel burden. Some notable differences across these variables include “No trouble” travel burden was reported by 64% of African American participants compared to 49% of Hispanic Latino/ Other participants, and 31% of participants with “fair/ poor” health reported “some trouble” or “a lot of trouble” compared to 16% of participants with “excellent/ very good/ good” health.

B. Multivariable Analyses

Confounding analysis identified age as confounder and income was selected *a priori*, so the final models were adjusted for age and income. Cross sectional analysis at baseline did not find a significant association of travel burden with high A1C (Table IV). Longitudinal models found the odds of having high A1C by increasing travel burden levels was statistically significant, with p-value of 0.0196, in the subgroup with only high A1C at baseline, but not in the full sample (p-value=0.2651) (Table V). We also identified that having “a lot of trouble” versus “no problem” in travel burden significantly increased the odds of having high A1C during the 2-year study period among the subgroup with high A1C at baseline, 5.417 (95% CI=1.703, 17.230; p-value=0.0043), and there was a nearly significant effect among the full sample 3.168 (95% CI=0.969, 10.357; p-value=0.0564). The effect of “little trouble” and “some trouble” did not differ significantly from “no trouble” travel burden.

Table II CHARACTERISTICS OF THE FULL SAMPLE AT BASELINE BY A1C LEVEL				
	Total (n, column %)	**High A1C[a] (n, row %)**	**Low A1C (n, row %)**	**P-value**
Number	244 (100)	129 (52.9)	115 (47.1)	
Sex				0.1995
Female	164 (67.2)	82 (50)	82 (50)	
Male	80 (32.8)	47 (58.8)	33 (41.2)	
Race/Ethnicity				0.9034
African American/Black	177 (72.5)	94 (53.1)	83 (46.9)	
Hispanic Latino/ Other	67 (27.5)	35 (52.2)	32 (47.8)	
Marital Status				0.9564
Single, never married	104 (42.6)	52 (50)	52 (50)	
Married or living with partner	70 (28.7)	44 (62.9)	26 (37.1)	
Widowed	20 (8.2)	6 (30)	14 (70)	
Separated	29 (11.9)	16 (55.2)	13 (44.8)	
Divorced	21 (8.6)	11 (52.4)	10 (47.6)	
Household Income				0.2180
Less than $10,000	86 (35.3)	46 (53.5)	40 (46.5)	
$10,000-$19,999	56 (23.0)	27 (48.2)	29 (51.8)	
$20,000-$49,999	41 (19.7)	24 (58.5)	17 (41.5)	
$50,000+	25 (12.0)	17 (68)	8 (32)	
Refused	36 (14.8)	15 (41.7)	21 (58.3)	
Highest Level of Education				0.0757
Less than high school	72 (29.5)	31 (43.1)	41 (56.9)	
High School Diploma/GED	117 (48.0)	66 (56.4)	51 (43.6)	
Any College	55 (22.5)	32 (58.2)	23 (41.8)	
Health Insurance				0.2704
None	13 (5.3)	11 (84.6)	2 (15.4)	
Public Aid/ Medicaid	138 (57.6)	73 (52.9)	65 (47.1)	
Medicare	47 (19.3)	19 (40.4)	28 (59.6)	
HMO/PPO	43 (17.6)	24 (55.8)	19 (44.2)	
Missing	3 (1.2)	2 (66.7)	1 (33.3)	
Health Status				0.9485
Excellent, Very Good, Good	96 (39.3)	51 (53.1)	45 (46.9)	
Fair, Poor	148 (60.7)	78 (52.7)	70 (47.3)	
Age Quartiles				0.0009*
24-47	62 (25.4)	42 (67.7)	20 (32.3)	
48-54	61 (25.0)	37 (60.7)	24 (39.3)	
55-61	60 (24.6)	24 (40)	36 (60)	
61-89	61 (25.0)	26 (42.6)	35 (57.4)	
BMI				0.3715
Healthy weight	16 (6.6)	6 (37.5)	10 (62.5)	
Overweight	48 (19.7)	26 (54.2)	22 (45.8)	
Obese	179 (73.4)	96 (53.6)	83 (46.4)	
Missing	1 (0.4)	1 (100)	0 (0)	
Diabetes Support from Friends and Family				0.2853
Low	57 (23.4)	28 (49.1)	29 (50.9)	
Moderate	69 (28.3)	34 (49.3)	35 (50.7)	
High	118 (48.4)	67 (56.8)	51 (43.2)	

*p value < 0.05 from logistic regression
[a]A1C ≥ 9% defined as high

Table III CHARACTERISTICS OF THE FULL SAMPLE AT BASELINE BY TRAVEL BURDEN						
	Total (n, column %)	**No Trouble (n, row %)**	**Little Trouble (n, row %)**	**Some Trouble (n, row %)**	**A Lot of Trouble (n, row %)**	**P-value**
Number	243 (100)	146 (60.1)	37 (15.2)	36 (14.8)	24 (9.9)	
Sex						0.1614
Female	163 (67.1)	90 (55.2)	27 (16.6)	27 (16.6)	19 (11.7)	
Male	80 (32.9)	56 (70)	10 (12.5)	9 (11.3)	5 (6.3)	
Race/Ethnicity						0.0171*
African American/Black	176 (72.4)	113 (64.2)	19 (10.8)	27 (15.3)	17 (9.7)	
Hispanic Latino/ Other	67 (27.6)	33 (49.3)	18 (26.9)	9 (13.4)	7 (10.4)	
Marital Status						0.4559
Single, never married	103 (42.4)	64 (62.1)	15 (14.6)	18 (17.5)	6 (5.8)	
Married or living with partner	70 (28.8)	46 (65.7)	12 (17.1)	6 (8.6)	6 (8.6)	
Widowed	20 (8.2)	11 (55)	2 (10)	3 (15)	4 (20)	
Separated	29 (11.9)	13 (44.8)	6 (20.7)	5 (17.2)	5 (17.2)	
Divorced	21 (8.6)	12 (57.1)	2 (9.5)	4 (19)	3 (14.3)	
Household Income						0.1504
Less than $10,000	85 (35.3)	45 (52.9)	15 (17.6)	16 (18.8)	9 (10.6)	
$10,000-$19,999	56 (23.0)	35 (62.5)	9 (16.1)	6 (10.7)	6 (10.7)	
$20,000-$49,999	41 (19.7)	29 (70.7)	2 (4.9)	6 (14.6)	4 (9.8)	
$50,000+	25 (12.0)	21 (84)	3 (12)	1 (4)	0 (0)	
Refused	36 (14.8)	16 (44.4)	8 (22.2)	7 (19.4)	5 (13.9)	
Highest Level of Education						0.0100*
Less than high school	72 (29.6)	33 (45.8)	19 (26.4)	10 (13.9)	10 (13.9)	
High School Diploma/GED	116 (47.7)	73 (62.9)	16 (13.8)	17 (14.7)	10 (8.6)	
Any College	55 (22.6)	40 (72.7)	2 (3.6)	9 (16.4)	4 (7.3)	
Health Insurance						0.1710
None	13 (5.3)	8 (61.5)	3 (23.1)	2 (15.4)	0 (0)	
Public Aid/ Medicaid	137 (56.4)	78 (56.9)	20 (14.6)	23 (16.8)	16 (11.7)	
Medicare	47 (19.3)	25 (53.2)	12 (25.5)	5 (10.6)	5 (10.6)	
HMO/PPO	43 (17.6)	33 (76.7)	2 (4.7)	5 (11.6)	3 (7)	
Missing	3 (1.2)	2 (66.7)	0 (0)	1 (33.3)	0 (0)	
Health Status						0.0204*
Excellent, Very Good, Good	96 (39.5)	68 (70.8)	13 (13.5)	11 (11.5)	4 (4.2)	
Fair, Poor	147 (60.5)	78 (53.1)	24 (16.3)	25 (17)	20 (13.6)	
Age Quartiles						0.7481
24-47	62 (25.5)	42 (67.7)	6 (9.7)	9 (14.5)	5 (8.1)	
48-54	61 (25.1)	38 (62.3)	10 (16.4)	9 (14.8)	4 (6.6)	
55-61	60 (24.7)	36 (60)	9 (15)	8 (13.3)	7 (11.7)	
61-89	60 (24.7)	30 (50)	12 (20)	10 (16.7)	8 (13.3)	
BMI						0.7938
Healthy weight	16 (6.6)	10 (62.5)	3 (18.8)	3 (18.8)	0 (0)	
Overweight	48 (19.8)	28 (58.3)	7 (14.6)	9 (18.8)	4 (8.3)	
Obese	178 (73.3)	108 (60.7)	26 (14.6)	24 (13.5)	20 (11.2)	
Missing	1 (0.4)	0 (0)	1 (100)	0 (0)	0 (0)	
Diabetes Support from Friends and Family						0.4910
Low	57 (23.5)	35 (61.4)	7 (12.3)	7 (12.3)	8 (14)	
Moderate	68 (28)	35 (51.5)	12 (17.6)	13 (19.1)	8 (11.8)	
High	118 (48.6)	76 (64.4)	18 (15.3)	16 (13.6)	8 (6.8)	
*p value < 0.05 from Chi-Square Test						

Table IV ODDS RATIOS (95% CI) FOR CROSS SECTIONAL ASSOCIATION OF HAVING HIGH A1C WITH INCREASED BURDEN TO TRAVEL TO CLINIC AT BASELINE ADJUSTED FOR AGE AND INCOME				
Study sample	**Travel Burden**	**N**	**Odds Ratio (95% C I) Adjusted for age and income**	**P-value**
Full sample with high and low A1C at baseline	Per increase in 1 category of travel burden	207	0.957 (0.725, 1.263)	0.7564
	No trouble	130	Reference	
	A little trouble	29	0.621 (0.263, 1.467)	0.2771
	Some trouble	29	0.834 (0.360, 1.933)	0.6719
	A lot of trouble	19	1.194 (0.432, 3.305)	0.7322

Table V ODDS RATIOS (95% CI) FOR LONGITUDINAL ASSOCIATION OF HAVING HIGH A1C DURING 2-YEAR STUDY WITH INCREASED BURDEN TO TRAVEL TO CLINIC ADJUSTED FOR AGE AND INCOME				
Study sample	**Travel Burden**	**N**	**Odds Ratio (95% C I) Adjusted for age and income**	**P-value**
High A1C at baseline	Per increase in 1 category of travel burden	114	1.367 (1.052, 1.776)	0.0196 *
	No trouble	76	Reference	
	A little trouble	12	1.015 (0.468, 2.203)	0.9698
	Some trouble	15	1.098 (0.542, 2.222)	0.7948
	A lot of trouble	11	5.417 (1.703, 17.230)	0.0043 *
Full sample with high and low A1C at baseline	Per increase in 1 category of travel burden	207	1.203 (0.869, 1.666)	0.2651
	No trouble	130	Reference	
	A little trouble	29	0.850 (0.325, 2.222)	0.7404
	Some trouble	29	0.842 (0.333, 2.132)	0.7163
	A lot of trouble	19	3.168 (0.969, 10.357)	0.0564
*p-value < 0.05 from logistic regression				

C. Effect Modification

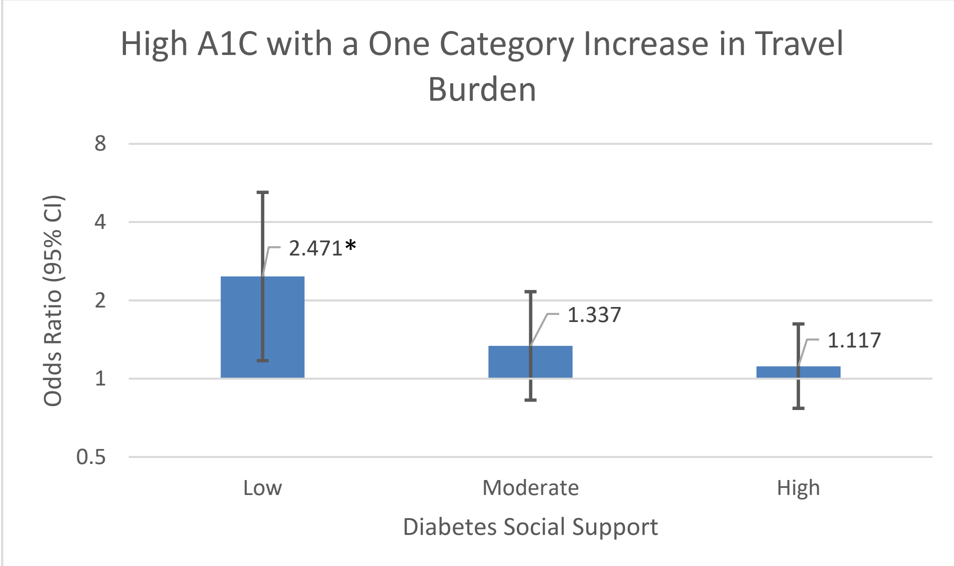
In the subgroup of participants with high A1C at baseline, diabetes support from friends and family modified the association of travel burden on having high A1C (interaction p-value=0.08), with significantly increased odds of high A1C with higher travel burden in those having low diabetes support (Figure 1). BMI was an effect modifier in models restricted to participants with high A1C at baseline (interaction p-value=0.04). The effect of travel burden on having high A1C was significantly increased by being obese (Figure 2). Odds ratios estimates by BMI were only available for overweight and obese participants. Too few participants had a healthy weight BMI to permit odds ratio calculations. Inclusion of both interactions in a single model did not substantially change the results (interaction p-values for travel burden and diabetes support=0.11 and travel burden and BMI=0.02). A three-way interaction between travel burden, BMI, and diabetes support was not significant (not shown).

In the full dataset, the effect of travel burden on having high A1C was significantly increased in participants having household incomes less than $10,000 (Figure 3).

D. Sensitivity Analyses

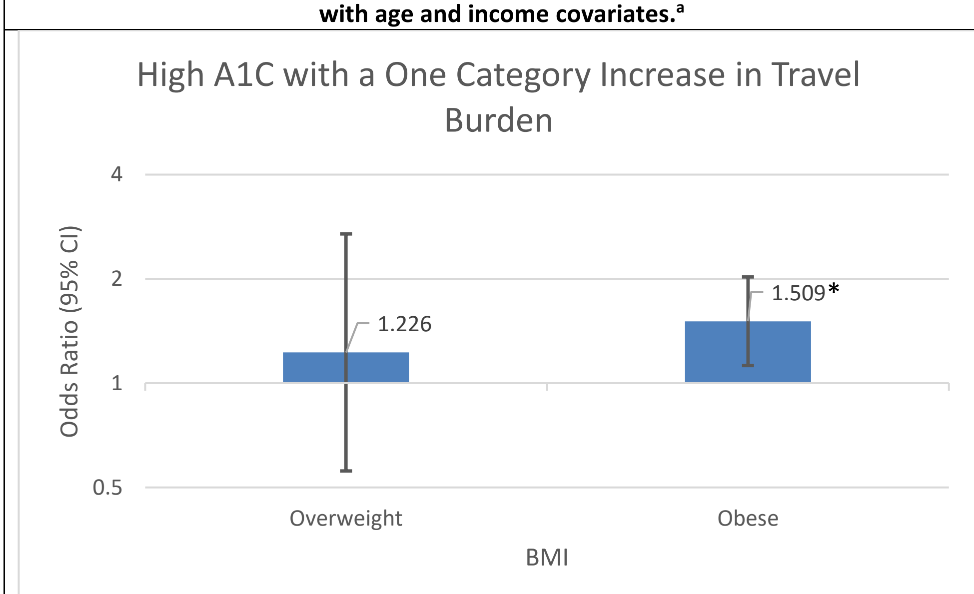
Income data was missing for 36 (15%) participants in the full sample, and 15 (12%) people in the sample with high A1C at baseline. Since we identified income *a priori* as a theoretically important confounder, we conducted analyses examining differences in other variables between participants with and without income data (Table VI). In the full data set, participants with missing income data had slightly worse travel burden (p-value=0.08), and were more likely to be female than male (p-value=0.03), older (p-value=0.02), have lower educational attainment (p-value=0.002), have public aid or no health insurance (p-value=0.03) and have lower diabetes support (p-value=0.009) than those reporting income data. Among those participants with high A1C, participants missing income data were more likely to have public aid or no health insurance (p-value=0.03).

Figure 1
Adjusted odds ratios (95% CI) for association of having high A1C during 2-year study with increased burden to travel to clinic by diabetes social support level. Participants with high A1C at baseline with age and income covariates.[a]



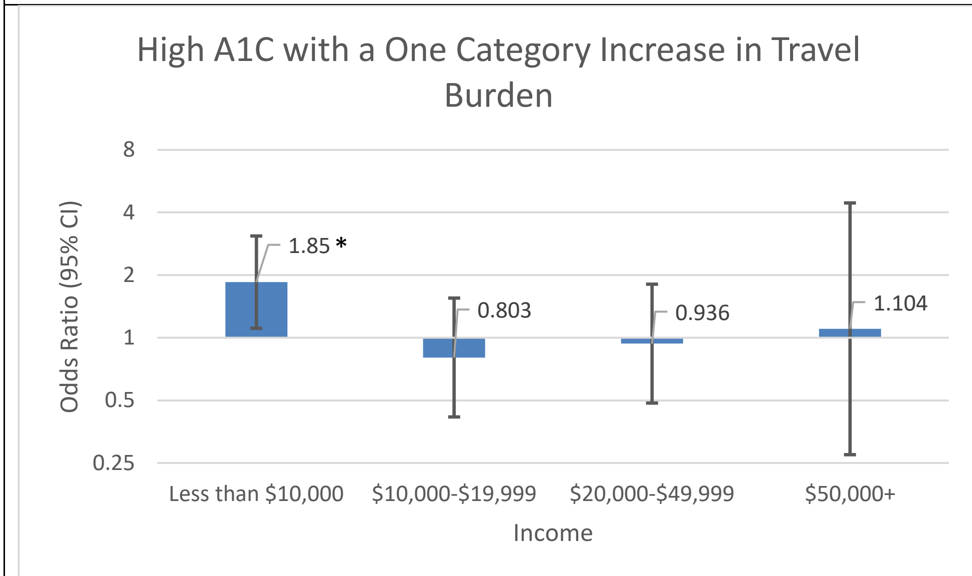
[a]Interaction p-value = 0.0830
*p-value < 0.05 for strata

Figure 2
Adjusted odds ratios (95% CI) for association of having high A1C during 2-year study with increased burden to travel to clinic by BMI. Participants with high A1C at baseline with age and income covariates.[a]



[a]Interaction p-value = 0.0382
*p-value < 0.05 for strata

Figure 3
Adjusted odds ratios (95% CI) for association of having high A1C during 2-year study with increased burden to travel to clinic by income level. Full sample with age and income covariates.[a]



[a]Interaction p-value = 0.0496
* p-value < 0.05 for strata

Table VI CHARACTERISTICS OF PARTICIPANTS WITH AND WITHOUT INCOME DATA							
		High A1C at baseline			Full Data Set		
	Total	Not Missing Income	Missing Income	P-value	Not Missing Income	Missing Income	P-value
	N=244	114 (88.4)	15 (11.6)		208 (85.2)	36 (14.8)	
Travel burden to primary care				0.2399			0.0801
No trouble	146 (59.8)	76 (66.7)	7 (46.7)		130 (62.5)	16 (44.4)	
Little trouble	37 (15.2)	12 (10.5)	3 (20.0)		29 (13.9)	8 (22.2)	
Some trouble	36 (14.8)	15 (13.2)	3 (20.0)		29 (13.9)	7 (19.4)	
A lot of trouble	24 (9.8)	11 (9.6)	2 (13.3)		19 (9.1)	5 (13.9)	
Missing	1 (0.4)				1 (0.5)		
A1C Level				-			0.1477
High A1C	129 (52.9)	114 (100)	15 (100)		114 (54.8)	15 (41.7)	
Low A1C	115 (47.1)	0	0		94 (45.2)	21 (58.3)	
Sex				0.1711			0.0307*
Female	164 (67.2)	70 (61.4)	12 (80)		134 (64.4)	30 (83.3)	
Male	80 (32.8)	44 (38.6)	3 (20)		74 (35.6)	6 (16.7)	
Race/Ethnicity				0.5667			0.0995
African American/Black	177 (72.5)	84 (73.7)	10 (66.7)		155 (74.5)	22 (61.1)	
Hispanic Latino/ Other	67 (27.5)	30 (26.3)	5 (33.3)		53 (25.5)	14 (38.9)	
Marital Status				0.4260			0.2442
Single, never married	104 (42.6)	46 (40.4)	6 (40)		93 (44.7)	11 (30.6)	
Married or living with partner	70 (28.7)	40 (35.1)	4 (26.7)		59 (28.4)	11 (30.6)	
Widowed	20 (8.2)	6 (5.3)	0 (0)		14 (6.7)	6 (16.7)	
Separated	29 (11.9)	13 (11.4)	3 (20)		24 (11.5)	5 (13.9)	
Divorced	21 (8.6)	9 (7.9)	2 (13.3)		18 (8.7)	3 (8.3)	
Highest Level of Education				0.1114			0.0023*
Less than high school	72 (29.5)	26 (22.8)	5 (33.3)		54 (26)	18 (50)	
High School Diploma/GED	117 (48)	57 (50)	9 (60)		102 (49)	15 (41.7)	
Any College	55 (22.5)	31 (27.2)	1 (6.7)		52 (25)	3 (8.3)	
Health Insurance				0.0297*			0.0331*
None	13 (5.3)	8 (7.1)	3 (21.4)		9 (4.3)	4 (11.1)	
Public Aid/ Medicaid	138 (57.6)	64 (56.6)	9 (64.3)		116 (55.8)	22 (61.1)	
Medicare	47 (19.3)	17 (15)	2 (14.3)		42 (20.2)	5 (13.9)	
HMO/PPO	43 (17.6)	24 (21.2)	0 (0)		40 (19.2)	3 (8.3)	
Missing	3 (1.2)				1(0.5)	2 (5.6)	
Health Status				0.5491			0.9518
Excellent, Very Good, Good	96 (39.3)	44 (38.6)	7 (46.7)		82 (39.4)	14 (38.9)	
Fair, Poor	148 (60.7)	70 (61.4)	8 (53.3)		126 (60.6)	22 (61.1)	
Age Quartiles				0.1857			0.0157*
24-47	62 (25.4)	41 (36)	1 (6.7)		59 (28.4)	3 (8.3)	
48-54	61 (25)	29 (25.4)	8 (53.3)		51 (24.5)	10 (27.8)	
55-61	60 (24.6)	22 (19.3)	2 (13.3)		50 (24)	10 (27.8)	
61-89	61 (25)	22 (19.3)	4 (26.7)		48 (23.1)	13 (36.1)	
BMI				0.2117			0.5144
Healthy weight	16 (6.6)	4 (3.5)	2 (13.3)		14 (6.7)	2 (5.6)	
Overweight	48 (19.7)	23 (20.4)	3 (20)		38 (18.3)	10 (27.8)	
Obese	179 (73.4)	86 (76.1)	10 (66.7)		155 (74.5)	24 (66.7)	
Missing	1 (0.4)				1 (0.5)		
Diabetes Support from Friends and Family				0.1278			0.0088*
Low	57 (23.4)	23 (20.2)	5 (33.3)		42 (20.2)	15 (41.7)	
Moderate	69 (28.3)	29 (25.4)	5 (33.3)		60 (28.8)	9 (25)	
High	118 (48.4)	62 (54.4)	5 (33.3)		106 (51)	12 (33.3)	
*p-value < 0.05 from logistic regression							

Based on these differences in characteristics of participants missing income versus reporting income levels, we conducted an analysis including participants with missing income data, using imputed median household incomes from United States census data. We used addresses obtained from subjects that were cleaned and fed through United States Census Bureau geocoding for the 2010 Census to get the most matches (52). Participants that did not match Census tract geocoding were resolved first by Google Maps (53) , and then submitted individually to the Census web site for a tract number. The census tract number was then matched with the median household income for that census tract during 2012 (54). This process produced a median household income for 239 total participants, and 35 of 36 participants who had self-reported income data missing. Five participants did not have enough information available to attain census income information.

Table VII
IMPUTED INCOMES AND SELF-REPORTED INCOMES IN PARTICIPANTS WITH BOTH MEASURES[a]

		Approximated Income from Census Tract			
		Less than $10,000	**$10,000-$19,999**	**$20,000-$49,999**	**$50,000+**
Self-Reported Income	**N = 204**		**34 (17.1)**	**131 (65.8)**	**39 (17.1)**
Less than $10,000	**82 (39.7)**	0	16	50	16
$10,000-$19,999	**56 (27.6)**	0	11	38	7
$20,000-$49,999	**41 (20.1)**	0	4	28	9
$50,000+	**25 (12.6)**	0	3	15	7

[a]Chi Square p-value = 0.5290

This distribution of the imputed incomes was not significantly associated (p-value=0.5290) with self-reported incomes in persons with both measures (Table VII). We examined the effect of using the four-level income variable as well as the eight-level income variable and produced similar results. Among participants missing self-reported income, imputed incomes were distributed as follows: $10,000-$19,000 = 11%, $20,000-$49,999 = 77%, and <$50,000 = 11%.

In general, the models that included imputed income for participants missing self-reported income were somewhat attenuated (Table VII). For the subgroup with high A1C at baseline, the longitudinal model adjusting for age and income covariates found a significant increase in the odds of having high A1c for “a lot of trouble” versus ”no trouble” travel burden on having high A1C during the 2-year study period, 3.276 (95% CI=1.210, 8.872; p-value=0.0197) and the odds ratio for an increase in 1 category of travel burden was significant as well, 1.311 (95% CI=1.015, 1.693; p-value=0.0383). There were no significant associations in models using the full sample when including participants with approximated income data.

With respect to effect modification, when including participants with imputed income in the analysis, BMI was no longer an effect modifier, but the association of high A1C with travel burden was modified by income (full sample) and diabetes support (high A1C at baseline sample) (data not shown).

Table VIII
ODDS RATIOS (95% CI) FOR ASSOCIATION OF HAVING HIGH A1C DURING 2-YEAR STUDY WITH INCREASED BURDEN TO TRAVEL TO CLINIC ADJUSTED FOR AGE AND INCOME, WITH IMPUTED INCOME IF SELF-REPORTED INCOME NOT AVAILABLE

Study sample	Travel Burden	N	Odds Ratio (95% C. I.) Adjusted for age and income	P-value
High A1C at baseline	Per increase in 1 category of travel burden	128	1.311 (1.015, 1.693)	0.0383*
	No trouble	83	Reference	
	A little trouble	15	1.122 (0.532, 2.367)	0.7610
	Some trouble	18	1.238 (0.600, 2.554)	0.5633
	A lot of trouble	12	3.276 (1.210, 8.872)	0.0197 *
Full sample with high and low A1C at baseline	Per increase in 1 category of travel burden	242	1.115 (0.818, 1.518)	0.4906
	No trouble	146	Reference	
	A little trouble	37	0.810 (0.330, 1.989)	0.6448
	Some trouble	36	0.923 (0.381, 2.236)	0.8586
	A lot of trouble	23	1.971 (0.642, 6.049)	0.2350

*p-value < 0.05 from logistic regression

We also modeled the A1C and travel burden relationship using only imputed incomes. Categorizing income using the same four definitions used in earlier analyses resulted in over 60% of participants being grouped into the $20,000-$49,999 category. We used a six-level of income variable to provide a more even distribution of participants (Table IX). Models using the six-level income variable produced similar results to treating income as a continuous variable.

Table IX
IMPUTED INCOMES FOR FULL SAMPLE

Income	N = 239
Less than $20,000	38 (15.9)
$20,000-$29,999	57 (23.9)
$30,000-$39,999	52 (21.8)
$40,000-$49,999	48 (20.1)
$50,000-$59,999	22 (9.2)
$60,000+	22 (9.2)

Among the subgroup with high A1C at baseline, the longitudinal model for the effect of travel burden on having high A1C during the 2-year study period adjusting for age and imputed income was significant, 1.291 (95% CI=1.004, 1.661; p-value=0.0468) (Table X). There was also a significant increase in the odds of having high A1c for “a lot of trouble” versus ”no trouble” travel burden on having high A1C during the 2-year study period, 3.208 (95% CI=1.185, 8.680; p-value=0.0219). Models using the full sample with imputed income data found no significant associations.

Table X ODDS RATIOS (95% CI) FOR ASSOCIATION OF HAVING HIGH A1C DURING 2-YEAR STUDY WITH INCREASED BURDEN TO TRAVEL TO CLINIC ADJUSTED FOR AGE AND IMPUTED INCOME				
Study sample	**Travel Burden**	**N**	**Odds Ratio (95% C. I.) Adjusted for age and income**	**P-value**
High A1C at baseline	Per increase in 1 category of travel burden	127	1.291 (1.004, 1.661)	0.0468*
	No trouble	82	Reference	
	A little trouble	15	1.085 (0.521, 2.260)	0.8279
	Some trouble	18	1.201 (0.588, 2.452)	0.6148
	A lot of trouble	12	3.208 (1.185, 8.680)	0.0219*
Full sample with high and low A1C at baseline	Per increase in 1 category of travel burden	238	1.059 (0.772, 1.452)	0.7223
	No trouble	143	Reference	
	A little trouble	37	0.754 (0.305, 1.862)	0.5399
	Some trouble	36	0.850 (0.348, 2.077)	0.7205
	A lot of trouble	22	1.792 (0.537, 5.505)	0.3605
*p-value < 0.05 from logistic regression				

V. DISCUSSION

This study adds to the knowledge of the impact of travel burden on healthcare outcomes. When controlling for confounding by age and income there was a statistically significant association between self-reported travel burden and high A1C (≥9%) in a low income, minority, urban population. Travel burden was measured with a 4-point scale of "no trouble, little trouble, some trouble, and a lot of trouble." The effect of travel burden on odds of high A1C was not proportionate across categories, and a statistically significant association was only found for "a lot of trouble" versus "no trouble" travel burden. This finding may reflect inconsistency in how respondents answered the three lower levels of the scale. Answering "a lot of trouble" on this scale may reflect a significant barrier to travel that should be considered in the care of diabetes and other health conditions. We also found stronger associations in the subgroup of participants who began the study with high A1C than in the full cohort that included participants with high and low A1C at baseline. Restricting the sample to participants with high A1C (≥9%) at baseline provided a subgroup of participants who had the potential to attain low A1C (<9%) during the 2-year study period. However, 25% of participants with low A1C at baseline were found to have high A1C during the two year follow up period.

Diabetes affects over 10% of the United States population with a higher prevalence among racial minority populations than non-Hispanic whites (1), and uncontrolled elevated blood glucose has been found to lead to heart disease, stroke, kidney disease, diabetic retinopathy and macular edema, dental disease, and diabetic neuropathy in extremities (9). Proper care for diabetes requires ongoing management and healthcare access (2). The need for ongoing access to healthcare makes transportation to healthcare a potential obstacle in successfully managing diabetes. Studies of rural people with diabetes found that greater driving distance to participants' primary care provider was associated with poorer glycemic control (47) (48) and less insulin use (49). An analysis of 973 adults in the Vermont Diabetes Information System divided participants into tertiles based on their driving distance to their primary care provider (47). Median A1C increased with each tertile of distance to the primary care provider in a significant trend (p-value =.022). Linear regression found an increase of .07% in A1C per 10 kilometers in driving distance (95% CI=+0.03, +0.11; p-value=.001). The effect among insulin users was greater, with an increase of .22% in A1C per 10 kilometers in driving distance (95% CI=+0.04, +0.40; p-value=.016). An additional analysis of 781 adults from the Vermont Diabetes Information System found that the odds ratio for insulin use for each kilometer of driving distance was 0.97 (CI=0.95, 0.99; p-value=0.013) (49). A study of 3,369 individuals with type 2 diabetes in Southwestern Pennsylvania examined the driving distances of participants with and without controlled A1C (≤ 7%) (48). The odds ratio for uncontrolled A1C for participants living greater than 10 miles from their primary care provider was 1.91 (CI=1.59, 2.30; p-value<0.0001).

To our knowledge there is limited data on transportation and barriers and diabetes management in urban populations. Urban and rural areas have significant differences in commuting transportation behaviors (50), so it is important to understand transportation burden for urban people with diabetes as well. In addition to having a higher prevalence of diabetes, racial minorities experience greater transportation burden to access health care (37). Our findings add to the literature by finding an association between self-reported transportation burden and high A1C levels for racial minorities with diabetes in an urban setting.

This study found differences in the association of travel burden with high A1C by level of diabetes support and BMI among participants with high A1C at baseline and by income in the full sample. Having lower diabetes support from friends and family, lower income, and being obese were each associated with travel burden having a greater effect on odds of high A1C. Prior literature has found low income to be associated with poorer diabetes control (24), increased diabetes-related deaths (19), and a greater impact of transportation barriers (37), but we are not aware of data identifying low income as an effect modifier of travel burden and health outcomes. Nor did we find any prior literature on diabetes social support or obesity as effect modifiers for this association. These findings provide easily identifiable factors that may indicate patients who may struggle with controlling their A1C due to travel burden. Group interventions could facilitate the diabetes social support for people with diabetes reporting low diabetes social support.

Collecting information on travel burden may be useful for longitudinal studies in a primary care setting to identify patients who may more frequently miss study clinic visits. Among our participants reporting “a lot of trouble” with travel to their primary care provider, only 58% completed all four data collection visits compared to approximately 75% for participants reporting any of the lower categories of travel burden. Greater efforts can be focused on collecting data from these participants to determine if they differ from participants who are not lost to follow up. Providing greater support to participants with high travel burden to get them to clinic visits may improve the quality of data collected during studies.

Our bivariate analysis of baseline characteristics found that higher self-reported travel burden was associated with Hispanic Latino/other versus African American/Black race/ethnicity, lower educational attainment, and lower self-reported health status. All participants in the study were racial minorities. Most prior research has focused on racial minority groups travel burden compared to Non-Hispanic Whites (37), but one study found Hispanics had a greater travel burden to cancer treatment than African Americans in Texas (55). Since the questionnaires were delivered in English and Spanish, it is possible that the scale was interpreted differently depending on language used. Prior literature did not provide information on self-reported travel burden and education or health status.

There are several limitations to this study. First, the results of this study are generalizable only to low-income Black and Hispanic people with uncontrolled diabetes in an urban setting. However, this population has substantial diabetes morbidity and has been understudied for the impact of travel burden on A1C levels. Second, self-reported income data was missing for 15% of participants. To address this, we imputed income using the 2012 median census tract household income. Sensitivity analyses using the imputed incomes for participants missing self-reported income, as well as imputed incomes for all participants were consistent with our primary findings in the subgroup of participants with high A1C at baseline. Third, independent variables were only measured at baseline, so the effect of changes in these variables over time is not encompassed in this analysis. Lastly, participants who reported the highest level of travel burden completed a smaller proportion of data collection visits, reducing our information about their A1C levels. Non-differential attrition could potentially bias the effect estimates, but the bias if present would be towards the null. The strengths of the study include a well-designed clinical trial that was efficiently leveraged to explore a novel hypothesis and took advantage of the longitudinal data using appropriate multivariable modeling methodology.

VI. SUMMARY

To our knowledge, this study is the first to examine the impact of travel burden on A1C levels in diabetics living in an urban setting. This study leverages data from a randomized trial that used community health workers to increase patients' adherence to lifestyle changes and medication use. Using two years of follow up data from patients, the study examined the impact of self-reported travel burden to primary care appointments on glycemic control. With the inclusion of age and income covariates, this study found a statistically significant longitudinal association between self-reported travel burden and patients' A1C levels among patients with high A1C (≥ 9%) at baseline. Models found a statistically significant association only found for "a lot of trouble" versus "no trouble" travel burden. The effect of "little trouble" and "some trouble" did not differ significantly from "no trouble" travel burden in any models. These findings were consistent when using self-reported income data and income data imputed based on median income in participants' census tracts.

Effect modification was identified for diabetes support, BMI, and income. Having low diabetes support from friends and family, low income, and being obese were each associated with travel burden having a greater impact on odds of high A1C. Our findings add to the literature by identifying an association between self-reported travel burden and a poorer health outcome for racial minorities with diabetes in an urban setting. However, these findings need replication in similar populations and should be extended to additional demographic groups. Future studies should also explore mediating factors between self-reported transportation burden and A1C level, such as clinic visits and medication adherence. The self-reported travel burden scale should be further examined as a tool to identify patients with difficulty making clinic visits. Bivariate analysis found associations between demographic variables (race, education, health status) and travel burden. Future studies should use adjusted models to examine these relationships.

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VITA

NAME: James McCombs

EDUCATION

M.S., *Public Health Sciences (Epidemiology)*
University of Illinois at Chicago, 2020
Thesis Topic: Healthcare Travel Burden and Diabetes Management

M.P.H., *Health Behavior and Health Education*
University of Michigan at Ann Arbor, 2011

B.S., *Recreation, Sport, and Tourism*
University of Illinois at Urbana-Champaign, 2009

RESEARCH EXPERIENCE

McCombs JL, Gerber BS, Sharp LK, Turyk ME (2020). Healthcare Travel Burden and Diabetes Management. *Manuscript in preparation.*

Ronald McNair Scholar, University of Illinois at Urbana-Champaign, 2008.

WORK EXPERIENCE

Community Health Program Coordinator, University of Illinois Extension, May 2015 – Present

Special Initiatives Coordinator, Illinois African American Coalition for Prevention, June 2013 – May 2015

Research Interviewer, National Opinion Research Center, August 2012 – March 2013

Research Project Assistant, Mathematica Policy Research, October 2011 – December 2012

Research Assistant, University of Michigan Center for Managing Chronic Disease, January – April 2011

SKILLS

Research Methods

SAS, STATA, & Excel

Health Education

Project Management