



Exploratory analysis of medication adherence and social determinants of health among older adults with diabetes

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ABSTRACT

Background: Diabetes is the fifth leading cause of death in the United States (US), affecting approximately 27%, or 15.9 million adults 65 years of age and older. Diabetes is the most expensive chronic condition in the US and accounts for the second largest avoidable healthcare cost. Adherence to long-term medication treatment plans is crucial among patients with diabetes because it decreases risk of developing comorbid conditions and improves quality of life. Greater exposure to adverse social determinants of health (SDOH) over an individual's lifespan can result in worse health outcomes. Hence, it is important to obtain a better understanding of how social determinants of health (SDOH) influence patients' behaviors and affect medication adherence among older adults with diabetes.

Objectives: Identify and prioritize SDOH associated with medication adherence among a nationally representative sample of older adults with diabetes. Secondary objectives were to characterize SDOH, estimate medication adherence, and explain implications for health disparity populations among older adults in the US who have been diagnosed with diabetes.

Methods: This study used a cross-sectional secondary data analysis to examine the National Health and Nutrition Examination Survey database, identifying associations between SDOH and medication adherence among older adults with diabetes in the US.

Results: A total of 1807 respondents' data were included in the analyses. Nearly three-quarters (73.9%) of patients were considered adherent to their oral diabetes medications. Multivariable analysis revealed significant differences in medication adherence based on disability status ($p = 0.016$), household balanced meals ($p = 0.033$), and interview language ($p = 0.008$).

Conclusions: Results revealed those with a disability, those who could not afford a balanced meal, and/or those who spoke English were associated with a higher likelihood of being nonadherent to their diabetes medications in comparison to individuals not in these groups. These findings can assist in developing SDOH-centered medication adherence strategies for pharmacists to implement with older patients with diabetes.

1. Introduction

Diabetes is a chronic health condition affecting how the body converts food into energy, and it is the fifth leading cause of death in the United States (US).¹ According to the American Diabetes Association (ADA), the percentage of Americans aged 65 and older with diabetes is

high, at approximately 29.2%, or 15.9 million older adults.² Further, diabetes is the most expensive chronic condition in the US^{3,4} accounting for the second largest amount of avoidable healthcare costs.⁵ Essentially, \$1 out of every \$4 in US healthcare costs are spent on caring for patients with diabetes.³ Approximately, 61% of diabetes expenses are for adults aged 65 or older, which is primarily paid by the Medicare program.^{3,6}

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Health inequities related to diabetes and diabetes-related complications are well documented and have been associated with greater risk and population prevalence for diabetes and poorer diabetes-related outcomes.^{4,7–9} Greater exposure to adverse social determinants of health (SDOH) over an individual's lifespan results in worse health outcomes.¹⁰ SDOH are defined as “the economic, environmental, political, and social conditions in which people live and are responsible for a major part of health inequality worldwide”.¹¹ The American Diabetes Association (ADA) 2023 Standards of Care recommend assessing SDOH including food insecurity, housing insecurity/homelessness, financial barriers, and social capital/social community support to inform treatment decisions.¹⁰

Despite the effects of diabetes medications on blood glucose levels,¹² a recent systematic review estimated that adherence rates to diabetes medications are relatively unchanged since 2007; these rates range from 31 to 87% (for retrospective studies) and 53–98% (in prospective studies), respectively.¹³ Hence, medication adherence continues to be a major challenge for those with diabetes.¹⁴ The World Health Organization (WHO) created a conceptual framework which demonstrates medication adherence is impacted by the interaction of five types of barriers: patient-related, health care system-related, therapy-related, condition related, and social and economic factors.¹⁵ There is evidence of a significant association between SDOH and medication adherence¹³; however, there has been relatively few studies that have examined the relationship between SDOH and medication adherence, especially for older adults with diabetes.^{13,16}

Given that low adherence and uncontrolled diabetes remain clinical challenges among older adults with diabetes, there is a critical need to identify and prioritize the SDOH associated with older adults' adherence to medications to better understand how pharmacists can assist in the development of strategies to modify the relationships between these factors for the prevention and management of diabetes.^{17,18}

Thus, the objective of this study was to identify and prioritize SDOH associated with medication adherence among a nationally representative sample of older adults with diabetes. Secondary objectives were to characterize SDOH, estimate medication adherence, and explain implications for health disparity populations among older adults in the US who have been diagnosed with diabetes.

2. Methods

2.1. Study design

This study was part of a larger project to identify the association between SDOH and medication adherence among older adults with chronic conditions (i.e., hypertension, high cholesterol and/or diabetes). The focus of this manuscript was medication adherence among individuals in the US with diabetes. This study used a cross-sectional secondary data analysis to examine the nationally representative National Health and Nutrition Examination Survey (NHANES) database to identify associations between SDOH and medication adherence among older adults with diabetes in the US. Applicable data were downloaded from the NHANES website for the five most recent biannual years of data collection. The NHANES includes a series of cross-sectional nationally representative health examination surveys and is designed to assess the health and nutritional status of US adults and children.¹⁹ The datasets were combined by the respondent's identification numbers using SAS version 9.4 (SAS Institute, Inc., Cary, NC). The study population was respondents aged 65 and older, whose healthcare providers told them they had diabetes. IRB approval was not required for this study since the research was performed on publicly available, deidentified secondary data. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement guidelines were consulted in the reporting of this manuscript.²⁰

2.2. Conceptual framework

Adeoye-Olatunde et al.'s integrated conceptual framework on social determinants of health and medication adherence was used to guide this study (Fig. 1) and is further described elsewhere.²¹ It consists of two complementary conceptual frameworks to identify SDOH and medication adherence-related variables from the NHANES database. First, structural and intermediary determinants of medication adherence were adapted from the WHO Commission on Social Determinants of Health (CSDH) Framework.²² The CSDH framework was adapted by redefining health system access as medication access and the health outcome of interest as medication adherence. Second intermediary determinants specific to medication access barriers were identified using the Pharmacy Quality Alliance Medication Access Conceptual Framework.²³

2.3. Data sources, variables, and management

Specific NHANES data sources, variables, how data variables mapped to conceptual framework elements, and how data were managed are described in detail in Appendix A. In summary, NHANES variables used to operationalize and examine structural determinants included lower social class, gender, race, ethnicity, highest level of education, employment status, and household income to poverty ratio. The intermediary determinants included household balanced meal status (material circumstances), alcohol consumption and smoking status (behaviors), age (biological factors), and marital status (psychosocial factors). Medication access barriers (also intermediary determinants) included health insurance status, language in which the NHANES interview was conducted, usual place for healthcare status (provider availability), disability status, and a proxy for health literacy based on the Demographic Assessment for Health Literacy (DAHL).²⁴

2.4. Statistical analysis

All respondents, ages 65 and older, who were told by their healthcare providers that they had diabetes were included in the analyses. The outcome was a binary variable indicating whether a respondent was adherent to their prescribed diabetes medication(s). Respondents currently taking prescribed oral medication(s) were considered adherent, while those who did not take prescribed medication(s) were defined as nonadherent. Those who were not told they had diabetes were not included in the sub-analysis. Logistic regression analyses were performed for continuous predictors and Rao-Scott Chi-Square tests for categorical ones. Predictors with p -values <0.20 in the univariate analyses were included in the multivariate analysis. A 5% significance level was used for all tests.

3. Results

A total of 1807 respondents' data were included in the analyses. Table 1 provides the demographic characteristics. Most respondents were 75 years of age or older (41.8%), identified as male (53.8%), Non-Hispanic White (40.2%), married (57.0%), completed at least a high school education but did not graduate from college (46.7%), and not employed (86.5%). Overall, nearly three-quarters of patients (73.9%) were considered adherent to their diabetes medications. The mean health literacy score was 66.3 (standard deviation (SD) =14.7), indicating marginal to adequate health literacy,²⁴ with a minimum score of 27.2 and a maximum score of 91.3 (Table 2). The mean household income to poverty ratio was 1.9 (SD = 1.1), indicating an income at 190% of the poverty level for their family,²⁵ with a minimum of 0.0 and a maximum of 5.0. The mean prescription medication count was 6.6 (SD = 3.3) with a minimum of one and a maximum of 22 medications.

Table 3 provides the results of the univariate analysis with categorical predictors. This analysis revealed significant differences in adherence to medications based on one structural determinant: race ($p =$

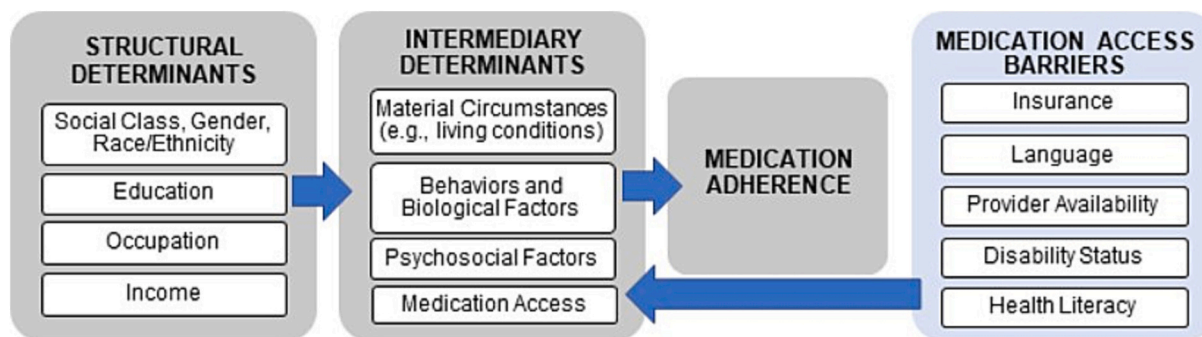


Fig. 1. Adeoye-Olatunde et al.'s integrated conceptual framework on social determinants of health and medication adherence.²¹

0.015) and several intermediary determinants: age group ($p = 0.001$), disability status ($p < 0.001$), household balanced meals ($p = 0.001$) and interview language ($p = 0.004$). Table 4 provides univariate analysis with continuous predictors, which revealed no statistically significant differences in adherence. After controlling for all predictors included in the model, multivariate analysis results provided in Table 5 revealed significant differences in medication adherence based on disability status ($p = 0.016$), household balanced meals ($p = 0.033$), and interview language ($p = 0.008$). Accordingly, the likelihood of being adherent to diabetes medication was about 56% higher for those individuals who did not have a disability when compared to individuals who had a disability ($p = 0.016$). The odds of being adherent to diabetes medication was about 44% higher for those individuals who could afford balanced meals when compared to those who could not afford balanced meals ($p = 0.033$). The odds of being adherent to diabetes medication was about 83% higher for those individuals who completed the NHANES survey interview in Spanish when compared to those individuals who completed the interview in English ($p = 0.008$).

4. Discussion

This is one of the first known studies to examine the association between SDOH and medication adherence among adults 65 years and older with diabetes in the US using NHANES data and an integrated SDOH and medication adherence conceptual framework. Previous researchers have investigated the causes of poor medication adherence and identified groups of people at risk of discontinuing treatment.^{8,13,26,27} Our findings are consistent with this growing body of literature that demonstrates SDOH negatively impacts health outcomes.^{8,13,26,27} For example, Walker et al. also found that race (and ethnicity) significantly and negatively affected medication adherence and health outcomes for adults with diabetes while Patel et al. identified cost-related nonadherence as a challenge for adults with diabetes.^{8,27} In the current study, being adherent to diabetes medication was higher for those individuals who did not have a disability when compared to individuals who had a disability. These findings are consistent with those of Zhang et al. whose results demonstrated that medication adherence was worse for patients with disabilities compared to those without a disability.²⁸

When examined individually, our findings indicate that structural and intermediary determinants of health are associated with medication adherence in older adults with diabetes. However, when examined collectively, one modifiable intermediary determinant of health remained significantly associated with medication adherence: ability to afford household balanced meals. A recently published systematic review and meta-analysis conducted by Wilder et al. supports our findings as they also found food insecurity demonstrated a strong relationship with medication adherence.¹³ Our multivariate analysis findings align with other previously published literature regarding a significant association between medication adherence and household balanced meals as well. For example, Sattler, Lee, and Bhargava found that 57% of food

insecure older adult Medicare beneficiaries were nonadherent to their diabetes medications.²⁹ Other published studies have also identified associations between medication nonadherence and food insecurity.^{30–32} Additional research collating and evaluating what Medicare is currently doing to address food insecurity is needed.

Brookhart et al. examined patient medication taking behaviors after long periods of nonadherence and determined whether reinitiating treatment was linked to potentially modifiable factors (i.e., physician visits, lab testing) or other encounters with the healthcare system.²⁶ Their findings suggest that continuity of care combined with increased follow-up and lab testing (i.e., HbA1c values) could promote long-term adherence by shortening or eliminating lengthy gaps in medication use. In addition, they recognized improving medication adherence is challenging and that multifaceted, patient-centered interventions are most effective. Our study sought to elaborate on Brookhart's work by using a comprehensive integrated conceptual framework to better understand patterns of medication use among individuals with diabetes as well as identify SDOH factors that impact adherence and could be addressed to improve adherence rates.

Like Wilder et al., our study results provide further evidence of the importance of conducting multidimensional SDOH assessments.³³ These assessments allow for better understanding of the multifaceted relationship between structural and intermediary determinants of health and medication adherence.

For patients with chronic, long-term conditions such as diabetes, their treatment plan may need to be reviewed and revised periodically, based on patient specific factors. Their prescribers will make appropriate modifications to their treatment plans that incorporate more effective interventions, as necessary, to achieve improved medication adherence and health outcomes. However, the prescriber may not be the first healthcare provider to become aware of their patients' challenges with medication adherence. Community pharmacists are medication experts and one of the most accessible health care professionals in the US.³⁴ In fact, pharmacists are the third largest group of healthcare professionals across the globe.³⁵ As such, they can identify potential challenges with medication adherence by initiating conversations with patients about adherence concerns and examining patient prescription dispensing data.

Research has demonstrated that pharmacists have positive impacts on medication adherence in diverse patient populations.³⁶ Pharmacists use various approaches to improve patient medication adherence including face-to-face communication, over the phone, via telehealth and/or the internet; they can also provide focused, individualized sessions through medication therapy management (MTM).³⁷ Baker, Forkum, and McNeal found that in-person and video telehealth patient-pharmacist interactions improved access and optimized pharmacists' roles in diabetes management.³⁸ Twigg, Motsko, Thomas, and David found that community pharmacist-led educational interventions resulted in improved A1c levels for older adults who were high-risk Medicare beneficiaries with diabetes.³⁹ Furthermore, findings from a systematic analysis of pharmacy-led interventions to improve adherence among

Table 1
Categorical characteristics for patients with diabetes.

Variable (N)	Level	N (%)
Age Group (N = 1807)	65–69 years	570 (31.5%)
	70–74 years	482 (26.7%)
	75+ years	755 (41.8%)
Alcohol Consumption Category ¹ (N = 1265)	Never Drinks	604 (47.7%)
	Light Drinking	610 (48.2%)
	Moderate Drinking	42 (3.3%)
	Heavy Drinking	9 (0.7%)
Disability Status (N = 1806)	No Disability	1127 (62.4%)
	Has Disability	679 (37.6%)
Education (N = 1800)	< High School Graduate	675 (37.5%)
	≥ High School Graduate, but not College Graduate	840 (46.7%)
	College Graduate	285 (15.8%)
Employment Status ² (N = 1806)	Not Employed	1562 (86.5%)
	Employed	244 (13.5%)
Ethnicity ³ (N = 1742)	Hispanic	416 (23.9%)
	Non-Hispanic	1326 (76.1%)
Gender (N = 1807)	Female	834 (46.2%)
	Male	973 (53.8%)
Household Balanced Meals (N = 1746)	Could Afford	1399 (80.1%)
	Could Not Afford	347 (19.9%)
Insurance ⁴ (N = 1805)	Medicaid	286 (15.8%)
	Medicare	1285 (71.2%)
	Other	178 (9.9%)
	None	56 (3.1%)
Interview Language (N = 1807)	English	1580 (87.4%)
	Spanish	227 (12.6%)
Lower Social Class ⁵ (N = 1612)	Not Lower Social Class	902 (56.0%)
	Lower Social Class	710 (44.0%)
Marital Status (N = 1807)	Not Married	777 (43.0%)
	Married	1030 (57.0%)
Race ⁶ (N = 1807)	Non-Hispanic Black	450 (24.9%)
	Other	630 (34.9%)
	Non-Hispanic White	727 (40.2%)
Smoking Status (N = 943)	Does Not Smoke	788 (83.6%)
	Smokes	155 (16.4%)
Usual Place for Healthcare (N = 1807)	Does Not Have Usual Place	33 (1.8%)
	Has Usual Place	1774 (98.2%)
Usual Place for Healthcare Type (N = 1772)	Clinic or Health Center	420 (23.7%)
	Doctor Office or HMO	1218 (68.7%)

Table 1 (continued)

Variable (N)	Level	N (%)
Diabetes Medication Adherence (N = 1807)	Hospital Emergency Room	50 (2.8%)
	Hospital Outpatient	58 (3.3%)
	Other	26 (1.5%)
	Not Adherent	471 (26.1%)
	Adherent	1336 (73.9%)

Abbreviations: HMO - Health maintenance organization.

¹ Alcohol consumption categories were calculated using responses for the number of days alcoholic drinks were consumed annually, the number of drinks consumed on those drinking days, and guidelines from previous literature.¹⁸

² Not Employed included those reporting they were not working at a job or business, looking for work, or retired. Employed included those who reported working at a job or business.

³ Ethnicity categories were developed from NHANES Race/Hispanic origin categories. “Hispanic” includes respondents identifying as Mexican American or Other Hispanic. “Non-Hispanic” includes respondents identifying as Non-Hispanic White, Non-Hispanic Black, and Non-Hispanic Asian. Respondents identifying as Other Race – Including Multiracial were categorized as missing.

⁴ Respondents with Medicaid as at least one source of health insurance are reflected in the “Medicaid” category, respondents with Medicare (but not Medicaid) as at least one source of insurance are reflected in the “Medicare” category, all other respondents without Medicaid or Medicare are reflected in the “Other” category. Insurance types reflected in the “Other” category include private insurance, Medi-Gap, military health care, state-sponsored health plans, other government insurance, and single-service health plans.

⁵ Respondents with annual family incomes of \$25,000 or less were classified as lower social class.

⁶ The “Other” race category contains those respondents who did not identify as Non-Hispanic Black or Non-Hispanic White. “Other” races include Mexican American [242 (13.4%)], Other Hispanic [174 (9.6%)], Non-Hispanic Asian [149 (8.3%)], and Other Races – Including Multiracial [65 (3.6%)].

Table 2

Continuous patient characteristics for diabetes subgroup.

Variable	N	Mean (SD)	Min	Q1	Median	Q3	Max
Health Literacy	1737	66.3 (14.7)	27.2	54.4	68.7	77.3	91.3
Household Income to Poverty Ratio	1405	1.9 (1.1)	0	1.0	1.6	2.5	5.0
Prescription Medication Count	1771	6.6 (3.3)	1	4	6	9	22

adults with diabetes supported the role of pharmacists in diabetes care to enhance medication adherence.⁴⁰

Pharmacists can provide screening services to identify potential medication adherence issues and to connect patients with appropriate resources.⁴¹ Pharmacists can conduct screenings as part of their usual patient care activities. Kiles et al. provides a helpful framework for pharmacists to effectively engage patients in SDOH screenings in community pharmacies.⁴² Their framework suggests pharmacists should receive training to integrate the themes of rationale, relationship, and resources into their interactions with patients to facilitate screenings for social risk factors. Screening of SDOH can provide insight into medication taking behaviors, lifestyle choices, management of diabetes, as well as health service utilization. Accordingly, pharmacists are well-positioned to assess the impact of SDOH such as food insecurity as well as other SDOH on medication taking and provide applicable resources based on individual needs.⁴³

The current findings present a crucial opportunity to expand community pharmacy-based Medicare beneficiary medication adherence programs to prioritize screenings and providing resources to patients for

Table 3
Univariate analysis of diabetes medication adherence with categorical predictors.

Determinant Type	Study Variable	Level	Medication Adherence				p-value
			Adherent		Not Adherent		
			N (%)	Weighted Frequency (%)	N (%)	Weighted Frequency (%)	
Structural Determinants	Gender	Female	608 (72.9%)	3,351,292 (72.9%)	226 (27.1%)	1,245,638 (27.1%)	0.139^b
		Male	728 (74.8%)	3,791,979 (77.4%)	245 (25.2%)	1,106,007 (22.6%)	
	Race	Black	321 (71.3%)	861,309 (70.3%)	129 (28.7%)	364,383 (29.7%)	0.015^a
		Other	488 (77.5%)	1,504,572 (80.2%)	142 (22.5%)	371,838 (19.8%)	
	Ethnicity	White	527 (72.5%)	4,777,391 (74.7%)	200 (27.5%)	1,615,425 (25.3%)	0.865
		Hispanic	311 (74.8%)	746,419 (75.0%)	105 (25.2%)	248,664 (25.0%)	
	Education	Not Hispanic	971 (73.2%)	6,028,392 (74.6%)	355 (26.8%)	2,054,914 (25.4%)	0.260
		<HS Grad	495 (73.3%)	1,778,442 (73.4%)	180 (26.7%)	645,613 (26.6%)	
	Employment Status	College Grad	220 (77.2%)	1,569,503 (79.3%)	65 (22.8%)	409,567 (20.7%)	0.579
		HS Grad	617 (73.5%)	3,783,470 (74.7%)	223 (26.5%)	1,281,964 (25.3%)	
	Lower Social Class	Not Employed	1146 (73.4%)	6,092,293 (74.9%)	416 (26.6%)	2,041,206 (25.1%)	0.951
		Employed	189 (77.5%)	1,049,999 (77.2%)	55 (22.5%)	310,439 (22.8%)	
	Age Group	Lower Social Class	671 (74.4%)	4,385,266 (75.9%)	231 (25.6%)	1,395,648 (24.1%)	0.001^a
		65–69	447 (78.4%)	2,422,016 (78.6%)	123 (21.6%)	660,032 (21.4%)	
	Alcohol Consumption Category ^c	70–74	374 (77.6%)	2,053,504 (81.3%)	108 (22.4%)	473,461 (18.7%)	0.312
75+		515 (68.2%)	2,667,752 (68.7%)	240 (31.8%)	1,218,153 (31.3%)		
Disability Status	Heavy	9 (100.0%)	41,978 (100.0%)	0 (0.0%)	0 (0.0%)	<0.001^a	
	Light	467 (76.6%)	3,001,230 (76.7%)	143 (23.4%)	909,941 (23.3%)		
Household Balanced Meals	Moderate	30 (71.4%)	199,296 (78.4%)	12 (28.6%)	54,872 (21.6%)	0.001^a	
	Never	430 (71.2%)	2,079,279 (74.0%)	174 (28.8%)	731,511 (26.0%)		
Insurance	No Disability	886 (78.6%)	4,972,736 (79.0%)	241 (21.4%)	1,323,670 (21.0%)	0.675	
	Has Disability	449 (66.1%)	2,168,273 (67.8%)	230 (33.9%)	1,027,975 (32.2%)		
Interview Language	Could Not Afford	1050 (75.1%)	6,043,482 (77.1%)	349 (24.9%)	1,797,963 (22.9%)	0.004^a	
	Could Not Afford	239 (68.9%)	908,644 (67.6%)	108 (31.1%)	436,178 (32.4%)		
Marital Status	Medicaid	213 (74.5%)	748,111 (75.9%)	73 (25.5%)	236,914 (24.1%)	0.219	
	Medicare	945 (73.5%)	5,553,212 (74.8%)	340 (26.5%)	1,873,676 (25.2%)		
Usual Place for Healthcare	None	44 (78.6%)	163,122 (84.9%)	12 (21.4%)	29,103 (15.1%)	0.182^b	
	Other	133 (74.7%)	676,908 (76.4%)	45 (25.3%)	209,445 (23.6%)		
Smoking Status	English	1148 (72.7%)	6,712,271 (74.8%)	432 (27.3%)	2,261,663 (25.2%)	0.649	
	Spanish	188 (82.8%)	431,000 (82.7%)	39 (17.2%)	89,982 (17.3%)		
Smoking Status	Not Married	552 (71.0%)	2,824,960 (74.5%)	225 (29.0%)	968,188 (25.5%)	0.219	
	Married	784 (76.1%)	4,318,311 (75.7%)	246 (23.9%)	1,383,457 (24.3%)		
Usual Place for Healthcare	Does Not Smoke	583 (74.0%)	3,364,288 (76.3%)	205 (26.0%)	1,044,787 (23.7%)	0.219	
	Smokes	109 (70.3%)	476,941 (69.2%)	46 (29.7%)	212,200 (30.8%)		
Usual Place for Healthcare	Does Not Have Usual Place	17 (51.5%)	85,263 (66.1%)	16 (48.5%)	43,748 (33.9%)	0.182^b	
	Have Usual Place						

(continued on next page)

Table 3 (continued)

Determinant Type	Study Variable	Level	Medication Adherence				p-value
			Adherent		Not Adherent		
			N (%)	Weighted Frequency (%)	N (%)	Weighted Frequency (%)	
Usual Place for Healthcare Type		Has Usual Place	1319 (74.4%)	7,058,008 (75.4%)	455 (25.6%)	2,307,897 (24.6%)	0.727
		Clinic/Health Center	324 (77.1%)	1,378,083 (77.7%)	96 (22.9%)	396,304 (22.3%)	
		Doctor Office	905 (74.3%)	5,221,996 (75.0%)	313 (25.7%)	1,740,137 (25.0%)	
		Hos ER	35 (70.0%)	147,410 (74.6%)	15 (30.0%)	50,280 (25.4%)	
		Hos OP	38 (65.5%)	212,058 (76.8%)	20 (34.5%)	64,156 (23.2%)	
		Other	16 (61.5%)	91,481 (64.0%)	10 (38.5%)	51,512 (36.0%)	

Abbreviations: HS- High School; Grad- Graduate; Hos- Hospital; ER- Emergency room; OP- Outpatient.

^a Predictors were significant at the alpha = 0.05 level and were included in the multivariable analysis.

^b Predictors with p-values <0.20 were included in the multivariate analysis.

^c To account for the Rao-Scott Chi-Square test's non-zero count assumption, an observation with diabetes medication adherence of "No" and Alcohol Consumption Category of "Heavy" was added to the dataset. This observation was given a small weight of 0.5 to avoid influencing the overall results. This observation is not reflected in the counts in the table above.

Table 4

Univariate analysis of diabetes medication adherence with continuous predictors.

Determinant Type	Variable	Adherent		Not Adherent		Estimate	Odds Ratio	p-value
		N	Mean (SD)	N	Mean (SD)			
Structural Determinant	Household Income to Poverty Ratio	1040	1.9 (1.1)	365	1.9 (1.1)	0.024	1.024	0.741
Intermediary Determinant	Medication Access Barrier	1279	66.6 (14.6)	458	65.3 (14.8)	0.010	1.010	0.060 ^a
Not Applicable	- Health Literacy							
	Prescription Medication Count	1332	6.6 (3.1)	439	6.8 (3.7)	0.024	1.024	0.284

Predictors with p-values <0.20 were included in the multivariate analysis.

Table 5

Multivariate analysis^a of diabetes medication adherence.

Diabetes Multivariate analysis (N = 1678)	Estimate	Odds Ratio	p-value
Age Group			0.097
Age Group (70–74 vs. 65–69)	0.244	1.241	0.068
Age Group (75+ vs. 65–69)	-0.273	0.740	0.065
Disability Status (No Disability vs. Has Disability)	0.223	1.563	0.016 ^b
Gender (Male vs. Female)	0.072	1.155	0.409
Health Literacy	0.003	1.003	0.718
Household Balanced Meals (Could Afford vs. Could Not Afford)	0.181	1.435	0.033 ^b
Interview Language (Spanish vs. English)	0.303	1.832	0.008 ^b
Race			0.722
Race (Black vs. White)	-0.093	0.877	0.434
Race (Other vs. White)	0.055	1.016	0.622
Usual Place for Health Care ^c (Does Not Have Usual Place vs. Has Usual Place)	-0.264	0.590	0.164

Have Usual Place" level from the usual healthcare binary variable.

^a Predictors with p-values <0.20 in the univariate analyses were included in the multivariate analysis.

^b Predictors were significant at the alpha = 0.05 level.

^c Whether the respondent had any usual place for healthcare and the specific usual place for healthcare type were combined into one predictor variable as all responses for a usual place for healthcare type had a response of "Yes" for a usual place for healthcare. The combined variable includes original responses for the usual healthcare place type variable plus the "Does Not

SDOH and medication adherence issues.^{44–46} Future research should evaluate screening/resource program implementation outcomes and determine whether these expansions reduce SDOH barriers and improve medication adherence among older adults with diabetes.

4.1. Limitations

One limitation of the current study was variables such as medication costs (to be examined as a medication access barrier) were not included in the analyses because they were not available in the NHANES database. Therefore, future studies should integrate other databases that include these variables, such as the Medical Expenditure Panel Survey (MEPS). Second, due to limitations with financial resources, the richness of SDOH variable information collected in the NHANES database was prioritized in this study. Future research without such limitations may be able to fully examine the abundance of SDOH variables for a more comprehensive understanding of how these factors impact patient behaviors and adherence. The current study findings are only relevant for older adults with diabetes. There could be differences in SDOH associated with medication adherence in other patient populations with diabetes and with comorbid chronic medical and mental health conditions, warranting additional research. This study used self-report data, which can provide incorrect and/or erroneous information and has the potential for socially desirable responses. Due to the nature of the secondary data analysis, it was not possible to determine which type of diabetes (Type I or II) patients had been diagnosed. Additionally, the way medication adherence was defined and measured for the NHANES could have likely overestimated participants' actual adherence rates. Respondents were not asked about how/often they were taking their prescribed oral medications. Future research should examine these associations with more robust measures of adherence.

5. Conclusions

Several SDOH (e.g., disability status, access to household balanced meals, and interview language) were associated with older adult populations being nonadherent to their oral diabetes medications. The

findings of this study can assist in the development of medication adherence strategies for pharmacists to implement with older patients with diabetes. Future research should build on the current results by examining differences in SDOH associations with medication adherence for patients with diabetes and comorbid medical and mental health conditions.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Appendix

NHANES Section	Data Files	Study Variable Name	Adapted WHO CDSH Framework Elements	SPECIFIC DETERMINANT +/- MED ACCESS BARRIER	NOTES
Study population: Age and number of prescription medications					
Demographics (DMQ)	DEMO_F.XPT, DEMO_G.XPT, DEMO_H.XPT, DEMO_I.XPT, DEMO_J.XPT	Age Group	N/A	N/A	
Prescription Medications (RXQ)	RXQ_RX_F.xpt, RXQ_RX_G.xpt, RXQ_RX_H.xpt, RXQ_RX_I.xpt, RXQ_RX_J.xpt	Prescription Medication Count	N/A	N/A	Included to characterize study population; not considered a SDOH.
Sub-group analysis variables: Inclusion criteria and adherence outcome variables					
Diabetes (DIQ)	DIQ_F.xpt, DIQ_G.xpt, DIQ_H.xpt, DIQ_I.xpt, DIQ_J.xpt	Not Applicable	N/A	N/A	Rationale for adherence variables and interpretation: Factors Associated With Physician Recommendation of Home Blood Pressure Monitoring and Blood Pressure in the US Population https://academic.oup.com/ajh/advance-article/doi/https://doi.org/10.1093/ajh/hpaa093/5857774
Diabetes (DIQ)	DIQ_F.xpt, DIQ_G.xpt, DIQ_H.xpt, DIQ_I.xpt, DIQ_J.xpt	Diabetes Medication Adherence	Medication Adherence	Diabetes	Rationale for adherence variables and interpretation: Factors Associated With Physician Recommendation of Home Blood Pressure Monitoring and Blood Pressure in the US Population https://academic.oup.com/ajh/advance-article/doi/https://doi.org/10.1093/ajh/hpaa093/5857774
Covariates: SDOH (structural and intermediate determinants) to be used for analyses					
Demographics (DMQ)	DEMO_F.XPT, DEMO_G.XPT, DEMO_H.XPT, DEMO_I.XPT, DEMO_J.XPT, DEMO_F.XPT, DEMO_G.XPT,	Gender	Structural Determinant	Gender	
Demographics (DMQ)	DEMO_H.XPT, DEMO_I.XPT, DEMO_J.XPT, DEMO_F.XPT, DEMO_G.XPT,	Race	Structural Determinant	Race/Ethnicity	Health disparity populations: National Institute on Minority Health and Health Disparities: Health Disparity Populations. Accessed 25 March, 2021.
Demographics (DMQ)	DEMO_H.XPT, DEMO_I.XPT, DEMO_J.XPT	Ethnicity	Structural Determinant	Race/Ethnicity	Health disparity populations: National Institute on Minority Health and Health Disparities: Health Disparity Populations. Accessed 25 March, 2021.
Demographics (DMQ)	DEMO_F.XPT, DEMO_G.XPT, DEMO_H.XPT, DEMO_I.XPT, DEMO_J.XPT	Education	Structural Determinant	Education	
Demographics (DMQ)	DEMO_F.XPT, DEMO_G.XPT, DEMO_H.XPT, DEMO_I.XPT, DEMO_J.XPT	Household Income to Poverty Ratio	Structural Determinant	Income	Source: WHO CSDH Framework. Interpretation: In general, a ratio <1 means that the family income was less than the poverty level. When the ratio equals 1, the family income and poverty level were the same, and when the ratio is >1, the family income was higher than the poverty level.

(continued on next page)

(continued)

NHANES Section	Data Files	Study Variable Name	Adapted WHO CDSH Framework Elements	SPECIFIC DETERMINANT +/- MED ACCESS BARRIER	NOTES
					For example, families with income below 50% of poverty indicates their income was half the poverty level. These were the poorest of the poor.
Occupation (OCQ_J)	DEMO_F.XPT, DEMO_G.XPT, DEMO_H.XPT, DEMO_I.XPT, DEMO_J.XPT	Employment Status	Structural Determinant	Occupation	Source: WHO CSDH Framework and Sociology - 8.3 Social Class in the United States: DOI: 10.24926/8668.2401
Demographics (DMQ)	DEMO_F.XPT, DEMO_G.XPT, DEMO_H.XPT, DEMO_I.XPT, DEMO_J.XPT	Age Group	Intermediary Determinant	Biological Factors	Rationale for age categories: Paranjpe R, Johnson ML, Essien EJ, et al. Group- Based Trajectory Modeling to Identify Patterns of Adherence and Its Predictors Among Older Adults on Angiotensin-Converting Enzyme Inhibitors (ACEIs)/ Angiotensin Receptor Blockers (ARBs). Patient Prefer Adherence. 2020;14:1935–1947. doi: https://doi.org/10.2147/ppa.s270809
Demographics (DMQ)	DEMO_F.XPT, DEMO_G.XPT, DEMO_H.XPT, DEMO_I.XPT, DEMO_J.XPT	Marital Status	Intermediary Determinant	Psychosocial	Source: WHO CSDH Framework
Alcohol use (ALQ)	ALQ_F.xpt, ALQ_G.xpt, ALQ_H.xpt, ALQ_I.xpt, ALQ_J.xpt	Alcohol Consumption Category	Intermediary Determinant	Behaviors	REFS: DOI: https://doi.org/10.1016/j.jand.2017.09.030 . United States Department of Agriculture and United States Department of Health and Human Services. Dietary Guidelines for Americans 2015–2020. 8th. Washington, DC: U.S. Government Printing Office; Dec, 2015.
Disability (DLQ)	PFQ_F.xpt, PFQ_G.xpt, DLQ_H.xpt, DLQ_I.xpt, DLQ_J.xpt	Disability Status	Intermediary Determinant	Mediation Access - Disability Status	REF: DOI: https://doi.org/10.1016/j.dhjo.2014.08.007 For this study, a broad definition of physical disability was used. Specifically, we adopted the ICF definition of activity limitation or disability, operationalizing physical disability as self-reported physical limitations or limitations in activities of daily living (ADLs), including difficulty with standing, walking, climbing stairs, bending, reaching, and grasping. Individuals with physical disabilities have 85% ($p < 0.000$) higher odds of having unmet prescription medication needs. Source: WHO CSDH Framework
Smoking - Cigarette Use (SMQ)	SMQ_F.XPT, SMQ_G.XPT, SMQ_H.XPT, SMQ_I.XPT, SMQ_J.XPT	Smoking Status	Intermediary Determinant	Behaviors	Source: WHO CSDH Framework
Hospital Utilization & Access to Care (HUQ)	HUQ_F.XPT, HUQ_G.XPT, HUQ_H.XPT, HUQ_I.XPT, HUQ_J.XPT	Usual Place for Healthcare	Intermediary Determinant	Medication Access - Provider Availability	PQA framework Provider Availability: Includes adequate medical infrastructure, facilities, and competent workforce to provide healthcare and medication after a need is identified.
Hospital Utilization & Access to Care (HUQ)	HUQ_F.XPT, HUQ_G.XPT, HUQ_H.XPT, HUQ_I.XPT, HUQ_J.XPT	Usual Place for Healthcare Type	Intermediary Determinant	Medication Access - Provider Availability	PQA framework Provider Availability: Includes adequate medical infrastructure, facilities, and competent workforce to provide healthcare and medication after a need is identified.
Demographics (DMQ)	DEMO_F.XPT, DEMO_G.XPT, DEMO_H.XPT, DEMO_I.XPT, DEMO_J.XPT	Lower Social Class	Structural Determinant	Social Class	Source: WHO CSDH Framework and Sociology - 8.3 Social Class in the United States: DOI: 10.24926/8668.2401
Health Insurance (HIQ)	HIQ_F.XPT, HIQ_G.XPT, HIQ_H.XPT, HIQ_I.XPT, HIQ_J.XPT	Insurance	Intermediary Determinant	Medication Access - Insurance	All of these health insurance variables will be used to assess insurance. According to PQA med access framework, insurance should be viewed by type vs. yes/no insurance. Source: PQA framework
Demographics (DMQ)	DEMO_J.xpt	Interview Language	Intermediary Determinant	Medication Access - Language	
Food Security (FSQ)	FSQ_F.XPT, FSQ_G.XPT, FSQ_H.XPT, FSQ_I.XPT, FSQ_J.XPT	Household Balanced Meals	Intermediary Determinant	Material Circumstances	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3662286/
Demographics (DMQ)	DEMO_F.XPT, DEMO_G.XPT, DEMO_H.XPT, DEMO_I.XPT, DEMO_J.XPT	Health Literacy	Intermediary Determinant	Medication Access - Health Literacy	REF: The Demographic Assessment for Health Literacy (DAHL): A New Tool for Estimating Associations between Health Literacy and Outcomes in National Surveys. DOI: https://doi.org/10.1007/s11606-008-0699-5

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