Examining Diabetes Status by the Social Determinants of Health Among Adults in Hawai‘i

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Abstract

The social determinants of health (SDoH) influence health outcomes based on conditions from birth, growth, living, and age factors. Diabetes is a chronic condition, impacted by race, education, and income, which may lead to serious health consequences. In Hawai‘i, approximately 11.2% of adults have been diagnosed with diabetes. The objective of this secondary cross-sectional study is to assess the relationship between the prevalence of diabetes and the social determinants of health among Hawai‘i adults who participated in the Behavioral Risk Factor Surveillance System between 2018-2020. The prevalence of diabetes among adults was 11.0% (CI: 10.4-11.5%). Filipino, Japanese and Native Hawaiian adults had the highest prevalence of diabetes at 14.4% (CI: 12.7-16.2%), 14.2% (CI: 12.7-15.7%), and 13.2% (CI: 12.0-14.4%), respectively. Poverty level and education were significantly associated with diabetes status. Within employment categories, the adjusted odds ratio (AOR) for retired and unable to work adults were large at AOR: 1.51 (CI: 1.26-1.81) and AOR: 2.91 (CI: 2.28-3.72), respectively. SDoH can impact the development and management of diabetes. Understanding the role SDoH plays on diabetes status is crucial for promoting health equity, building community capacity, and improving diabetes management.

Keywords

Social Determinants of Health, Diabetes, Hawai‘i, Socioeconomic Status, Built Environment

Abbreviations

AOR = adjusted odds ratio
BRFSS = Behavioral Risk Factor Surveillance System
CDC = Centers for Disease Control and Prevention
NHPI = Native Hawaiian and Pacific Islander
OR = odds ratio
SDoH = social determinants of health
SES = socioeconomic status

Introduction

Social determinants of health (SDoH) influence health outcomes based on conditions from birth, growth, living, and age factors.[1] As the SDoH encompass a variety of factors including both social and environmental factors, multiple models exist for operationalizing this term for scientific inquiry. One model developed by Healthy People 2030 separates the SDoH into 5 different domains: (1) economic stability, (2) education, (3) health care, (4) neighborhood and the built environment, and (5) social and community context.[2] While the Healthy People 2030 model divides SDoH into categories, it is important to note that social and environmental factors have a complex interconnected relationship.[3] The reciprocal interactions of the SDoH impact an individual's health rather than the independent effect of a singular domain.[3]

SDoH play a critical role in health and contribute to health inequities including disparities in diabetes prevalence.[4] Diabetes is a serious chronic health condition, and a leading cause of death in the US.[5] Furthermore it may lead to a variety of adverse health outcomes including blindness, and cardiovascular disease.[6] Type II diabetes, a preventable condition, accounts for 90 – 95% of all diabetes cases in the US.[7] Recent data estimates that 14.7% of adults in the US have diabetes, of which 11.3% have been diagnosed with diabetes, and 3.4% are undiagnosed.[7] In Hawai‘i, an estimated 11.2% of the adult population have been diagnosed with diabetes, and approximately 10 000 adults are newly diagnosed with diabetes every year.[8]

The prevalence of diabetes is unequally distributed among the adult population, especially among racial and ethnic minority groups.[6] In 2019, a study in Hawai‘i found a higher prevalence of diabetes in Native Hawaiians and Pacific Islanders (NHPIs) and Filipino residents compared to White residents.[9] This finding is consistent with previous research examining a multiethnic cohort that found Native Hawaiians and Asian populations had a higher risk for diabetes compared to their White counterparts.[10] This disparity among the Indigenous and racial minority populations in Hawai‘i is similar across the US with American Indian, Alaskan Native, Black, and Hispanic populations compared to White populations.[6] Historically, NHPI and Asian populations have been under-represented in research and placed into aggregate groupings masking subgroup differences and limiting generalizability of results.[11] Efforts to improve NHPI and Asian representation in clinical research have been made. Within the National Institutes of Health (NIH), the availability of funding for inclusion of NHPI and Asian populations in research has increased, yet underrepresentation remains an issue.[12] Inequities within minority populations go beyond clinical representation in research. Limited understanding of ethnic and cultural back-

grounds may inhibit care due to language barriers and cultural differences.[13] Considering these racial inequities that may be tied to historical injustices, additional factors such as the SDoH are needed to truly understand the intersectionality with race and ethnicity. Systemic racism and discrimination have driven social and economic inequities hindering people of color from achieving optimal health.[14-15]

Education has been reported as inversely associated with the prevalence of diabetes among adults.[6] A recent systematic review has indicated that low socioeconomic status (SES) may be a risk factor for diabetes-related complications.[16] Diabetes has an economic impact which may affect an individual's economic stability. Individuals diagnosed with diabetes have an estimated 130% higher medical expenditure compared to individuals living without diabetes.[8] In 2017, the estimated total economic burden of diagnosed diabetes in the US was upwards of $300 billion.[17] Health care access and quality are also related to diabetes prevalence, as health care access is directly related to diabetes diagnosis, surveillance, and treatment.[18-19] In neighborhood and built environment studies, green space and safe neighborhood walkability have been associated with a reduced risk for type II diabetes.[20]

Research examining the independent effects and the complex interconnected relationships between the SDoH domains can help identify nonmedical factors that influence health outcomes. The objective of this study is to assess the association between diabetes and the SDoH domains among adults in Hawai'i. By evaluating these associations, health care and public health professionals can gain a better understanding of diabetes and improve intervention efforts in at-risk populations that may be experiencing health inequities.

Methods

Data Source

The Behavioral Risk Factor Surveillance System (BRFSS) is a state-based Centers for Disease Control and Prevention (CDC)-funded survey that collects adult health-related data from randomly selected adults within each state and US territory.[21] The survey includes questions focused on health and lifestyle data pertaining to demographic characteristics, health conditions, preventive services, and health related behaviors that are collected via landline and mobile telephones using disproportionate stratified sampling.[21]

Study Population

This secondary cross-sectional study consists of Hawai'i residents who participated in BRFSS between 2018-2020. A total population of 23 338 adults, 7901 adults from 2018, 7683 adults from 2019, and 7754 adults from 2020 were included in the study. These adults represented a total weighted population of 3 348 355 adults with a weighted average population of 1 116 118 adults per year. Adults with missing information on diabetes status (n=42) were excluded from the study.

Measures

Adults with diabetes were defined based on respondents reporting "yes" to the question "have you ever been told by a doctor, nurse, or healthcare professional that you have diabetes?" Adults who responded "no," and those with gestational diabetes or pre-diabetes were defined as not having diabetes as they are distinct conditions and are separately identified through other BRFSS questions. Responses with "don't know, not sure, and refused" were classified as missing. Demographic variables included age, sex assigned at birth, race and ethnicity, marital status, home ownership, education, employment status, health care coverage, and county information.

Measures for Healthy People 2030 SDoH domains:

(1) Social and community context were not directly measured as they involve a variety of concepts such as social cohesion, support, and capital which are not easily operationalized and present within BRFSS. Age, sex assigned at birth, and race, key factors that influence a person's health outcome and overall quality of life, were used as indirect measurements and subsequently adjusted for.
(2) County and neighborhood support were used to measure the neighborhood and the built environment domain. The counties in the state of Hawai'i include Hawai'i, Maui, Honolulu, and Kaua'i county. Counties provide information regarding the resources and development of the built environment while neighborhood support was chosen as it provides information about existing physical activity related infrastructure.
(3) Employment status and poverty level were chosen to measure the economic stability domain based on precedent within existing literature.[22]
(4) Educational attainment was used to measure the education access and quality domain.
(5) Health care coverage and insurance type were chosen to measure the health care access and quality domain as they provide information related to both the access and quality components of this domain.

Age was categorized into 3 age groups including: younger adults (18-44 years), middle aged adults (45-64 years), and older adults (65 years and older). Race was categorized into White, Native Hawaiian, Filipino, Japanese, Other Asian, Pacific Islander (excludes Native Hawaiians), and Other Race groups. The Native Hawaiian category includes full and part Native Hawaiian individuals. Education included 5 categories: never attended school/only kindergarten to 8th grade, some high school (grade 9-11), high school graduate (Grade 12, or GED), some college/technical school (college 1-3 years), and college

graduate (college 4 years, or more). Neighborhood support was determined by the question on if physical activity supporting infrastructure was available within a neighborhood. Poverty levels (0-130%, 131-185%, and 186% or more) were based on the number of children less than 18 years old and adults in a household and annual household income.[23] Health insurance included private, Medicaid, and Medicare coverage. All missing data were reported.

Statistical Analysis

All analyses accounted for the complex survey design using survey weights, clustering, and design strata to represent the state's population.[24-26] Demographic characteristics (age, sex assigned at birth, race/ethnicity, home ownership, household income, employment, education level, health care coverage, and county) were examined by diabetes status and presented as weighted frequencies and 95% confidence intervals (CIs). Chi-square tests were performed to compare the frequency distribution of categorial measures in **Table 1**. Missing responses were included as a missing category but excluded from the multivariable model analysis.

Unadjusted and adjusted multivariable logistic regression models examined the association of diabetes status with each SDoH indicator. Reference groups for each SDoH indicator were based on the normative or largest category. Models were adjusted for race, sex assigned at birth, and age. Results generated from the regression models are presented as odds ratios (ORs) with 95% CIs. All statistical significance was based on $P<.05$. Statistical analysis was performed in SAS Studio version: Release 3.8 Enterprise Edition (SAS Institute, Inc., Cary, NC).

Results

The prevalence of diabetes was 11.0% (CI: 10.4-11.5%) for the total population (**Table 1**). Among age groups, older adults (65+) had the highest diabetes prevalence at 20.7% (CI: 19.3-22.1%). Males had higher diabetes prevalence compared to females at 12.0% (CI: 11.2-12.8%) and 10.3% (CI: 9.5-11.0%). Filipino, Japanese, and Native Hawaiian adults had the highest prevalence of diabetes at 14.4% (CI: 12.7-16.2%), 14.2% (CI: 12.7-15.7%), and 13.2% (CI: 12.0-14.4%), respectively. Diabetes prevalence was higher among adults with health care coverage (11.3%, CI: 10.7-11.9%) compared to those without health care coverage (7.0%, CI: 5.4-8.6%). Education status followed a negative step-wise pattern with fewer adults having diabetes with increasing education levels. Adults who never attended school, or only completed kindergarten to 8th grade had a diabetes prevalence of 18.2% (CI: 11.2-25.3%) compared to 8.4% (CI: 7.7-9.1%) among college graduates.

Table 1. Sociodemographic Characteristics and Prevalence (% [95% Confidence Interval, CI]) of Diabetes Among Adults in Hawai'i from the Hawai'i Behavioral Risk Factor Surveillance System (BRFSS) 2018-2020

Characteristics	Observed Frequency n	Weighted Prevalence % (95% CI)	Diabetes Prevalence % (95% CI)	*P*-value[a]
Total Population	23 338	N/A	11.0 (10.4-11.5)	N/A
Age Group, years				
Young Adult (18-44)	7 494	45.0 (44.1-45.9)	3.5 (2.9-4.0)	<.001
Middle Aged Adult (45-64)	7 779	30.2 (29.5-31.0)	14.3 (13.2-15.4)	
Older Adult (65+)	7 783	23.7 (23.0-24.4)	20.7 (19.3-22.1)	
Missing	282	1.2 (1.1-1.4)		
Sex Assigned at Birth				
Female	12 136	49.6 (48.7-50.5)	10.3 (9.5-11.0)	.002
Male	10 979	48.9 (48.0-49.8)	12.0 (11.2-12.8)	
Missing	223	1.5 (1.3-1.8)		
Race/Ethnicity				
White	8 306	25.7 (25.0-26.4)	6.0 (5.3-6.7)	<.001
Native Hawaiian	4 261	17.6 (17-18.3)	13.2 (12.0-14.4)	
Filipino	2 686	14.9 (14.3-15.6)	14.4 (12.7-16.2)	
Japanese	3 307	17.1 (16.4-17.8)	14.2 (12.7-15.7)	
Other	851	4.7 (4.2-5.1)	10.5 (8.8-12.1)	
Other Asian[b]	2 065	11.9 (11.3-12.5)	12.5 (10.1-14.9)	
Pacific Islander[c]	1 108	5.6 (5.1-6.0)	7.4 (5.0-9.8)	
Missing	754	2.9 (2.6-3.2)		

Table 1. Sociodemographic Characteristics and Prevalence (% [95% Confidence Interval, CI]) of Diabetes Among Adults in Hawai'i from the Hawai'i Behavioral Risk Factor Surveillance System (BRFSS) 2018-2020 (Con't)				
Marital Status				
Divorced	3 102	9.6 (9.2-10.1)	12.6 (11.1-14.2)	<.001
Married	11 627	51.9 (51.0-52.7)	12.1 (11.3-12.9)	
Never Married	5 034	25.4 (24.6-26.2)	6.5 (5.7-7.4)	
Separated	397	1.5 (1.3-1.7)	14.8 (8.4-21.2)	
Unmarried Couple	992	4.5 (4.2-4.9)	6.6 (4.6-8.5)	
Widowed	2 064	6.6 (6.1-7.0)	20.0 (17.2-22.7)	
Missing	122	0.5 (0.4-0.6)		
Home Ownership				
Other arrangement	2 513	10.3 (9.8-10.8)	6.7 (5.5-7.9)	<.001
Own	13 230	62.7 (61.9-63.5)	12.5 (11.8-13.3)	
Rent	7 485	26.4 (25.7-27.1)	9.0 (8.2-9.8)	
Missing	110	0.7 (0.5-0.8)		
Employment Status				
Employed for wages	10 331	50.3 (49.4-51.2)	7.7 (7.1-8.4)	<.001
Homemaker	687	3.3 (2.9-3.6)	7.0 (4.9-9.2)	
Not Employed	1 371	6.2 (5.7-6.6)	9.0 (7.1-10.9)	
Retired	6 445	20.9 (20.3-21.6)	21.3 (19.8-22.8)	
Self-Employed	2 646	10.4 (9.9-10.9)	7.6 (6.2-8.9)	
Student	565	3.9 (3.5-4.3)	1.7 (0.5-2.9)	
Unable to work	1 013	3.6 (3.3-3.9)	24.1 (20.4-27.7)	
Missing	280	1.4 (1.2-1.7)		
Health Coverage				
No	1 415	6.8 (6.3-7.2)	7.0 (5.4-8.6)	<.001
Yes	21 868	92.9 (92.4-93.4)	11.3 (10.7-11.9)	
Missing	55	0.3 (0.2-0.5)		
Education Level				
Never attended school/Less than Grade 8	218	2.2 (1.8-2.6)	18.2 (11.2-25.3)	<.001
Some High School	640	6.1 (5.5-6.7)	15.5 (12-18.9)	
High School Graduate	6 050	28.9 (28.1-29.7)	12.0 (11.0-13.0)	
Some College/ Technical School	6 571	32.8 (32.0-33.7)	11.1 (10.1-12.0)	
College Graduate	9 804	29.7 (29-30.4)	8.4 (7.7-9.1)	
Missing	55	0.2 (0.2-0.3)		
County				
Hawai'i	4 549	13.5 (13.1-13.9)	10.8 (9.7-12)	.154
Honolulu	10 994	65.0 (64.4-65.6)	11.4 (10.7-12.2)	
Kaua'i	2 675	4.7 (4.5-4.8)	11.2 (9.7-12.7)	
Maui	3 986	11.2 (10.9-11.6)	9.9 (8.8-11.1)	
Missing	1 134	5.6 (5.2-6.0)		

[a] *P*-values are based on a chi-square test for Diabetes prevalence
[b] Excludes Filipino and Japanese racial groups
[c] Excludes Native Hawaiian racial group

All SDoH indicators except for county and neighborhood support were associated with diabetes in the unadjusted model and adjusted model for age, sex assigned at birth, and race/ethnicity (**Table 2**). Within the unadjusted model, all household income groups had higher OR's compared to the $75 000 or more reference group. However, in the adjusted model, the $20 000 to $24 999, $25 000 to $34 999, and $50 000 to $74 999 household income groups were not associated with odds of diabetes.

Diabetes status was statistically associated with poverty level and employment status, after adjusting for age, sex and race/ethnicity. However, the employment statuses of homemaker, not employed, and self-employed, and poverty level 186-300% were not associated with diabetes in either model. Adults with diabetes were more likely to be in the 0-100% poverty level (adjusted odds ratio [AOR]: 1.64, CI: 1.36-1.97), and the 101-185% poverty level (AOR: 1.30, CI: 1.10-1.55) compared to the 301% or more poverty group. Adults who are retired (AOR: 1.51, CI: 1.26-1.81) or unable to work (AOR: 2.91, CI: 2.28-3.72) were more likely to have diabetes compared to the individuals employed for wages.

Among education level, diabetes was inversely associated with higher levels of educational attainment. Never attended school/grade 8 or less was not associated with diabetes in the adjusted model but was associated with diabetes in the unadjusted model (AOR: 2.48, CI: 1.53-4.02). Diabetes status was inversely associated with no health care coverage for the unadjusted model (OR: 0.59, CI: 0.46-0.76) but this was not statistically significant in the adjusted model (AOR: 0.78, CI: 0.59-1.02). Among those with health insurance, individuals with Medicare and Medicaid were 1.22 (CI: 1.04-1.44), and 1.58 (CI: 1.23-2.02) times as likely to have diabetes compared to those with private health insurance in the adjusted model.

Table 2. Unadjusted and Adjusted[a] Odds Ratio (OR) and Confidence Intervals (CI) of Diabetes Status by the Social Determinants of Health (SDoH) Domains, Hawai'i Behavioral Risk Factor Surveillance System (BRFSS), 2018 – 2020

SDoH Domain	Unadjusted OR [95% CI]	*P*-value	Adjusted[a] OR [95% CI]	*P*-value
SDoH Domain: Neighborhood and the Built Environment				
County				
Hawai'i	0.94 [0.82-1.09]	.411	0.91 [0.78-1.06]	.211
Honolulu	Ref		Ref	
Kaua'i	0.98 [0.83-1.16]	.820	0.93 [0.78-1.11]	.439
Maui	0.85 [0.74-0.99]	.037	0.86 [0.73-1.01]	.062
Neighborhood Support				
Yes	Ref		Ref	
No	1.06 [0.93-1.19]	.395	0.95 [0.83-1.08]	.399
SDoH Domain: Economic Stability				
Household Income				
Less than $10,000	2.06 [1.54-2.76]	<.001	2.02 [1.43-2.85]	<.001
$10,000 to $14,999	2.41 [1.80-3.23]	<.001	2.01 [1.46-2.76]	<.001
$15,000 to $19,999	1.78 [1.42-2.24]	<.001	1.56 [1.21-2.00]	.001
$20,000 to $24,999	1.37 [1.09-1.72]	.006	1.25 [0.98-1.59]	.075
$25,000 to $34,999	1.47 [1.18-1.82]	.001	1.23 [0.99-1.53]	.057
$35,000 to $49,999	1.68 [1.40-2.02]	<.001	1.48 [1.22-1.80]	<.001
$50,000 to $74,999	1.32 [1.11-1.58]	.002	1.19 [0.98-1.43]	.077
$75,000 or more	Ref		Ref	
Employment Status				
Employed for wages	Ref		Ref	
Homemaker	0.91 [0.64-1.28]	.583	1.04 [0.73-1.50]	.82
Not Employed	1.18 [0.92-1.52]	.193	1.22 [0.93-1.60]	.151
Retired	3.25 [2.85-3.70]	<.001	1.51 [1.26-1.81]	<.001
Self-Employed	0.98 [0.79-1.22]	.840	0.87 [0.70-1.09]	.234
Student	0.20 [0.10-0.43]	<.001	0.47 [0.22-1.00]	.051
Unable to work	3.82 [3.07-4.76]	<.001	2.91 [2.28-3.72]	<.001

Table 2. Unadjusted and Adjusteda Odds Ratio (OR) and Confidence Intervals (CI) of Diabetes Status by the Social Determinants of Health (SDoH) Domains, Hawai'i Behavioral Risk Factor Surveillance System (BRFSS), 2018 – 2020 (Con't)				
Poverty Level				
0-100%	1.42 [1.21-1.66]	<.001	1.64 [1.36-1.97]	<.001
101-185%	1.31 [1.11-1.54]	.001	1.30 [1.10-1.55]	.003
186-300%	0.93 [0.80-1.10]	.394	1.05 [0.89-1.25]	.558
301% or more	Ref		Ref	
SDoH Domain: Education Access and Agency				
Education Level				
Never attended school/ Grade 8 or less	2.48 [1.53-4.02]	<.001	1.31 [0.75-2.29]	.337
Some High School	2.01 [1.52-2.66]	<.001	1.83 [1.34-2.51]	<.001
High School Graduate	1.49 [1.31-1.70]	<.001	1.49 [1.29-1.72]	<.001
Some College/Technical school	1.36 [1.19-1.54]	.002	1.24 [1.08-1.42]	.003
College Graduate	Ref		Ref	
SDoH Domain: Healthcare Access and Agency				
Health Coverage				
No	0.59 [0.46-0.76]	<.001	0.78 [0.59-1.02]	.073
Yes	Ref		Ref	
Health Insurance Type				
Private	Ref		Ref	
Medicaid	1.42 [1.13-1.78]	.002	1.58 [1.23-2.02]	<.001
Medicare	2.08 [1.83-2.36]	<.001	1.22 [1.04-1.44]	.017

[a] Adjusted for age, sex assigned at birth, and race/ethnicity

Discussion

Diabetes status was associated with age, sex assigned at birth, race, education, poverty level, and health coverage. Previous studies have reported associations with diabetes and income, education, the built environment, and race.[27-39] In this study, diabetes status was also associated with economic stability, and other researchers have found similar associations with income and poverty level.[28-29] Research in Hawai'i has demonstrated increased diabetes risk with lower household income.[9] One study utilizing national health data found a stepwise association gradient with increasing diabetes prevalence among the lower income group.[30] Hawai'i has a high cost of living and subsequently a high median household income of $83 173.[40] For this reason, poverty level may be a better indicator of SES than income because it incorporates the cost of living and number of people in the household. SES is a combined measure known to be inversely associated with diabetes. A 2006 study conducted by Borell et al found an association between education and diabetes prevalence, similar to the results of this study.[41]

Having health care is the strongest predictor for diabetes screening among adults,[42] and uninsured adults are more likely to have undiagnosed diabetes because of limited access to medical care.[43] This may explain why not having health care coverage was inversely associated with diabetes status in this study. Health care is important in the diagnosis and monitoring of diabetes by medical professionals. Increased access to adequate health care and resources in remote communities living in rural areas are needed. Limited internet accessibility, public transportation, food, and economic insecurity, far distance from health facility, and social isolation present challenges for at-risk populations from receiving optimal care.[44-46] The COVID-19 pandemic highlighted the persistent challenge populations in remote areas face, especially older adults, in receiving health care and social services.

This study's findings differed from previous findings that found associations between diabetes and the neighborhood and built environment.[27, 31-39] As a multiple-island state, the geographical composition of Hawai'i is different from previously studied locations. The natural environment and wet and dry season climate of Hawai'i promote outdoor recreation that supports more physical activity compared to other geographic locations. The islands in Hawai'i are relatively small compared to other US states, and the short distance between hiking trails and beaches may increase the use of these spaces for physical activity. This may explain why physical activity promotion infrastructure, a measure of neighborhood support, was not statistically associated with diabetes. Overall, the residents of Hawai'i have

the highest life expectancy in the US at 80.7 years which may be attributed to an active lifestyle among many other potential factors.[47] Previous studies have reported large differences in life expectancy by race groups in Hawai‘i.[48] Associations between diabetes and the built environment may exist by race groups, which this study did not assess.

In Hawai‘i, the majority of adults living with diabetes were among minority racial groups with low socioeconomic status, less education, and no health care coverage compared to adults living without diabetes. This study did not stratify by race when examining the SDoH by diabetes. However, a 2019 Hawai‘i BRFSS study reported an association with diabetes and SDoH inequities among those who identified as Japanese, Filipino, Native Hawaiian and Pacific Islander, or Chinese compared to White adults.[9] Another study reported income and education disparities in minority racial groups and diabetes status.[29] Native Hawaiian populations from low SES are at an increased risk of social and health inequities, such as limited access to care and substandard living conditions.[49]

The relationship between the SDoH and diabetes is complex as the SDoH may not only contribute to the development of diabetes but also impact diabetes management. Research on a national level has shown that houselessness, food insecurity, lack of health insurance, and low economic stability all negatively impact diabetes management.[50-53] As many of these factors are similarly associated with diabetes prevalence, more research is needed to tease out the role the SDoH play in the development and management of diabetes. Through new research, targeted interventions may be developed to help improve both diabetes prevention and management.

This study has several limitations. The SDoH among adults living with diabetes were assessed, yet the cross-sectional methodology inhibits causal inferences from being made. It is unclear the directionality of the associations, if the SDoH influenced a person's diabetes status, or if the diabetes status affected the SDoH. The BRFSS collects self-reported information that could lead to information bias. Individuals without a phone, and incarcerated are not included in BRFSS which is a potential source of selection bias. Houselessness is associated with low income, less education, and limited access to care that may lead to undiagnosed and untreated diabetes prevalence. Although this study did not examine houselessness by race, the authors did assess home ownership that included adults who own, rent, or have other living arrangements. Data regarding undiagnosed diabetes were not available, and thus could not be evaluated in the context of the SDoH. It is likely that the prevalence of undiagnosed diabetes is associated and impacted by the various SDoH indicators assessed in this study. The term SDoH is very broad and complex with numerous levels of measures. While this study was able to examine the SDoH in the context of the five domains from the Healthy People 2030 model, other facets such as food, community safety, and more were not assessed in this study. Commonly studied disparities with diabetes such as food insecurity, health literacy, and health care provider availability were not evaluated. Furthermore, confounding factors such as smoking, and obesity were not adjusted for in the multivariable model as the focus of this study was to evaluate the SDoH.

This study adjusted for race, sex assigned at birth, and age. While it is common practice to adjust for race, it is important to note that race is a social construct and a primary driver for SDoH and inequities in income, living conditions, and education especially among communities of color. Race is not an appropriate predictor for various health outcomes and conditions.[54] Instead, the causal effect of race may be better understood through evaluation of social factors such as the SDoH.[55] Previous studies have found that SDoH indicators are better predictors for adverse health outcomes compared to race.[56-57] This study did not compare the predictive power of SDoH indicators versus race. Further research on diabetes and SDoH inequities among race groups is needed.

This study has many strengths. The BRFSS is conducted every year throughout the state of Hawai‘i and uses validated methodology to collect information. The survey also accounts for population weights to be a representative sample of the population. Unlike many studies, Hawai‘i has a diverse minority race/ethnic population and a high representation of NHPI and Asian groups. The NHPI group can be disaggregated into two groups to further assess and better understand each group specific health needs. Key aspects of the SDoH domains were evaluated from the Healthy People 2030 model.

Conclusion

These results add to the growing literature on SDoH, health disparities, and diabetes status in Hawai‘i. A variety of SDoH indicators were statistically associated with lifetime prevalence of health care provider-diagnosed diabetes in Hawai‘i. The study's findings are consistent with other studies, except for neighborhood environment, which evaluated SDoH and diabetes in other populations, supporting that SDoH are associated with general health outcomes and diabetes. Additional research is needed to evaluate the impact of SDoH on diabetes prevalence and incidence within Hawai‘i. Understanding the role SDoH plays on diabetes status is crucial for promoting health equity, building community capacity, and improving diabetes management.

Conflict of Interest

None of the authors identify a conflict of interest.

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References

1. Social Determinants of Health. World Health Organization. 2022. Accessed July 26, 2022. https://www.who.int/health-topics/social-determinants-of-health#tab=tab_1
2. Social Determinants of Health. Healthy People 2030. 2022. Accessed July 26, 2022. https://health.gov/healthypeople/priority-areas/social-determinants-health
3. Darin-Mattsson A, Fors S, Kåreholt I. Different indicators of socioeconomic status and their relative importance as determinants of health in old age. *Int J Equity Health*. 2017;16(1). https://doi.org/10.1186/s12939-017-0670-3
4. Haire-Joshu D, Hill-Briggs F. The next generation of diabetes translation: a path to health equity. *Annu Rev Public Health*. 2019;40(1):391-410. https://doi.org/10.1146/annurev-publhealth-040218-044158
5. National Center for Health Statistics - Deaths and Mortality. Centers for Disease Control and Prevention. Updated January 13, 2022. Accessed June 29, 2022. https://www.cdc.gov/nchs/fastats/deaths.htm.
6. Centers for Disease Control and Prevention. *National Diabetes Statistics Report, 2020*. Atlanta, GA: Centers for Disease Control and Prevention, U.S. Dept of Health and Human Services. 2020. Accessed July 26, 2022. https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf
7. Diabetes - Prevalence of Both Diagnosed and Undiagnosed Diabetes. Centers for Disease Control and Prevention. 2021. Accessed June 22, 2022. https://www.cdc.gov/diabetes/data/statistics-report/diagnosed-undiagnosed-diabetes.html
8. The Burden of Diabetes in Hawaii. American Diabetes Association. 2021. Accessed June 22, 2022. https://diabetes.org/sites/default/files/202111/ADV_2021_State_Fact_sheets_Hawaii_rev.pdf
9. Uchima O, Wu YY, Browne C, Braun KL. Disparities in diabetes prevalence among Native Hawaiians/other Pacific Islanders and Asians in Hawai'i. *Prev Chronic Dis*. 2019;16:E22. February 21, 2019. doi:10.5888/pcd16.180187
10. Maskarinec G, Jacobs S, Morimoto Y, Chock M, Grandinetti A, Kolonel LN. Disparity in diabetes risk across Native Hawaiians and different Asian groups: the multiethnic cohort. *Asia Pac J Public Health*. 2015;27(4):375-384. https://doi.org/10.1177/1010539514548757
11. Kanaya AM, Hsing AW, Panapasa SV, et al. Knowledge gaps, challenges, and opportunities in health and prevention research for Asian Americans, Native Hawaiians, and Pacific Islanders: a report from the 2021 National Institutes of Health workshop. *Ann Intern Med*. 2022;175(4):574-589. https://doi.org/10.7326/M21-3729
12. Đoàn LN, Takata Y, Sakuma KK, Irvin VL. Trends in clinical research including Asian American, Native Hawaiian, and Pacific Islander participants funded by the US National Institutes of Health, 1992 to 2018. *JAMA Netw Open*. 2019;2(7):e197432. July 3, 2019. doi:10.1001/jamanetworkopen.2019.7432
13. Maneze D, Everett B, Kirby S, DiGiacomo M, Davidson PM, Salamonson Y. 'I have only little English': language anxiety of Filipino migrants with chronic disease. *Ethn Health*. 2016;21(6):596-608. https://doi.org/10.1080/13557858.2016.1143091
14. Bailey ZD, Feldman JM, Bassett MT. How structural racism works - racist policies as a root cause of U.S. racial health inequities. *N Engl J Med*. 2021;384(8):768-773. https://doi.org/10.1056/NEJMms2025396
15. Krieger N. Structural racism, health inequities, and the two-edged sword of data: structural problems require structural solutions. *Front Public Health*. 2021;9:655447. April 15, 2021. https://doi.org/10.3389/fpubh.2021.655447
16. Tatulashvili S, Fagherazzi G, Dow C, Cohen R, Fosse S, Bihan H. Socioeconomic inequalities and type 2 diabetes complications: a systematic review. *Diabetes Metab*. 2020;46(2):89-99. https://doi.org/10.1016/j.diabet.2019.11.001
17. American Diabetes Association. Economic costs of diabetes in the U.S. in 2017. *Diabetes Care*. 2018;41(5):917-928. https://doi.org/10.2337/dci18-0007
18. Canedo JR, Miller ST, Schlundt D, Fadden MK, Sanderson M. Racial/ethnic disparities in diabetes quality of care: the role of healthcare access and socioeconomic status. *J Racial Ethn Health Disparities*. 2017;5(1):7-14. https://doi.org/10.1007/s40615-016-0335-8
19. Nguyen M, Brown C, Sun N, Brown JS. The relationship between healthcare provider density and diabetes prevalence in the United States. *J Health and Hum Serv Admin*. 2021;44(3):245-259. https://doi.org/10.37808/jhhsa.44.3.3
20. Beulens JWJ, Pinho MGM, Abreu TC, et al. Environmental risk factors of type 2 diabetes—an exposome approach. *Diabetologia* 2022;65:263–274._https://doi.org/10.1007/s00125-021-05618-w
21. CDC - BRFSS. Centers for Disease Control and Prevention. June 21, 2022. Accessed July 26, 2022. https://www.cdc.gov/brfss/index.html
22. Irvin JA, Kondrich AA, Ko M, et al. Incorporating machine learning and social determinants of health indicators into prospective risk adjustment for health plan payments. *BMC Public Health*. 2020;20(1):608. May 1, 2020. https://doi.org/10.1186/s12889-020-08735-0
23. Hawaii State Department of Health, Hawaii Health Data Warehouse, Behavioral Risk Factor Surveillance System, Poverty (2014+) by Year and Poverty Level (2014+), 2014-2020. June 20, 2022. Accessed August 9, 2022. https://hhdw.org/report/query/result/brfss/PovertyLevelCat/PovertyLevelCatCrude11_.html
24. CDC - 2018 BRFSS survey data and Documentation. Centers for Disease Control and Prevention. October 27, 2022. Accessed November 1, 2022. https://www.cdc.gov/brfss/annual_data/annual_2018.html
25. CDC - 2019 BRFSS survey data and Documentation. Centers for Disease Control and Prevention. October 27, 2022. Accessed November 1, 2022. https://www.cdc.gov/brfss/annual_data/annual_2019.html
26. CDC - 2020 BRFSS survey data and Documentation. Centers for Disease Control and Prevention. October 27, 2022. Accessed November 1, 2022. https://www.cdc.gov/brfss/annual_data/annual_2020.html
27. Pasala SK, Rao AA, Sridhar GR. Built environment and diabetes. *Int J Diabetes Dev Ctries*. 2010;30(2):63-68. https://doi.org/10.4103/0973-3930.62594
28. Gaskin DJ, Thorpe RJ Jr, McGinty EE, et al. Disparities in diabetes: the nexus of race, poverty, and place. *Am J Public Health*. 2014;104(11):2147-2155. https://doi.org/10.2105/AJPH.2013.301420
29. Braveman PA, Cubbin C, Egerter S, Williams DR, Pamuk E. Socioeconomic disparities in health in the United States: what the patterns tell us. *Am J Public Health*. 2010;100(S1). https://doi.org/10.2105/ajph.2009.166082
30. Beckles GL, Chou CF. Disparities in the prevalence of diagnosed diabetes - United States, 1999-2002 and 2011-2014. *MMWR Morb Mortal Wkly Rep*. 2016;65(45):1265-1269. November 18, 2016. https://doi.org/10.15585/mmwr.mm6545a4
31. Drewnowski A, Buszkiewicz J, Aggarwal A, Rose C, Gupta S, Bradshaw A. Obesity and the built environment: a reappraisal. *Obesity (Silver Spring)*. 2020;28(1):22-30. https://doi.org/10.1002/oby.22672
32. Martin A, Ogilvie D, Suhrcke M. Evaluating causal relationships between urban built environment characteristics and obesity: a methodological review of observational studies. *Int J Behav Nutr Phys Act*. 2014;11(1). https://doi.org/10.1186/s12966-014-0142-8
33. Mayne SL, Auchincloss AH, Michael YL. Impact of policy and built environment changes on obesity-related outcomes: a systematic review of naturally occurring experiments. *Obes Rev*. 2015;16(5):362-375. https://doi.org/10.1111/obr.12269
34. Chandrabose M, Rachele JN, Gunn L, et al. Built environment and cardio-metabolic health: systematic review and meta-analysis of longitudinal studies. *Obes Rev*. 2019;20(1):41-54. https://doi.org/10.1111/obr.12759
35. Smalls BL, Gregory CM, Zoller JS, Egede LE. Assessing the relationship between neighborhood factors and diabetes related health outcomes and self-care behaviors. *BMC Health Serv Res*. 2015;15:445. October 1, 2015. https://doi.org/10.1186/s12913-015-1086-7
36. Bilal U, Auchincloss AH, Diez-Roux AV. Neighborhood environments and diabetes risk and control. *Curr Diab Rep*. 2018;18(9):62. July 11, 2018. https://doi.org/10.1007/s11892-018-1032-2
37. Leal C, Chaix B. The influence of geographic life environments on cardiometabolic risk factors: a systematic review, a methodological assessment and a research agenda. *Obes Rev*. 2011;12(3):217-230. https://doi.org/10.1111/j.1467-789X.2010.00726.x
38. Twohig-Bennett C, Jones A. The health benefits of the great outdoors: a systematic review and meta-analysis of greenspace exposure and health outcomes. *Environ Res*. 2018;166:628-637. https://doi.org/10.1016/j.envres.2018.06.030
39. Durand CP, Andalib M, Dunton GF, Wolch J, Pentz MA. A systematic review of built environment factors related to physical activity and obesity risk: implications for smart growth urban planning. *Obes Rev*. 2011;12(5):e173-e182. https://doi.org/10.1111/j.1467-789X.2010.00826.x
40. Census Bureau QuickFacts. U.S. Census Bureau Quickfacts: Hawaii. 2022. Accessed November 14, 2022. https://www.census.gov/quickfacts/HI
41. Borrell LN, Dallo FJ, White K. Education and diabetes in a racially and ethnically diverse population. *Am J Public Health*. 2006;96(9):1637-1642. https://doi.org/10.2105/AJPH.2005.072884
42. Kazemian P, Shebl FM, McCann N, Walensky RP, Wexler DJ. Evaluation of the cascade of diabetes care in the United States, 2005-2016. *JAMA Intern Med*. 2019;179(10):1376-1385. https://doi.org/10.1001/jamainternmed.2019.2396
43. Danaei G, Friedman AB, Oza S, Murray CJ, Ezzati M. Diabetes prevalence and diagnosis in US states: analysis of health surveys. *Popul Health Metr*. 2009;7:16. September 25, 2009. https://doi.org/10.1186/1478-7954-7-16
44. Scott Kruse C, Karem P, Shifflett K, Vegi L, Ravi K, Brooks M. Evaluating barriers to adopting telemedicine worldwide: A systematic review. *J Telemed Telecare*. 2018;24(1):4-12. https://doi.org/10.1177/1357633X16674087
45. Xu D, Jenkins A, Ryan C, et al. Health-related behaviours in a remote indigenous population with type 2 diabetes: a Central Australian primary care survey in the Telehealth Eye and Associated Medical Services Network [TEAMSnet] project. *Diabet Med*. 2019;36(12):1659-1670. https://doi.org/10.1111/dme.14099
46. Hirko KA, Kerver JM, Ford S, et al. Telehealth in response to the COVID-19 pandemic: Implications for rural health disparities. *J Am Med Inform Assoc*. 2020;27(11):1816-1818. https://doi.org/10.1093/jamia/ocaa156
47. Life expectancy at birth by State. Centers for Disease Control and Prevention. August 24, 2022. Accessed November 1, 2022. https://www.cdc.gov/nchs/pressroom/sosmap/life_expectancy/life_expectancy.htm
48. Wu Y, Braun K, Onaka AT, Horiuchi BY, Tottori CJ, Wilkens L. Life expectancies in Hawai'i: a multi-ethnic analysis of 2010 life tables. *Hawaii J Med Public Health*. 2017;76(1):9-14.
49. Mokuau N, DeLeon PH, Keawe'aimoku Kaholokula J, Soares S, Tsark JAU, Haia C. Challenges and promise of Health Equity for Native Hawaiians. *NAM Perspectives*. 2016;6(10). https://doi.org/10.31478/201610d
50. Keene DE, Guo M, Murillo S. "That wasn't really a place to worry about diabetes": housing access and diabetes self-management among low-income adults. *Soc Sci Med*. 2018;197:71-77. https://doi.org/10.1016/j.socscimed.2017.11.051
51. Seligman HK, Lyles C, Marshall MB, et al. A pilot food bank intervention featuring diabetes-appropriate food improved glycemic control among clients in three states. *Health Aff (Millwood)*. 2015;34(11):1956-1963. https://doi.org/10.1377/hlthaff.2015.0641
52. Hill-Briggs F, Adler NE, Berkowitz SA, et al. Social determinants of health and diabetes: a scientific review. *Diabetes Care*. 2020;44(1):258-279. https://doi.org/10.2337/dci20-0053

53. Li D, Chinn CC, Fernandes R, Wang CMB, Smith MD, Ozaki RR. Risk of diabetes mellitus among Medicaid beneficiaries in Hawaii. *Prev Chronic Dis*. 2017;14:E116. November 22, 2017. https://doi.org/10.5888/pcd14.170095
54. Kowalsky RH, Rondini AC, Platt SL. The case for removing race from the American Academy of Pediatrics Clinical Practice guideline for urinary tract infection in infants and young children with fever. *JAMA Pediatr*. 2020;174(3):229. https://doi.org/10.1001/jamapediatrics.2019.5242
55. Julian BA, Gaston RS, Brown WM, et al. Effect of replacing race with apolipoprotein L1 genotype in calculation of kidney donor risk index. *Am J Transplant*. 2017;17(6):1540-1548. https://doi.org/10.1111/ajt.14113
56. Quan D, Luna Wong L, Shallal A, et al. Impact of race and socioeconomic status on outcomes in patients hospitalized with COVID-19. *J Gen Intern Med*. 2021;36(5):1302-1309. https://doi.org/10.1007/s11606-020-06527-1
57. Howell CR, Zhang L, Yi N, Mehta T, Garvey WT, Cherrington AL. Race versus social determinants of health in COVID-19 hospitalization prediction. *Am J Prev Med*. 2022;63(1 Suppl 1):S103-S108. https://doi.org/10.1016/j.amepre.2022.01.034