

Article

Impact of Cumulative Social Determinants of Health on Odds of Diabetes Incidence in US Veterans

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Abstract

Background: Type 2 diabetes mellitus (T2DM) is a chronic condition that has been attributed to social factors; however, the cumulative effect of social determinants of health (SDOH) on T2DM incidence is not known. **Objective:** The aim of the present study was to examine the association between T2DM and the cumulative burden of multiple SDOH. **Design:** The study is a retrospective cohort study with a baseline between 2008 and 2009 and a ten-year follow-up between 2010 and 2019. **Setting:** The study was conducted using data from the United States Veterans Health Administration (VHA). **Participants:** Out of 10,537,027 patients treated in the VHA between 2010 and 2019, 6,518,102 patients were selected who had no evidence of T2DM or Elixhauser comorbidities at baseline (2008–2009). **Measurements:** Over 10 years following baseline, the exposure consisted of seven types of SDOH occurring in structured data: social isolation, financial stress, employment issues, food insecurity, transportation insecurity, unstably housed, and psychosocial need. Incidence of T2DM in the ten-year follow-up window was the primary outcome. **Results:** Veterans with ≥ 3 SDOH doubled their adjusted odds of T2DM (2.07; CI: 2.05–2.09). There were significant racial differences in cumulative SDOH, with 8.8% of Black individuals having the highest burden of ≥ 3 SDOH compared with 3.8% of White individuals. Transportation insecurity, psychosocial need, and financial stress significantly increased the odds of T2DM across all racial and ethnic groups. Black individuals had the highest T2DM odds ratio for psychosocial need (OR = 1.58; CI: 1.56, 1.60). **Limitations:** The Veteran population is predominantly male, limiting generalization to the wider population. **Conclusions:** With each additional SDOH burden, the odds of T2DM increased, and ≥ 3 SDOH doubled the odds. The cumulative SDOH burden and associated disparities warrant investigation to reduce T2DM incidence.

Keywords: social determinants; health disparity; race and ethnicity; type 2 diabetes mellitus



Academic Editor: Jie Hu

Received: 18 December 2025

Revised: 23 January 2026

Accepted: 5 February 2026

Published: 11 February 2026

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1. Introduction

Social determinants of health (SDOH) capture components of behavioral, economic, and social experiences that impact people's lives and have been shown to have significant effects on the chronic disease of type 2 diabetes mellitus (T2DM) [1–4]. T2DM affects over 37 million Americans [5], and is 2.5 times more likely in United States Veterans than in the general population, with approximately 25% of Veterans having T2DM [6]. Prevalence of T2DM is higher in Hispanic and Black Veterans compared with White Veterans [7]. Despite the Veterans Healthcare Administration (VHA) Medical Centers being part of an equal access healthcare system that establishes policies to reduce disparities, racial disparities continue to exist [8,9]. For the US Veteran population, there are significant racial disparities in clinical outcomes, with Black Veterans having a higher mortality rate with a diagnosis of T2DM and having an increased risk of cardiovascular-related mortality [8,9]. Given that the VHA has tracked SDOH for over a decade [10], it is possible to study the association between SDOH and T2DM in a large cohort with a racially and ethnically diverse population. Understanding the association between SDOH and health outcomes is important to inform policy, program design, and manage limited resources.

There are several studies that track the impact of specific SDOH on T2DM outcomes. Brady et al. [11] examined the odds ratio of having diabetes and reporting a social need. Using a screen of multiple SDOH, they found higher odds of those with diabetes reporting transportation insecurity, food insecurity, housing instability, and lack of companionship [11]. Other studies examining food insecurity have found relationships between poor diabetes glucose control and food insecurity [4,12]. Housing instability has also been associated with poor glucose control, with differences across racial groups [12–14]. Other studies have found that patients with transportation insecurity are more likely to have food insecurity and unmet healthcare needs [15]. Combined measures show an impact on glycemic control in diabetes, with the strongest cluster including housing security, material needs, and lack of transportation contributing the largest risk score, increasing the likelihood of uncontrolled T2DM [16]. Such findings indicate that studies are needed that provide information on SDOH cumulative burden instead of only specific SDOH on the risk of T2DM.

The burden of having multiple SDOH associated with T2DM is not well understood, especially for racial and ethnic minorities. Research tends to focus on the evaluation of specific types of individual SDOH (e.g., food insecurity) [17], and the results are mixed, with White, Black, and Hispanic individuals having larger or smaller risk depending upon the study and type of SDOH [18,19]. Some of the differences in SDOH, particularly if we examine combinations of types of SDOH, could reflect structural racism, which consists of interconnected systems in a society that reinforce inequality and collectively increase odds of adverse health outcomes [20,21]. The World Health Organization (WHO) conceptual framework for SDOH has been used to relate structural racism as an antecedent to SDOH that impacts diabetes outcomes [22,23]. The framework includes structural determinants such as social and public policies that influence SDOH, which aligns with VHA goals of establishing policies to reduce health disparities [24]. The comprehensive dataset on Veterans with social needs provides a consistent resource to examine both specific and cumulative odds of SDOH stratified by race and ethnicity that can inform policy to reduce the burden of SDOH and associated disparities.

In the VHA, SDOH has been associated with mortality of Veterans [25], and there is evidence of cumulative effects from SDOH on suicide ideation and attempts, with risk increasing from an accumulation of SDOH burden [10]. Even though interventions that target SDOH to improve T2DM outcomes are an active area of research [26], the cumulative burden of different types of SDOH on the incidence of T2DM is not well understood and

needs to be investigated. The present study extends work in the field by examining the incidence of T2DM on a large scale with sufficient data to examine race and ethnicity subgroups over a ten-year observational period using the VHA infrastructure for tracking SDOH. This study is timely, given that programs are currently being implemented to address different SDOH [27].

2. Methods

Data Source: A retrospective cohort of Veterans 18 years or older, with and without T2DM, was constructed using the data resources of the VA Informatics and Computing Infrastructure (VINCI). This data were extracted from the VHA Corporate Data Warehouse (CDW) using SQL Server Management Studio 20 and include records from 172 medical centers national level.

Study Population: Primary care patients were selected from the national VA population who were treated in the VHA between 1 January 2008 and 31 December 2019 and had no evidence of T2DM during a baseline window starting 1 January 2008 through 31 December 2009. The baseline cohort was defined between 1 January 2008 and 31 December 2009, and the follow-up period extended from 1 January 2010 through 31 December 2019. Out of the total patient cohort of 10,537,027 individuals (T2DM = 2,418,345 and non-T2DM = 8,118,682), we excluded 1,191,741 patients from the diabetes group who had uncomplicated or complicated diabetes at baseline, and 31,719 patients from the non-diabetes group who had uncomplicated or complicated diabetes at baseline or during follow-up. In addition, we excluded 5914 non-diabetic patients who received insulin at baseline or during follow-up. The purpose of excluding individuals with a diabetes diagnosis during the baseline window was to rule out any prevalent cases of T2DM (identified via ICD-9 codes or medications). Furthermore, we excluded patients with one or more Elixhauser comorbidities during the baseline window of 2008–2009. The diabetes incidence was extracted during the follow-up period from 1 January 2010 to 31 December 2019. Finally, a total of 6,518,102 participants were included in the study (see Figure 1). The methods used to construct the cohort were consistent with our prior involvement in establishing other VHA T2DM cohorts [28].

Exposure and Covariates: The primary exposure variables were seven SDOH that include food insecurity, employment issues, financial stress, unstably housed, social isolation, transport insecurity, and psychosocial need that were captured in the 10-year follow-up window. We followed a similar method used by Blois and colleagues, consisting of a list of codes, sources of data, and definitions of the adverse SDOH [10]. For details on the sources of social determinants of health, see the Supplementary Materials.

The covariates consisted of demographic and clinical data [29]. Sex was coded as ‘female’ and ‘male’ (reference group). Age was separated into the groups of ≥ 65 years, 50–64 years, and < 50 years (reference group). Race and ethnicity were coded as non-Hispanic Black (hereafter, Black), Hispanic, Other (consisting of Asian, American Indian, Alaskan Native, Native Hawaiian and Other Pacific Island individuals), and non-Hispanic White (hereafter, White), analyzed as reference group given the large number of White individuals in the cohort, according to a previously proposed definition combining Veterans Affairs (VA) and Center for Medicare and Medicaid Services (CMS) data [30]. To code for rurality, we aggregated highly rural and rural census tracts based on population density and commuting patterns and coded them as ‘rural’ and urbanized census tract areas defined by the census as ‘urban’ (reference group) [31]. The status of marriage was coded as ‘married’ or ‘non-married’ (reference group). Whether a primary care visit (PCV) occurred in the baseline window was coded with a value of ‘Yes’ or ‘No’ (reference group). Service-connected disability (SCD) was coded as ‘Yes’ if the percentage of military-related disability

was greater than $\geq 50\%$ and 'No' (reference group) if less than 50%. The status of smoking was coded as 'smoker' or 'non-smoker' (reference group).

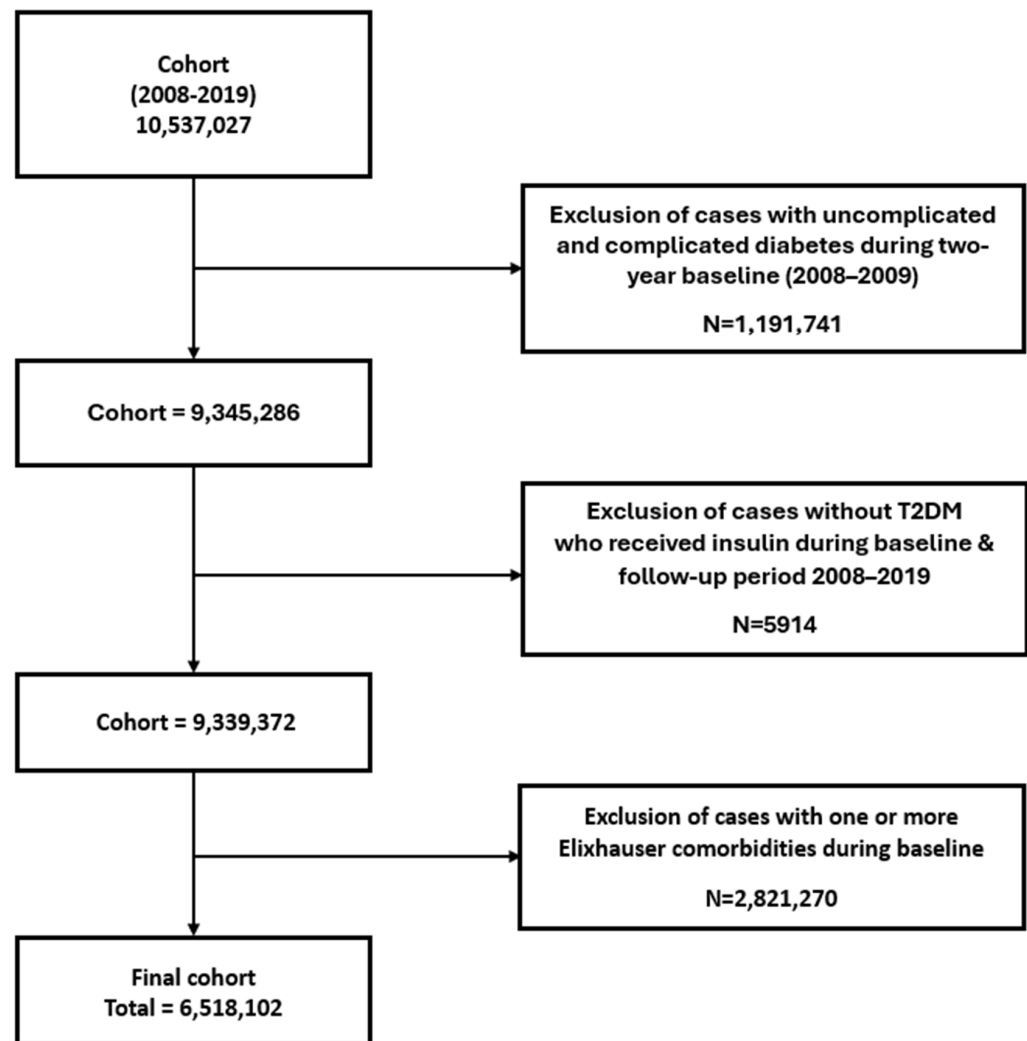


Figure 1. Flow chart for Veterans with and without type 2 diabetes mellitus.

Outcome: A diagnosis of T2DM consisting of two or more ICD9/10 codes of diabetes (250.x0, 250.x2, 357.2, 362.0, or 366.41, E11*) occurring in the follow-up window was the primary outcome. The outcome was coded as a binary value: T2DM = 1 and no-T2DM = 0 (reference group).

Statistical Analysis: Descriptive statistics were computed for each of the demographic and adverse SDOH variables. The distribution of categorical variables between the outcome of T2DM and no-T2DM was compared using chi-square tests. To account for the correlation of repeated measures within individuals and clustering, we used generalized estimating equation (GEE) [32] with an exchangeable correlation structure for estimating the association between the outcome (diabetes status) and the primary exposure (adverse social determinants of health) with adjustment for covariates. GEE was used to model the cumulative burden of SDOH using a category variable denoting burden stratified by race and ethnicity. A separate GEE model was used to assess the individual SDOH stratified by race and ethnicity. Odds ratios (OR) and 95% confidence intervals (CIs) were computed.

The variance inflation factor (VIF) was used to assess collinearity, and the correlation structure was assessed for goodness of fit using the quasi-likelihood information criterion (QIC) [33,34]. Furthermore, we did a sensitivity analysis by fitting the same models for the cohort with and without Elixhauser comorbidities at baseline. The results were consistent

between the main analysis and the sensitivity analysis. A p -value of 0.05 was used for statistical significance, and Stata (ver. 17) was used to conduct analysis, including the xtgee procedure [35].

Role of funding source: The funders of the study had no role in the study design, data collection, analysis, interpretation, writing, or submission of the report.

3. Results

The study population included a total of 6,518,102 patients with a T2DM incidence rate of 12.8% over the 10-year follow-up window (Table 1). All adverse SDOH were more likely among those who developed T2DM. Black individuals had the highest cumulative burden of three or more SDOH at 8.8%, compared with 5.4% for Hispanic, 4.3% for Other, and 3.8% for White individuals. All the GEE logistic regression models in the tables present the variables in the adjusted logistic regression model for the odds of first occurrence of diabetes over the 10-year follow-up window (diabetes status) adjusted for the following demographic and clinical characteristics covariates: race, ethnicity, sex, rurality, age, marital status, PCV, SCD, and smoking status.

Table 1. Descriptive and social determinants of health.

	Total	Diabetes	Non-Diabetes	p -Value
Patients, n (%)	6,518,102 (100)	831,700 (12.8)	5,686,402 (87.2)	
Rurality				<0.001
Urban	4,559,561 (69.95)	540,420 (64.98)	4,019,141 (70.68)	
Rural	1,936,137 (29.70)	289,189 (34.77)	1,646,948 (28.96)	
Missing	22,404 (0.34)	2091 (0.25)	20,313 (0.36)	
Sex				<0.001
Male	5,430,599 (83.32)	790,284 (95.02)	4,640,315 (81.60)	
Female	1,087,456 (16.68)	41,416 (4.98)	1,046,040 (18.40)	
Missing	47 (0)	0 (0)	47 (0)	
Race/ethnicity				<0.001
NHW	4,087,637 (62.71)	581,363 (69.90)	3,506,274 (61.66)	
NHB	929,418 (14.26)	154,404 (18.56)	775,014 (13.63)	
Hispanic	398,014 (6.11)	55,827 (6.71)	342,187 (6.02)	
Other	208,903 (3.20)	29,593 (3.56)	179,310 (3.15)	
Missing	894,130 (13.72)	10,513 (1.26)	883,617 (15.54)	
Marital status				<0.001
Non-Married	2,566,163 (39.37)	310,735 (37.36)	2,255,428 (39.66)	
Married	3,184,348 (48.85)	511,891 (61.55)	2,672,457 (47.00)	
Missing	767,591 (11.78)	9074 (1.09)	758,517 (13.34)	
Age				<0.001
<50 years	2,997,058 (45.98)	168,213 (20.23)	2,828,845 (49.75)	
50–64 years	1,944,936 (29.84)	412,955 (49.65)	1,531,981 (26.94)	
≥65 years	1,343,672 (20.61)	250,176 (30.08)	1,093,496 (19.23)	
Missing	232,436 (3.57)	356 (0.04)	232,080 (4.08)	

Table 1. Cont.

	Total	Diabetes	Non-Diabetes	p-Value
PCV [†]				<0.001
No	5,804,240 (89.05)	752,119 (90.43)	5,052,121 (88.85)	
Yes	713,862 (10.95)	79,581 (9.57)	634,281 (11.15)	
SCD [‡] (≥50%)				<0.001
No	6,482,131 (99.45)	826,333 (99.35)	5,655,798 (99.46)	
Yes	35,971 (0.55)	5367 (0.65)	30,604 (0.54)	
Smoking status [§]				<0.001
Non-smoker	6,238,522 (95.71)	803,104 (96.56)	5,435,418 (95.59)	
Smoker	279,580 (4.29)	28,596 (3.44)	250,984 (4.41)	
SDH Individual *				
Food insecurity	51,738 (0.79)	8967 (1.08)	42,771 (0.75)	<0.001
Employment issue	296,572 (4.55)	42,154 (5.07)	254,418 (4.47)	<0.001
Financial stress	291,727 (4.48)	63,483 (7.63)	228,244 (4.01)	<0.001
Unstable housed	716,685 (11.0)	115,899 (13.94)	600,786 (10.57)	<0.001
Social isolation	117,289 (1.80)	25,088 (3.02)	92,201 (1.62)	<0.001
Transport insecurity	179,745 (2.76)	53,034 (6.38)	126,711 (2.23)	<0.001
Psychosocial need	966,365 (14.83)	192,358 (23.13)	774,007 (13.61)	<0.001
SDH score *				<0.001
0	4,940,777 (75.80)	545,913 (65.64)	4,394,864 (77.29)	
1	974,688 (14.95)	164,139 (19.74)	810,549 (14.25)	
2	329,476 (5.05)	64,684 (7.78)	264,792 (4.66)	
≥3	273,161 (4.19)	56,964 (6.85)	216,197 (3.80)	
SDH binary *				<0.001
No	4,940,777 (75.80)	545,913 (65.64)	4,394,864 (77.29)	
Yes	1,577,325 (24.20)	285,787 (34.36)	1,291,538 (22.71)	

* Individual, accumulated, and binary occurrence of social determinants of health score at follow-up, 2010–2019.

[†] Annual primary care visit at baseline, 2008–2009. [‡] Service-connected disability at baseline, 2008–2009.

[§] Smoking status at baseline, 2008–2009.

Table 2 depicts the adjusted GEE logistic regression models examining how diabetes status differs across SDOH burden, race and ethnicity; the odds of having T2DM for patients who had one adverse SDOH were 1.5 times higher (OR = 1.50; CI: 1.49, 1.51), and the odds for patients who had three or more (≥3) adverse SDOH were 2.07 times higher (OR = 2.07; CI: 2.05; 2.09) than for those who had no adverse SDOH. Black patients had 1.55 times higher odds of T2DM compared with White patients, while Hispanic and Other patients had odds 1.47 and 1.35 times higher, respectively, than White patients. Patients between 50 and 64 years had 4.13 times higher (OR = 4.13; CI: 4.11, 4.16), and patients 65 or older had 3.35 times higher (OR = 3.35; CI: 3.32, 3.37) odds of T2DM compared with patients younger than 50 years old. When stratified by race and ethnicity, White patients with ≥3 SDOH had 2.20 times higher odds (OR = 2.20; CI: 2.16, 2.23), and Black patients had 1.80 times higher odds (OR = 1.80; CI: 1.76, 1.83) compared with the reference group of no SDOH.

Table 2. Odds ratio of T2DM with cumulative exposure to SDOH by race and ethnicity.

	Total	Non-Hispanic White	Non-Hispanic Black	Hispanic	Other
	Odds Ratio (95%CI)	Odds Ratio (95%CI)	Odds Ratio (95%CI)	Odds Ratio (95%CI)	Odds Ratio (95%CI)
Patients (n)	5,230,399	3,817,871	862,294	367,029	183,205
Exposure					
SDOH Burden *					
0 (Ref.)	1.50 (1.49, 1.51)				
1	1.79 (1.77, 1.81)	1.55 (1.55, 1.57)	1.34 (1.32, 1.36)	1.44 (1.40, 1.47)	1.42 (1.37, 1.47)
2	2.07 (2.05, 2.09)	1.88 (1.86, 1.91)	1.55 (1.52, 1.58)	1.78 (1.72, 1.85)	1.89 (1.79, 1.99)
≥3		2.20 (2.16, 2.23)	1.80 (1.76, 1.83)	2.14 (2.06, 2.23)	2.29 (2.16, 2.42)
Covariates					
Race/ethnicity					
Non-Hispanic White (Ref.)					
Non-Hispanic Black	1.55 (1.54, 1.56)				
Hispanic	1.47 (1.45, 1.48)				
Other	1.35 (1.33, 1.37)				
Sex					
Male (Ref.)					
Female	0.53 (0.52, 0.53)	0.48 (0.48, 0.49)	0.63 (0.62, 0.64)	0.47 (0.45, 0.49)	0.47 (0.44, 0.49)
Rurality					
Urban (Ref.)					
Rural	1.16 (1.15, 1.16)	1.16 (1.15, 1.17)	1.17 (1.15, 1.19)	1.08 (1.05, 1.06)	1.14 (1.11, 1.18)
Age					
<50 years (Ref.)					
50–64 years	4.13 (4.11, 4.16)	4.53 (4.49, 4.57)	2.94 (2.90, 2.98)	5.52 (5.40, 5.64)	4.26 (4.13, 4.39)
≥65 years	3.35 (3.32, 3.37)	3.50 (3.47, 3.53)	2.98 (2.93, 3.03)	4.82 (4.69, 4.95)	3.42 (3.30, 3.55)
Marital Status					
Non-married (Ref.)					
Married	1.24 (1.23, 1.24)	1.19 (1.18, 1.19)	1.36 (1.34, 1.38)	1.32 (1.29, 1.35)	1.41 (1.37, 1.45)
PCV †					
No (Ref.)					
Yes	0.72 (0.71, 0.73)	0.68 (0.67, 0.69)	0.88 (0.86, 0.90)	0.77 (0.75, 0.80)	0.75 (0.71, 0.79)
SCD ‡ (≥50%)					
No (Ref.)					
Yes	1.20 (1.17, 1.24)	1.18 (1.14, 1.23)	1.26 (1.17, 1.36)	1.30 (1.14, 1.48)	1.25 (1.08, 1.45)
Smoking status §					
Non-smoker (Ref.)					
Smoker	0.74 (0.73, 0.75)	0.74 (0.72, 0.75)	0.74 (0.71, 0.76)	0.83 (0.78, 0.88)	0.80 (0.74, 0.87)

The odds of having any diabetes compared to non-diabetes (ref. group). * Accumulated social determinants of health score at follow-up, 2010–2019 (zeros are ref. group). † Primary care visit at baseline, 2008–2009. ‡ Service-connected disability at baseline, 2008–2009. § Smoking status at baseline, 2008–2009.

Table 3 depicts the adjusted logistic regression models for the seven types of SDOH by race and ethnicity. All seven types of SDOH were significantly associated with T2DM

incidence over the ten-year window, with the top three being transportation insecurity (1.60; CI: 1.58–1.62), psychosocial need (1.55; CI: 1.54–1.56), and financial stress (1.21; CI: 1.19–1.22). Adjusting for race and ethnicity on SDOH, Black patients had 58% increased odds of T2DM, and Hispanic patients had 47% increased odds compared to White patients. Compared to no transportation insecurity, patients with transportation insecurity had the largest increased odds of T2DM across race and ethnicity, with both Hispanic (1.76; CI: 1.68–1.85) and Other (1.76; CI: 1.64–1.88) patients having significantly higher odds of T2DM compared with Black (1.60, CI: 1.56–1.64) and White (1.57, CI: 1.54–1.59) patients. White patients with financial stress had increased odds of T2DM (1.22; CI: 1.20; 1.24), as well as Black (1.17; CI: 1.15; 1.20) and Hispanic (1.19; CI: 1.14; 1.25) patients; Other patients had the greatest odds (1.27; CI: 1.18; 1.35). Patients with psychosocial needs had higher odds of T2DM, with Black patients having the highest odds ratio (OR = 1.58; CI: 1.56; 1.60). Social isolation increases odds of T2DM across all racial and ethnic groups and is largest in White (1.21; CI: 1.18–1.23) patients, compared with Black (1.10; CI: 1.07–1.14) and Hispanic (1.06; CI: 1.00–1.13) patients. Food insecurity increased the odds of T2DM for White (1.21; CI: 1.18–1.26) and Hispanic (1.16; CI: 1.07–1.27) patients, while there was no significant change in odds for Black (1.03; CI: 0.89–1.07) patients. Other (1.16; CI: 1.11; 1.21) patients who were unstably housed had the largest odds of T2DM compared with White, Black, and Hispanic patients. The SDOH of unstably housed increased the odds of T2DM for White (1.11, CI: 1.10–1.12) and Hispanic (1.09; CI: 1.06–1.12) patients, while Black patients had lower odds of T2DM (0.89; CI: 0.87–0.90) when unstably housed.

Table 4 shows the cumulative burden of SDOH by race and ethnicity. Compared with other groups, Black patients had consistently higher rates of SDOH burden across all levels.

Table 3. Odds ratio of T2DM with exposure to each SDOH by race and ethnicity.

	Total	Non-Hispanic White	Non-Hispanic Black	Hispanic	Other
	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Patients (n)		3,817,871	862,294	367,029	183,205
Exposure					
SDOH Individual *					
Food insecurity	1.13 (1.10, 1.15)	1.21 (1.18, 1.26)	1.03 (0.89, 1.07)	1.16 (1.07, 1.27)	1.20 (0.98, 1.28)
Employment issue	1.02 (1.00, 1.03)	1.00 (0.99, 1.02)	1.06 (1.04, 1.08)	1.13 (1.08, 1.18)	1.12 (1.05, 1.20)
Financial stress	1.21 (1.19, 1.22)	1.22 (1.20, 1.24)	1.17 (1.15, 1.20)	1.19 (1.14, 1.25)	1.27 (1.18, 1.35)
Unstable housed	1.04 (1.03, 1.05)	1.11 (1.10, 1.12)	0.89 (0.87, 0.90)	1.09 (1.06, 1.12)	1.16 (1.11, 1.21)
Social isolation	1.17 (1.15, 1.19)	1.21 (1.18, 1.23)	1.10 (1.07, 1.14)	1.06 (1.00, 1.13)	1.12 (1.02, 1.23)
Transport insecurity	1.60 (1.58, 1.62)	1.57 (1.54, 1.59)	1.60 (1.56, 1.64)	1.76 (1.68, 1.85)	1.76 (1.64, 1.88)
Psychosocial need	1.55 (1.54, 1.56)	1.55 (1.54, 1.57)	1.58 (1.56, 1.60)	1.47 (1.44, 1.51)	1.45 (1.40, 1.51)
Covariates					
Race/ethnicity					
Non-Hispanic White (Ref.)					
Non-Hispanic Black	1.58 (1.57, 1.59)				
Hispanic	1.47 (1.46, 1.48)				
Other	1.38 (1.34, 1.38)				

Table 3. Cont.

	Total	Non-Hispanic White	Non-Hispanic Black	Hispanic	Other
Sex					
Male (Ref.)					
Female	0.52 (0.52, 0.53)	0.48 (0.47, 0.49)	0.61 (0.60, 0.62)	0.46 (0.44, 0.48)	0.46 (0.44, 0.49)
Rurality					
Urban (Ref.)					
Rural	1.15 (1.15, 1.16)	1.16 (1.15, 1.16)	1.14 (1.13, 1.16)	1.07 (1.05, 1.10)	1.14 (1.11, 1.18)
Age					
<50 years (Ref.)					
50–64 years	4.06 (4.03, 4.08)	4.42 (4.39, 4.47)	2.90 (2.86, 2.94)	5.56 (5.34, 5.58)	4.21 (4.08, 4.35)
≥65 years	3.17 (3.15, 3.20)	3.34 (3.31, 3.37)	2.71 (2.66, 2.76)	4.59 (4.46, 4.71)	3.27 (3.15, 3.40)
Marital Status					
Non-married (Ref.)					
Married	1.21 (1.20, 1.21)	1.16 (1.15, 1.17)	1.30 (1.28, 1.31)	1.29 (1.27, 1.32)	1.39 (1.35, 1.43)
PCV [†]					
No (Ref.)					
Yes	0.72 (0.71, 0.73)	0.68 (0.67, 0.69)	0.87 (0.85, 0.89)	0.77 (0.75, 0.80)	0.75 (0.71, 0.79)
SCD [‡] (≥50%)					
No (Ref.)					
Yes	1.19 (1.15, 1.22)	1.17 (1.13, 1.21)	1.24 (1.15, 1.34)	1.28 (1.13, 1.46)	1.23 (1.06, 1.43)
Smoking status [§]					
Non-smoker (Ref.)					
Smoker	0.74 (0.73, 0.75)	0.74 (0.72, 0.75)	0.74 (0.72, 0.77)	0.83 (0.79, 0.88)	0.80 (0.74, 0.88)

The odds of having any diabetes compared to non-diabetes (ref. group). * Individual social determinants of health at follow-up, 2010–2019 (zeros are ref. group). [†] Primary care visit at baseline, 2008–2009. [‡] Service-connected disability at baseline, 2008–2009. [§] Smoking status at baseline, 2008–2009.

Table 4. Social determinants of health score by race/ethnicity for all patients.

Patients (n)	Non-Hispanic White 4,087,637		Non-Hispanic Black 929,418		Hispanic 398,014		Other 208,903	
Number of Adverse SDOH *	n	%	n	%	n	%	n	%
0	3,099,795	75.83	579,260	62.33	274,956	69.08	154,382	73.90
1	631,701	15.45	187,641	20.19	75,450	18.96	34,168	16.36
2	201,005	4.92	81,156	8.73	26,159	6.57	11,449	5.48
3	88,340	2.16	43,895	4.72	12,014	3.02	5175	2.48
4	46,106	1.13	24,265	2.61	6477	1.63	2571	1.23
5	17,005	0.42	10,251	1.10	2435	0.61	946	0.45
6	3383	0.08	2634	0.28	480	0.12	190	0.09
7	302	0.01	316	0.03	43	0.01	22	0.01

* Social determinants of health at follow-up, 2010–2019.

4. Discussion

T2DM is one of the most prevalent chronic conditions among adults in the US [5,36]. Previous research has shown that one out of four Veterans have this disease [6]. In evaluating the cumulative burden of SDOH, we found that the odds of T2DM increased with a greater number of SDOH in a national sample of Veterans from diverse racial/ethnic backgrounds; specifically, the odds of T2DM increased with the number of SDOH reported by

patients. For instance, patients who had ≥ 3 SDOH had doubled odds of T2DM compared to those who had no social risk factors. With respect to individual SDOH, T2DM incidence was most strongly associated with transportation insecurity, psychosocial issues, financial stress, and social isolation. We also found significant racial/ethnic disparities in the cumulative number of SDOH among patients. Black individuals were most likely to have ≥ 3 SDOH (8.8%) compared to White (3.8%) and Hispanic (5.4%) individuals. Disparities in exposure to SDOH among the racial and ethnic groups are likely a reflection of differences in the lived experiences among Black, White, Hispanic, and Other individuals. Recent research has shown that Black prostate cancer patients are more likely than White patients to live in geographic areas that have high levels of social deprivation [37]. Recent reports describe the connection between structural racism, SDOH, and diabetes outcomes based on structural determinants in the World Health Organization (WHO) SDOH Framework and SDOH of health equity [22,23,38,39]. The WHO Framework focuses on structural determinants, including policy that can reinforce structural racism and its influence on SDOH that impact health outcomes. The WHO Framework can be used to support the VHA's commitment to eliminating racial disparities and achieving equity across all vulnerable groups through enacting policies that reduce structural determinants that reinforce structural racism and associated SDOH [24]. Our findings highlight the importance of social factors in relation to T2DM incidence and describe how they are associated with the odds of occurrence. The findings emphasize the wider context in which the social factors are intimately entwined with diabetic complications and outcomes. For example, a range of studies have shown social factors impacting diabetic foot outcomes and degraded quality of life [40–42]. Current guidelines of the CMS for screening patients for SDOH include identifying multiple types of unmet needs [43]. Existing CMS tools ask patients about their transportation, housing, financial strain, food insecurity, and other issues [43]. Our findings underscore the importance of understanding the cumulative burden of SDOH among patients. However, we also found that when individual SDOH are stratified by race and ethnicity, there are differences in the prevalence of unmet needs, and the odds ratios of T2DM also differ across groups. For instance, among Hispanic individuals, the odds of T2DM were 1.76 (CI: 1.68, 1.85) for patients who had unmet transportation needs, whereas the odds were 1.6 (CI: 1.56, 1.64) among Black and 1.57 (CI: 1.54, 1.59) among White patients. Similarly, among Black patients, the odds of T2DM were 1.58 (CI: 1.56, 1.60) for patients who had unmet psychosocial needs, whereas odds were 1.55 (CI: 1.54, 1.57) among White patients and 1.47 (CI: 1.44, 1.51) among Hispanic patients. The finding that Black Veterans, when unstably housed, had lower odds of incident T2DM could be influenced by such factors as the variability of SDOH coding, survivor bias, or different usage patterns of VHA programs. Future research should examine such factors, given the different relationships between SDOH and T2DM across race and ethnicity groups. Overall, the findings from the present study underscore the importance of developing integrated programs that address more than one SDOH simultaneously to address the cumulative burden of these factors on T2DM.

An important first step in developing integrated approaches to address the cumulative burden of SDOH among Veterans is to ensure that current programs are used and expanded to those who are at increased risk for developing chronic conditions such as T2DM based on their SDOH risk profile. For instance, wartime Veterans who are 65 and older can qualify for pension and transportation benefits to attend healthcare visits [44,45]; however, Veterans who are 50–64 are less likely to be eligible for this benefit. Policies about eligibility requirements are based on many different factors (e.g., cost-effectiveness); to our knowledge, SDOH are not currently considered as part of establishing policies for program eligibility. Our findings allude to the importance of considering SDOH as part of

determining eligibility for socially informed programs. Food insecurity is another actionable leverage point that could be addressed in the VHA. Hager et al. [26] found that when healthcare providers gave produce prescriptions that included a monthly food stipend to those with food insecurity, glucose control improved in a racially mixed population. Our data suggest that implementing this type of program in the VHA could be beneficial and should be assessed across racial and ethnic groups to determine optimum benefit.

Previous research has shown that there are racial/ethnic differences in uptake of public health programs that have been developed to address social factors. For instance, Allen et al. (2016) found that Black individuals who report food insecurity are more likely than White individuals to use the Supplemental Nutrition Assistance Program [46]. Our findings describe the distribution and impact of SDOH at the population level; however, SDOH impact individual patients, and clinicians need to take into consideration the specifics of individual cases when choosing an intervention. Additional research is needed to identify best practices for identifying patient preferences for offering programs to address multiple SDOH.

A limitation of the study is that the population is predominantly male, which limits the generalization of the findings to the wider population. We used ICD codes to identify the outcome of T2DM, and the codes are known to have associated bias [29]. The data on SDOH served as risk factor proxies derived from the International Classification of Diseases (ICD), stop codes, and health factors, all of which are dependent upon the coding system. The variability of SDOH encoding is another limitation of the study and is a caveat that should be taken into consideration when interpreting the results. SDOH were measured during the follow-up period along with the incidence of T2DM, so causality was not assessed; only associations of SDOH with the outcome of T2DM were assessed. Since the SDOH occurred during the ten-year observation period, it is not clear if SDOH got worse after the occurrence of T2DM, resulting in reverse causation. Future research is needed to assess the causal inference of SDOH and T2DM incidence. Those getting treatment in the VHA were included in the study, which could introduce bias since those with more comorbidities get more treatment. Although all patients started with no Elixhauser comorbidities, the selection processes potentially introduced bias. Sensitivity analysis was performed and demonstrated the consistency of the results when patients with comorbidities were included. Veterans can get financial support when unstably housed, which could mitigate effects and cause bias in our study, with more involvement in healthcare of unstably housed patients than in the general population [47,48]. The impact of such programs in the VHA could result in underrepresenting the association of SDOH with T2DM incidence compared with the general population.

A strength of our study is the large retrospective Veteran population that addresses a need in the field to construct models using multiple SDOH adjusted for covariates, including race and ethnicity. Taking these differences into account could result in improved health outcomes and more efficient use of resources in the complex interactions of SDOH that emerge when stratified by race and ethnicity. Additional study is warranted to examine how benefits that address SDOH for Veterans impact T2DM incidence.

5. Conclusions

Our analysis of transportation insecurity, psychosocial need, financial stress, social isolation, food insecurity, employment issues, and unstable housing showed that the burden of SDOH cumulatively was associated with increased odds of T2DM. The result speaks to the need to mitigate the impact of structural racism, given the disparities in minority groups, with Black patients having higher levels of cumulative SDOH burden. The finding of overarching SDOH like transportation insecurity, psychosocial needs, financial stress,

and social isolation that affect racial and ethnic groups broadly suggests the need for programs that address combinations of these SDOH to reduce T2DM incidence risk on a wide scale. Our finding that the effects of SDOH on the outcome of T2DM incidence vary by race and ethnicity provides insight into the complex interactions that have been observed in the field. The data and analysis of SDOH tracked over multiple years in the VHA offer information that can be considered when targeting resources to patients, providers, and communities to improve T2DM outcomes. Supporting groups with higher risk in specific SDOH could engage patients in their areas of highest need and potentially increase the efficacy of programs.

In conclusion, our findings regarding differential effects of specific SDOH components on T2DM incidence across racial and ethnic subgroups provide insight into complex interactions that have not been well-defined in the field. In addition, this study of a large national VHA cohort over ten years adds novel evidence that the cumulative burden of multiple SDOH is a strong predictor of T2DM incidence.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/diabetology7020037/s1>, File S1: Sources of social determinates of health; Table S1: ICD-9 and ICD-10 Codes for SDH in VHA databases; Table S2: Health factors for SDH in VHA databases; Table S3: Stop Codes for SDH in VHA databases.

Author Contributions: L.J.F. and C.H.H. conceived the research concept and design of the study. K.G.B. and M.G. contributed to the design and performed statistical analysis. B.Y., J.S.O., J.S. and P.R.A. contributed to the interpretation of the data and results. All authors contributed to the drafting and revisions of the important intellectual content of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Veterans Affairs Health Systems Research Merit Grant 1I01HX003379 (PIs: L.J.F. and M.G.).

Institutional Review Board Statement: The Ralph H. Johnson VA Research and Development Committee and the Medical University of South Carolina institutional review board approved the study, Pro00110786, on the 5 August 2021.

Informed Consent Statement: Our data is de-identified and obtained from medical records without any direct contact with subjects. Thus, our study is exempt from informed consent requirements.

Data Availability Statement: Veterans Affairs policy does not allow the data for the study to be shared publicly. The data is available with the VINCI system and can be accessed with appropriate approvals.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

Abbreviation	Definition
T2DM	Type 2 Diabetes Mellitus
SDOH	Social Determinants of Health
VHA	Veterans Health Administration
VINCI	VA Informatics and Computing Infrastructure
CDW	Corporate Data Warehouse
VA	Veterans Affairs
CMS	Center for Medicare and Medicaid Services
PCV	Primary Care Visit
SCD	Service-Connected Disability
GEE	Generalized Estimating Equation
OR	Odds Ratio

Abbreviation	Definition
CIs	Confidence Intervals
QIC	Quasi-Likelihood Information Criterion
WHO	World Health Organization
ICD	International Classification of Diseases

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