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by

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2022

Approval of The Dissertation Committee

This dissertation has been duly read, reviewed, and critiqued by the Committee listed below, which hereby approves the manuscript of Gaole Song as fulfilling the scope and quality requirements for meriting the degree of Doctor of Public Health.

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Abstract

Racial and Ethnic Disparities in Diabetes-Related Healthcare Service Use in the United States, 2016–2020

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Gaole Song

Claremont Graduate University: 2022

Diabetes is a serious public health issue in the United States. As one of the leading causes of death, the prevalence of diabetes has increased steadily and leads to an enormous medical and societal burden each year. Compared to non-Hispanic White adults, racial/ethnic minority adults have a higher risk to develop diabetes and its complications. Proper healthcare service use is important for reducing the prevalence of diabetes and the risk of complications. However, minority populations receive a lower quality healthcare service and have greater barriers to diabetes self-management. To get a better understanding of racial disparities in diabetes-related healthcare service use, this project assessed service use status among adults who have been diagnosed with diabetes and adults who were at risk of developing diabetes and examined factors that potentially affected these disparities. The results of this project suggested that the use of diabetes-related care services was lower among minority patients with diabetes; the rate of undergoing diabetes screening tests was also lower among minority adults who are at risk of developing diabetes. Socioeconomic status, healthcare insurance coverage, self-rated health status, and health behaviors were factors that significantly impacted the diabetes-related care services use. The findings of this project implicated that promoting the use of diabetes-related care services is critical for reducing the burden caused by diabetes among minority populations. More effective and culturally tailored diabetes intervention programs and related healthcare policies are needed.

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Chapter 1. Introduction

Diabetes is a chronic disease caused by insufficient insulin (defined as "a hormone produced by the pancreas to regulate blood glucose") amount or ineffective insulin use [1]. Patients with diabetes cannot maintain normal blood glucose level, which leads to a persistent high blood sugar level (hyperglycemia) [2]. Hyperglycemia caused by uncontrolled diabetes can seriously damage the body's organs over time and lead to serious health problems such as heart disease, kidney failure, diabetic retinopathy, neuropathy, etc. [1,2]. Age, race, abnormal body mass index (BMI, calculated as an individual's weight in kilograms divided by height in meters squared), physical inactivity, family history of diabetes, and diagnosis of hypertension or heart disease are all risk factors of diabetes [3]. If an individual exhibits any of these factors, he or she is most likely at higher risk of developing diabetes. Prediabetes is another serious health condition that is also related to hyperglycemia; it refers to higher blood sugar levels than normal but not as high to be diagnosed as diabetes [4]. Over the past few decades, the prevalence of diabetes has increased steadily in the world and this disease has become one of the leading causes of death [2].

As the nation's seventh leading cause of death, diabetes is a serious public health problem in the United States [5]. In 2018, approximately 34.2 million people (counted for 10.5% of the total US population) had been diagnosed with diabetes and more than 88 million adults had prediabetes (34.5% of the US population) [5]. The number of undiagnosed diabetes adults was 7.3 million in 2018, which represented 21.4% of adults with diabetes [5]. Due to the failure of early diabetes control, undiagnosed diabetes adults were more likely to develop related complications than those with prediabetes, which would add a further burden [6]. Although efforts have been made to slow down the increased prevalence of diabetes, it continues to remain a health crisis. By 2030, the prevalence of diabetes was anticipated to increase by 54%; the medical and societal burden caused by diabetes would increase 53% to more than $622 billion each year [7]. With this unaffordable burden, patients with diabetes, especially ethnic minority patients, will have a lower quality of life.

In this serious situation, racial and ethnic disparities in diabetes persist and should not be ignored. Previous research has stated that racial and ethnic minorities (defined as Black or African Americans, Hispanics or Latinos, Asian Americans, American Indians and Alaska Natives, Native Hawaiians, and other Pacific Islanders) had greater economic burden caused by diabetes [8,9]. Compared to non-Hispanic White adults, racial/ethnic minority adults have a higher prevalence of diabetes [8]. The age- and sex-adjusted prevalence of diabetes was 19.1% for non-Hispanic Asians, 20.4% for non-Hispanic Blacks, and 22.1% for Hispanics, respectively, while the prevalence was 12.1% for non-Hispanic Whites [9]. The National Diabetes Statistics Report also revealed that prevalence of both diagnosed diabetes and undiagnosed diabetes was higher for minority adults than that for non-Hispanic White adults [5]. Minority groups such as African Americans, American Indians, and Asian Americans have higher rates of developing complications including cardiovascular disease and stroke [5,10]. When responding to disparities in diabetes, it is important to understand this high risk among minority adults. Instead of targeting the general population, specific interventions for high-risk minorities can be more effective for preventing diabetes.

Diabetes and its complications negatively impact an individual’s health. Previous studies found that evidence-based diabetes healthcare practices could prevent acute complications and reduce the risk of developing long-term complications [11,12]. The American Diabetes Association (ADA) suggested that patients should continually take proper medical care and self-care activities to reduce the risk for diabetes complications (such as diabetic retinopathy and diabetic neuropathy) and prolong life expectation. Examples of such activities include participating in self-management education programs, taking medications with instructions of healthcare providers, regularly monitoring blood glucose and checking feet condition as well as eyes, keeping a healthy diet, quitting smoking, and doing more physical exercises [13]. Thus, encouraging patients with diabetes, especially minority patients with high risk of developing complications, to use healthcare service properly is expected to significantly improve a patient's quality of life.

For individuals who are aged 45 and older, ADA recommends that they should take a screening test for type 2 diabetes every 3 years. If adults who are overweight or obese with major risk factors (such as racial/ethnic minority status, unhealthy lifestyle, family history of diabetes, a history of gestational diabetes, diagnosis of hypertension, diagnosis of cardiovascular disease, diagnosis of high cholesterol level, etc.), earlier and more frequent screening tests are strongly suggested [13]. Regular diabetes screening tests can also help undiagnosed patients detect disease status. Early detection and treatment can reduce the economic burden caused by diabetes since it helps to control diabetes condition and reduce the risk of developing long-term complications. Taking diabetes screening tests is a simple but valuable method for individuals who are at risk to prevent diabetes related complications.

Proper healthcare service use is important for reducing the prevalence of diabetes as well as the risk of complications. Facilitating good service use among patients with diabetes and individuals who are at risk of developing diabetes can reduce medical and societal burden caused by this chronic disease. However, many people, especially minority populations, may have various social and economic barriers to access to healthcare services. Minority populations may experience a lower quality of healthcare and greater barriers to health self-management [15]. The overall reported rate of diabetes screening tests was lower than expected. Among the 136 million US adults who met ADA screening criteria, only 46.2% of them reported ever having a screening [16]. As the first step of improving diabetes-related healthcare service use, it is urgent to take such disparities into account. Figuring out potential factors that lead to low rates of both diabetes healthcare use and screening can also help to tackle this disparity. In addition, more efforts are needed for protecting the health of the minority population. Improving the health status of minorities is also an important component of improving the overall public health.

Although racial disparities in healthcare use have been known, previous research focused more on service use of patients with diabetes but failed to include individuals who are at risk. Many studies also did not use the most recent nationally representative data. Therefore, a study that covers all diabetes-related care services with the most recent national data source would hold a good promise to address current racial/ethnic disparities in diabetes health care services.

With the purpose to address such a research gap, this dissertation project aimed to:

a. assess racial/ethnic disparities in diabetes-related healthcare service use among adults who have been diagnosed with diabetes. Services included in the project were clinical care service and self-care activities.
b. assess racial/ethnic disparities in diabetes-related healthcare service use among adults who are at risk of developing diabetes. The service included in the project was the diabetes screening test.
c. examine factors that potentially affect these disparities, such as health behavior factors, demographic factors, self-reported health status, other health conditions, and healthcare status.

All analyses of this project used 2016–2020 Behavioral Risk Factor Surveillance System (BRFSS) data, which is an annual telephone survey that collects health-related information of U.S. residents, including their chronic health conditions, health-related behaviors, preventive services utilization, etc. [17]. In addition, the conceptual model of this project was developed based on the Behavioral Model of Health Services Use (also known as the Andersen Healthcare Utilization Model), which is one of the most widely acknowledged models in analyzing health care utilization [18].

Findings of this project can contribute to developing more effective diabetes intervention programs and healthcare policies. Future guidelines, recommendations, and intervention programs need to be more tailored for minority groups based on their culture and lifestyles, which can achieve better compliance and outcomes. Reliable and proper healthcare policies, regulations, and guidelines can help to increase diabetes-related healthcare service use among minority adults. The results of this project can also help to understand current disparities better and provide insights into improving the effectiveness of diabetes education programs and interventions by modifying possible factors that impact healthcare service use.

Chapter 2. Literature Review

a. Diabetes Care Practices for Patients

For patients who have been diagnosed with diabetes, healthcare practices include two categories: clinical diabetes care and self-care activities.

(1) Clinical Diabetes Care

The ADA's clinical care guidelines recommend patients with diabetes complete three clinical care activities every year, which include at least two hemoglobin A1c (HbA1c) tests, one dilated eye examination by a health care provider, and one comprehensive foot evaluation by a health care provider [13]. HbA1c test is a blood test that reflects "an individual's average blood sugar level over the past 3 months" [19]. This test is used for the diagnosis of prediabetes and type 2 diabetes; meanwhile, it is the major test for monitoring the status of diabetes management [20]. Comprehensive dilated eye examinations can be used to detect eye problems and prevent blindness caused by diabetes [21]. The foot evaluation includes dermatological assessment, neurologic assessments, musculoskeletal assessment, and vascular assessment; it can help to prevent serious foot health problems caused by diabetes [22].

Many relevant studies were conducted based on ADA standards. Results of studies showed that the overall rate of completing all recommended clinical care activities was low [23] but rates of some activities increased [24]. In the New England area, approximately half (50.4%) of patients failed to complete all three annual diabetes healthcare activities (HbA1c tests, dilated eye examination, and foot evaluation), which indicated the low rate of diabetes care use there [23]. Compared to other states, the New England area is a relatively wealthy region in the US with high percentages of healthcare services and insurance coverage; patients there thus were expected to have adequate use of diabetes care services [23]. However, the actual rate of utilization was low. In North Carolina, the rate of healthcare service use was low, especially the rates of having eye examinations, which was decreased year by year; although rates of having HbA1c test, foot examinations, and flu shots among patients with diabetes were increased respectively [24]. Both studies were conducted in a specific area and focused on the general population instead of racial/ethnic minorities. Status was unknown for either the nationwide diabetes-related healthcare service use or racial/ethnic disparities in completing clinal healthcare activities.

(2) Diabetes Self-care Activities for Patients

Diabetes is a complex health condition that requires effective self-management behaviors. The ADA's guidelines recommend that all patients with diabetes should participate in self-management education and training (DSME/T) for diabetes [13]. Education programs can provide patients with the necessary knowledge, skills, and support for successfully and effectively living with diabetes [13]. In 2020, the Association of Diabetes Care & Education Specialist (ADCES) updated their AADE7 Self-Care Behaviors Framework for Patient-centered Diabetes Self-management Education, Training, and Care [25]. In this framework, ADCES recommends 7 self-care activities, which are "healthy coping, healthy eating, being active, monitoring, taking medication, problem solving, and reducing risks" [25].

Previous studies had assessed self-care activities differently based on their purposes. All existing research indicated low participation in self-care management education programs among patients with diabetes. No research included all recommended self-care management activities although these activities are important, which indicated the overall rate of participation in all self-care activities was unknown. Since there was limited research focused on racial/ethnic minority populations, the disparities in participating self-care activities were also unknown.

In New Jersey, approximately 58% of patients with diabetes never participated in any diabetes self-management education programs [26]. In addition, the participation rate was found to be varied by race/ethnicity [26]. Similar to New Jersey, a low engagement level was also found in North Carolina [24]. However, both studies failed to further assess the potential reason for this disparity. If factors that lead to the disparity could be found and improved upon, the participation rate may increase.

Meanwhile, studies have stated that diabetes self-care management education (DSME) was significantly related to achievement of important self-management activities such as self-monitoring blood glucose and self-checking foot conditions [27]. Patients who had participated in DMSE were more likely to monitor blood sugar and perform foot status checks at home as well as be physically active since they were taught related skills to perform tests and were more confident in completing them [27]. Therefore, DSME plays an important role in completing self-care activities since it provides knowledge about self-management and helps patients with diabetes develop key skills.

Previous research also stated different racial/ethnic groups performed self-care activities differently [28]. However, the rate of self-care activities completion was not satisfied regardless of race/ethnicity; only 20% of studied participants engaged in self-care activities (home blood sugar level monitoring, home feet check, and sufficient physical activity) [28].

(3) Mixed Diabetes Care Services

With different research goals, some studies did not identify clinical care services and self-care services clearly [29,30]. Instead, they combined specific services from both categories into one group: diabetes care. Previous research emphasized the importance of utilization of diabetes care services; however, the rate is relatively low. In addition, no research focused on nationwide diabetes care use status; racial/ethnic disparities in completing mixed diabetes care were also unknown.

Certain factors were found to influence diabetes care use. Income level and healthcare insurance status were significantly related to service use [29]. Preventive care services for patients with diabetes (including participating in a DSME at least once, self-monitoring blood sugar level daily, self-checking foot status daily, visiting doctors for diabetes at least once in the past year, having 2 or more HbA1c tests annually, having one foot examination in the past year, and having one eye examination in the past year) were important for diabetes control [29]. Patients with diabetes living in the U.S. territories were found to lag behind in diabetes care engagements (ever participating in a DSME, self-monitoring blood sugar level daily, having 2 or more HbA1c tests annually, and having one foot examination annually) than other patients; however, the nationwide status was unknown [12]. Compared to non-Hispanic White patients, non-Hispanic Asian American patients were less likely to monitor their blood sugar level at home every day, which indicated the disparities [30].

b. Diabetes Care Practice for Individuals at risk

Individuals at risk of developing diabetes are defined as adults aged 45 years or older and overweight or obese adults of any age with at least one additional risk factor [13]. Specifically, the BMI standards are different between non-Hispanic Asian Americans and other racial/ethnic groups: BMI ≥ 23 kg/m^2 is considered as overweight or obese for non-Hispanic Asian Americans while BMI ≥ 25 kg/m^2 is the baseline for other racial/ethnic groups [13]. ADA introduces risk factors including family history of diabetes, racial/ethnic minority, history of cardiovascular disease, high blood pressure ($\geq$140/90 mmHg or taking medications for hypertension), high-density lipoprotein (HDL) cholesterol level less than 35 mg/dL, women with polycystic ovary syndrome, and sedentary lifestyle [13]. Individuals who are at risk of developing diabetes should detect any health conditions related to diabetes in the early stage. ADA's guidelines suggest that they should have a screening test regularly [13]. In addition, For the screening test, fast plasma glucose test, 2-h plasma glucose during 75-g oral glucose tolerance test, and HbA1c test are all considered equally appropriate by ADA [13]. All adults with high risk should have the screening test once every three years; for adults with prediabetes, an annual screening test is recommended [13].

Currently, only limited studies focused on health disparities in diabetes screening; most of these studies were conducted before ADA updated BMI baselines for non-Hispanic Asian Americans. Previous studies have provided strong evidence that an increasing BMI is correlated with a significantly increased risk for developing diabetes and research also indicated racial difference in BMI [31-33].

Shai et al. (2006) tracked potential patterns of weight changes and risk of developing diabetes and found that the risk of non-Hispanic Asian American women was double the risk of non-Hispanic White women at the same BMI level; weight gain over time was more harmful in Asians than in the other racial/ethnic groups [34]. Other studies also addressed that Asian Americans would have a higher risk of developing metabolic diseases than other racial/ethnic groups given the same BMI level [35-37]. Zhu et al. (2019) found that when given a certain diabetes prevalence, racial/ethnic minorities would reach that prevalence with lower BMIs than Whites [38].

The exact mechanism of such racial difference in BMI is unknown. Body fat levels may explain why Asian Americans are more likely to develop diabetes at lower BMI levels. Given the same BMI, Asians had higher levels of total body fat than Whites [39]. Misra et al. (2004, 2009) found South Asians had more total body fat, which led to a higher risk of obesity as well as type 2 diabetes, even when the BMI level might be the same as Whites [40,41].

In order to reflect more accurate categories for determining abnormal weight, multiple studies suggested setting lower cutoff points of BMI for the Asian population [36,37,36]. In 2015, ADA renewed guidelines to reflect the Asian Americans' true risk more accurately and use BMI ≥23 kg/m^2 as Asian Americans' new standard [13]. Previous studies in this literature review still used the old BMI standard for Asian Americans as BMI ≥25 kg/m^2. Compared to other racial and ethnic groups, Asian Americans reported the lowest rate to have the screening test; the overall odds of receiving screening tests of Asian Americans were 34% lower than non-Hispanic Whites [43]. Moreover, all BMI groups (underweight, normal, overweight, obesity) among Asian Americans aged ≥45 were less likely to be screened, which indicated that inadequate screening can be one major factor that leads to the high prevalence of diabetes among Asian Americans. [43]. Another study also found race/ethnicity was significantly associated with diabetes screening history [44].

c. The Importance of Diabetes Healthcare Practices

Previous studies have indicated that evidence-based diabetes healthcare practices could reduce the risk of developing diabetes complications and help patients with diabetes/individuals at risk have better quality of life. One of the public health goals of Healthy People 2030 is reducing the burden caused by diabetes and its complications as well as improving the quality of life for patients with diabetes/individuals at risk [45]. In order to achieve this goal, Health People 2030 addressed the significance of interventions that can help people understand strategies for managing or preventing diabetes [45]. Based on the Health People 2030 plan, the overall burden of diabetes would be reduced by increasing the percentage of patients who monitor blood sugar level daily, increasing the rate of adults participating in formal diabetes education programs, increasing the proportion of people having recommended tests, etc. [45]. Strategies that encourage more people to get adequate healthcare services can help control most diabetes cases; in the end, it would help people improve their quality of life.

Moreover, the Association of Diabetes Care & Education Specialist emphasized the importance of participating in formal diabetes education/prevention programs for both patients with diabetes and adults at high risk [46]. On the one hand, education programs can provide information about diabetes management, methods of using devices (such as continuous glucose monitors, blood glucose meters, insulin pumps, etc.), interpretations of clinical test results, facts of diabetes medications (such as prescribed dosage, side effects, action and efficacy, etc.), and efficient strategies for self-care and problem-solving [46]. On the other hand, building healthy behaviors is one of the most important strategies to prevent Type 2 diabetes and complications related to diabetes [47]. Evidence-based education/prevention programs can provide services including nutrition education, weight-loss strategies, stress counseling, etc.

[46]. Adults who are at high risk can learn how to change unhealthy lifestyles (such as eating habits, physical exercise, tobacco use, alcohol assumption, stressful situations, etc.) in prevention programs that are designed specifically to reduce the risk of developing diabetes [46].

For those who are at risk of developing diabetes, regular diabetes screening tests can also help them detect disease status. With early detection and treatment, adults who are at risk can better prevent and control diabetes conditions, which would reduce the risk of developing long-term complications. Eventually, the economic burden caused by diabetes can be reduced too.

d. Racial/Ethnic Disparities in Healthcare Service Quality

Race/ethnicity is an important risk factor of developing diabetes; adults in some minority racial/ethnic groups are at higher risk [9]. However, adults in these minority racial/ethnic groups usually have more barriers in healthcare service access and use. According to the 2019 National Healthcare Quality and Disparities Report, compared to non-Hispanic Whites, all other racial/ethnic groups reported receiving poorer healthcare quality [48]. Among all healthcare quality measures (including person-centered care, effective treatment, care coordination, care affordability, patient safety, and healthy living), approximately 40% of all services given to Blacks and American Indians/Alaska Natives were worse in quality than received by non-Hispanic Whites [48]. About 35% of care received by Hispanics and 30% of care received by Asians and Native Hawaiian/Pacific Islanders was worse when compared to non-Hispanic Whites [48]. These numbers indicated racial/ethnic minority groups are facing serious disparities in receiving healthcare. In addition, Manual’s research indicated that non-Hispanic Black participants consistently faced poor healthcare service access and use from 2012–2014 while non-Hispanic White participants had the most consistent gains [49].

Previous studies mentioned in this literature review also supported the existence of racial/ethnic disparities in healthcare service use. Dumont et.al addressed the rate of not knowing HbA1c test among Hispanic/Latino patients was higher than that among non-Hispanic White patients. Since the HbA1c test is one of the most important measures for controlling diabetes, it should have been introduced to patients if they ever had any diabetes management education [23]. Lower rate of knowing measures for controlling diabetes indicated that Hispanic/Latino patients had less management knowledge, which also indicated disparities in receiving diabetes education [23]. Meanwhile, based on Boakye et.al, Hispanic patients reported a lower rate to participate in diabetes education programs than non-Hispanic White respondents [27]. In terms of clinical healthcare services, Luo et.al found that only the rates of having clinical foot examinations and HbA1c tests among non-Hispanic White participants increased from 2000–2015; other groups did not show significant change [24]. For self-care services, Johnson et.al indicated fewer non-Hispanic Black and American Indian/Alaska Natives patients engaged in self-care activities compared to other racial/ethnic patients [28]. Yan et.al also found that non-Hispanic Asian Americans were less likely to monitor their blood sugar levels at home daily than non-Hispanic Whites [30]. The difference in diabetes screening tests among different racial/ethnic groups is significant too. Tung et.al addressed that compared to non-Hispanic Whites, non-Hispanic Asian Americans, non-Hispanic Pacific Islanders, non-Hispanic American Indians or Alaskan Natives, and Hispanics/Latinos all reported lower rates of having screening tests; among all racial/ethnic groups, non-Hispanic Asian Americans were least likely to have screening tests [43].

Racial/ethnic minority groups are at higher risk of developing diabetes and its complications; they should take related tests more actively to protect their health. However, various barriers obstruct the access or use of healthcare services among minority groups and lead to disparities in healthcare service use. With the existence of disparities, minority patients or individuals at risk have less service use and they are less likely to control their diabetes very well. Failure of diabetes management adds an extra burden for both patients themselves and society since it increases healthcare costs that could be avoided. Understanding and eliminating the disparities in healthcare service use will improve healthcare access and use among minority groups, decrease the risk of developing serious complications caused by uncontrolled diabetes, and eventually reduce medical and societal burdens.

e. Current Research Gaps

This recent literature search indicates there are still some research gaps in the field of racial/ethnic disparities in diabetes health care service use.

(1) Lack of study on racial/ethnic disparities in diabetes service use with national representative data

Many studies were conducted to analyze diabetes care using regional but not national data: Ogilvie et al. compared the U.S. Territories with other states; Dumont et al. focused on the New England area; Luo et al. focused on North Carolina; and Santorelli et al. analyzed data of New Jersey state [12,23,24,26]. However, diabetes is a serious public health issue for the country; racial/ethnic disparities can impact all adults in this nation. Efforts for reducing the diabetes burden require actions from the whole country instead of specific areas. Although most healthcare policies and regulations are administered at the state level, national results can provide essential insights on local interpretation. By addressing the serious disparities in national results, states that have not paid enough attention to this issue can be motivated to facilitate healthcare service use among minority groups. Nationwide results can also work as a fundamental guideline to help states make decisions and strategies tailored to local specifications. Therefore, it is important to understand the nationwide trend and changes about racial/ethnic disparities. Using national representative data can provide more comprehensive conclusions of racial/ethnic disparities in diabetes service use.

(2) Lack of study focusing on racial/ethnic disparities specifically

There is no doubt that race/ethnicity is an important factor in diabetes-related research. However, many studies used race/ethnicity in analyses as a covariate variable instead of a study variable. Research conducted by Ogilvie et al., Dumont et al., Luo et al., Santorelli et al., Kang et.al, and Tran et.al all included race/ethnicity as one of the sociodemographic characteristics in the research [12,23,24,26,29,32]. These studies emphasized the importance of race/ethnicity, but they did not explain the racial/ethnic disparities in diabetes health care service use. Since achieving racial/ethnic equity in healthcare service use can help reduce the diabetes burden, more research focusing on this issue is necessary.

(3) Lack of study on all diabetes-related healthcare services

Currently, most researchers analyzed diabetes care service use on individuals with diabetes diagnoses (i.e., patients with diabetes) and individuals at risk of diabetes separately. Based on the ADA's Standards of Medical Care in Diabetes, patients with diabetes should complete recommended clinical care services as well as self-care activities [13]. It also suggests adults who are at high risk of developing diabetes to receive screening tests to prevent or delay the development of Type 2 Diabetes [13]. Therefore, it is reasonable to include both diabetes screening tests and diabetes clinical service and self-care activities into the agenda of health disparity research. Studies conducted by Tung et al. and Tran et.al only focused on factors impacting access to diabetes screening services [43,44]. On the other hand, Dumont et al. mainly assessed clinical care services use in their study [23]. Luo et.al combined and analyzed clinical care services and self-care activities; Kang et.al similarly included both clinical tests services and self-care activities; and Yan et.al also analyzed mixed healthcare management activities in their research [24,29,30]. Moreover, both Santorelli et al. and Boakye et.al analyzed diabetes self-management education participation and potential influence factors, and Johnson et al. examined differences in completing diabetes self-care activities by race/ethnicity [26,27,28]. These studies only focused on one aspect of diabetes care but failed to cover more comprehensive healthcare services related to diabetes.

(4) Lack of update on recent changes of racial/ethnic disparities

Multiple studies analyzed data collected approximately 5 years ago [12,23,24,26,30,44]; other studies analyzed data collected approximately 10 years ago or earlier [27,28,29,43]. As one of the most serious public health issues, diabetes requires timely attention. Any changes in diabetes-related healthcare use can be significant for developing public health policies and guidelines. Thus, it is important to capture recent trends of diabetes service use with the most recent data.

In order to bridge the gap, a study that covers all diabetes-related care services with the most recent national data source is necessary. It would hold a good promise to address current racial/ethnic disparities in diabetes health care services utilization and provide support for developing future public health policies.

Chapter 3. Methods

a. Project objectives

This study assessed the most recent racial/ethnic disparities in diabetes-related healthcare services use among adults who have been diagnosed with diabetes and those who are at risk of developing diabetes. Additionally, this project:

(1) compared differences in diabetes-related healthcare service use among patients with diabetes in different racial/ethnic groups.

(2) compared differences in diabetes screening service use among individuals who are at risk of developing diabetes in different racial/ethnic groups.

(3) examined how potential factors such as sociodemographic factors, self-rated health status, other health conditions, health behaviors, etc. were associated with racial/ethnic disparities in diabetes-related healthcare service use.

b. Hypotheses

There are three hypotheses of this dissertation project.

(1) Patients with diabetes in racial/ethnic minority groups will have lower diabetes-related healthcare service use than non-Hispanic White patients in the period from 2016 to 2020 (completion of diabetes clinical care activities and self-care activities).

(2) Individuals who are at risk of developing diabetes in racial/ethnic minority groups will have lower rate of having diabetes screening tests than non-Hispanic White individuals in the period from 2016 to 2020.

(3) Sociodemographic factors (e.g., age, educational level, income), health insurance

status, self-reported health status, and health behaviors will be significantly related to the racial/ethnic disparities in using diabetes-related healthcare services and having screening tests.

c. Methods and Design

(1) Conceptual Framework

The Behavioral Model of Health Services Use Model (also known as the Andersen Healthcare Utilization Model) was used as the concept model for this dissertation project. This model is used to discover the factors that either facilitate or impede the utilization of health services [50]. Based on this model, an individual's use of healthcare services can be determined by three categories: predisposing factors, enabling factors, and need factors [50].

In the early 2000s, Andersen and Davidson improved the model in their later report by adding contextual determinants (contextual predisposing characteristics, contextual enabling characteristics, and contextual need characteristics) [51]. Some example contextual factors mentioned in the advanced model are proportion of recent immigrants, crime rate in the interested community, budget for health services, healthcare facilities and personnel conditions, water quality, air quality, housing quality, etc. [51]. Rather than individual character, contextual factors focus more on the general healthcare environment, which impacts the whole population [51]. Andersen addressed that access to healthcare could be a complex outcome of interactions between contextual and individual factors and the model should take key contextual components into account [51].

While contextual determinants play an important role in healthcare service use, this project focused on individual determinants and population related factors. How contextual determinants impact healthcare service use among different races and ethnicities would be discussed in future studies. Since the goal of this dissertation project was to investigate impacts of predisposing factors, enabling factors, and need factors, the original model was used [50].

Following is a description of determinants introduced in the original Andersen Healthcare Utilization Model:

a) Environment:

i. Healthcare system: health policies (at local and national levels), financing (incentives to purchase or provide health services, and per capita expenditures for healthcare services), organization (the amount, distribution, and structure of healthcare facilities and personnel) [50].

ii. External environment: environment (housing quality, injury rate, and death rate) [50]

b) Population characteristics:

i. Predisposing factors: demographic characteristics (age, gender, marital status), social characteristics (an individual's education level, occupation, race/ethnicity, culture, social networks, and social interactions), and health beliefs (attitudes, values, and healthcare-related knowledge) [50].

ii. Enabling factors: financing (income or wealth for healthcare services, knowledge of methods to access healthcare services, healthcare insurance status, and cost-sharing requirements), community (availability of healthcare personnel and facilities, regular sources of healthcare, types of the regular source, transportation time and waiting time for healthcare services), and genetic factors or psychological characteristics [50].

iii. Need factors: perceived need (personal views of health status, experience and emotional response to diseases, and perceptions of a health problem), evaluated need (judgments and measurements of an individual's health status by health professionals, professional decisions of the need for medical care) [50].

c) Health Behaviors:

i. Personal health practices (diet and nutrition, physical exercise, mental health status, alcohol consumption, tobacco use, self-care, and adherence to medical regimens) [50]

ii. The use of personal health services [50].

d) Outcomes:

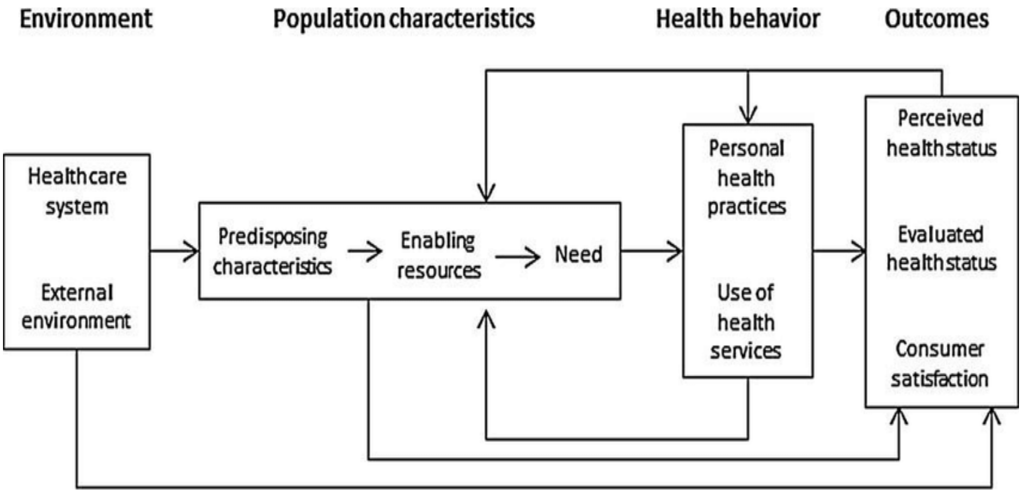
i. Perceived health status (self-rated general health status, activities of daily life, and disability) [50].

ii. Evaluated health status (tests, diagnosis and prognosis of health condition) [50].

iii. Consumer satisfaction (how individuals are satisfied with the health care service they receive) [50].

Figure 1 shows the interactions of all factors from the model [50]. Based on the model, the healthcare system, external environment, population characteristics, and individual health behaviors can impact the healthcare use outcomes jointly. Meanwhile, the feedback on outcomes will also influence population characteristics and health behaviors. Each determinant plays a significant role in the loop. Thus, improving these determinants can improve healthcare use outcomes; better outcomes of healthcare services use can improve related determents in turn. In the end, the overall healthcare quality as well as the percentage of healthcare service use will be improved, which would benefit public health.

Figure 1 The Behavioral Model of Health Services Use Model [50]



A systematic review assessed the use and implementation of this model addressed that the Andersen Healthcare Utilization Model (1995 version) had been used widely in the field of investigating the use of health services [52]. Most studies that used this model in their research were secondary data analyses using national survey sources with the purposes of investigating overall healthcare utilization [52]. Previous studies that focused on healthcare services use categorized the target variables identically. The majority of these studies analyzed predisposing determinants (age, gender, marital status, education, and ethnicity), enabling factors (income, health insurance status, and whether having a regular source of healthcare), and need factors (self-reported health status, evaluated health status, and various diseases/health conditions) [52]. As a secondary data analysis project that also focused on healthcare use, this project included the variables above in accordance with the theoretical model and previous research.

(2) Data Source

This dissertation project used Behavioral Risk Factor Surveillance System (BRFSS) Combined Landline Telephone and Cellular Telephone data from 2016–2020 as the data source.

a) Behavioral Risk Factor Surveillance System Overview

BRFSS is a national telephone survey system that aims to collect health-related data about the U.S. noninstitutionalized adult population (≥18 years) living in all 50 states and the District of Columbia as well as three U.S. territories at the state level and local level [53]. As a powerful tool for understanding and improving health-related activities in the U.S., BRFSS can collect data from more than 400,000 adults each year through both landline telephone-based interviews and cellular telephone-based interviews [53]. Questions of the BRFSS survey cover important health-related aspects including health-related risk behaviors, chronic health conditions, health care access, self-rated general/physical/metal health status, health-related quality of life, and use of preventive services [54]. Responses of BRFSS participants are self-reported and there is no proxy interview [54].

The BRFSS questionnaire has three parts: core component, optional BRFSS modules, and state-added questions [54]. The core component includes standardized questions that are used by all states, while optional modules are questions focusing on specific topics and used by different states. Since BRFSS aims to ensure the width of question range in optional modules, CDC creates three split versions of the questionnaire for states to decide which one would be used each year. Although all versions follow the state sample design, states using different versions of the questionnaires will include different optional modules and state-added questions [54]. The majority of diabetes-related data were stored in the Combined Landline Telephone and Cellular Telephone (core version); therefore, this project used a set of 5-year core version data as the source.

b) Response Rates

According to the BRFSS Summary Data Quality Report, response rates are defined as "the number of respondents who completed the survey as a proportion of all eligible and likely-eligible people" [55 - 59]. Table 1 shows BRFSS ranges of response rates and median response rates for all states, Washington DC, and territories from 2016 to 2020 [55 - 59].

Table 1 2016-2020 BRFSS Response Rates

Year	**Range (%)**		**Median (%)**
2016	30.7	65.0	47.0
2017	30.6	64.1	45.1
2018	38.8	67.2	49.9
2019	37.3	73.1	49.4
2020	34.5	67.2	47.9

c) BRFSS versus Other National Data Sources

Based on the previous literature review, some research that investigated on similar topics may use other national survey data as data sources, such as The National Health and Nutrition Examination Survey (NHANES) and The National Health Interview Survey (NHIS). Compared to NHANES and NHIS, BRFSS has its own strengths, therefore, BRFSS was the preferred data source for this dissertation project.

i. Brief Introductions of NHANES and NHIS

1. NHANES

The National Health and Nutrition Examination Survey (NHANES) is a program designed by the National Center for Health Statistics (NCHS). The goal of NHANES is to assess the health and nutritional status of its participants [60]. In order to obtain health-related information at national level, NHANES interviews approximately 5,000 participants each year as a nationally representative sample; all participants live in 15 selected counties across this country

[60].

Compared to other similar programs, NHANES is unique in that it not only has questionnaire interviews but also has a comprehensive physical examination for each participant. The questionnaire component of NHANES collects demographic information, socioeconomic information, dietary information, chronic conditions status (such as cardiovascular disease and diabetes), lifestyle information (such as physical exercises, constitution, health behaviors like tobacco use and alcohol consumption), heredity data, etc. [61]. The physical examination part of NHANES is operated by highly trained health professionals and for all participants regardless of age. During the examination, participants are required to take laboratory tests such as blood glucose tests and cholesterol tests [61]. Meanwhile, participants also receive anthropometric (e.g., weight and height) as well as other clinical, dental, and physiological assessments [61]. NHANES questionnaire information is collected in the participant's home while physical examinations are conducted in mobile centers which are specially designed and equipped [61].

Data collected by NHANES can expand the health knowledge of the country and make contributions to various health-related fields. For example, based on the statistics of height and weight measurements, CDC can develop the national standards of height and weight. Diseases and risk behaviors information can be used in epidemiological research to determine the disease prevalence and evaluate potential relationships between diseases and risk factors, which will also help to develop disease prevention programs and health promotion programs. In addition, policymakers can develop sound health policies and design proper healthcare services according to the findings of NHANES.

2. NHIS

The National Health Interview Survey (NHIS) is another program designed by the NCHS. NHIS aims to monitor the health status of the population in this country and provide health-related data collected through the questionnaire survey [62]. As a cross-sectional household survey program, NHIS uses a geographically clustered sampling method to determine the sample of dwelling units, which can ensure the sample is nationally representative [62]. Participants enrolled in NHIS are residents of households and noninstitutional group quarters including adults and children in the 50 states and the District of Columbia; individuals who do not have a fixed household address are excluded [62]. Beginning in 2019, the NHIS sample had been reduced to 30,000 adults and 9,000 children due to limited budget [62].

In NHIS, face-to-face interviews are conducted in participants' homes with telephone follow-ups interviews [62]. The questionnaire of NHIS covers important health-related topics such as demographic characteristics, chronic diseases, health behaviors, healthcare use, and healthcare coverage [62]. NHIS data can be used in epidemiologic research and other health-related studies. Findings of the NHIS survey can contribute to figuring out trends of chronic diseases and disability as well as identifying the progress of improving population health [62]. Policymakers can also use data to analyze potential barriers to healthcare access and use, which will help to develop appropriate healthcare policies and intervention programs.

ii. Comparison of data collecting method

For self-reported questionnaire data including demographic information and health-related information, BRFSS collects data by telephone surveys while NHANES and NHIS collect data through in-person interviews [53,61,62]. Previous studies have supported the equivalence between telephone surveys and in-person interviews for measuring various health behaviors and indicated both approaches were valid and reliable [63-67]. Thus, there would be no significant difference between using BRFSS and NHANES/NHIS as a data source in terms of questionnaire information.

However, biological markers collected by NHANES strengthen the data quality. While BRFSS and NHIS collect all information by the standardized questionnaire solely, NHANES has a standardized physical examination component to collect participants' medical, dental, physiological measurements such as height and weight [60]. Participants of NHANES will also take laboratory tests performed by highly trained medical personnel for identifying disease status [61].

In this dissertation project, BMI is an important variable for classifying individuals who meet the standards of taking regular diabetes screening tests. Compared to NHANES, BMI information in BRFSS data is self-reported, which may not be accurate due to potential recall bias. In order to evaluate the robustness of results and better understand service use among individuals at risk of developing diabetes, additional sensitivity analyses that use the most recent NHANES data (2017-March 2020 Pre-pandemic NHANES) were conducted as a supplement to evaluate if trends of taking screening tests estimated in NHANES data were similar with BRFSS results

Other key information such as demographic characteristics, diabetes clinical care service use status, and diabetes screening test receipt are all self-reported responses and collected by questionnaire interview, regardless of survey programs [68-70].

iii. Comparison of definitions of diabetes status

1. Diagnosed diabetes patients

Diagnosed diabetes is defined by the self-reported affirmative response during the questionnaire interview. If a participant indicated ever been told to have diabetes (excluding gestational diabetes) by a doctor, nurse, or other health professionals, then that participant is identified as a diagnosed diabetes patient. This definition was used in previous research widely regardless of taking BRFSS [23,24,26-30,43,44], NHANES [71-74], or NHIS [75,76] as a data source.

2. Individuals at risk

ADA identifies individuals who are at risk to develop diabetes as “all adults 45 years and older" and “adults under 45 years with overweight or obesity (BMI ≥ 25 kg/m^2 or ≥ 23 kg/m^2 for Asian Americans) who have at least one additional risk factor, such as family history of diabetes, high-risk race/ethnicity (e.g., African American, Latino, Native American, Asian American, Pacific Islander), history of cardiovascular disease, hypertension, hyperlipidemia, and physical inactivity” [13]. Previous research applied this standard in defining individuals at risk regardless of using BRFSS [43], NHANES [77], or NHIS [78] as a data source. For all data sources mentioned, screening test recipients are interviewed during the questionnaire survey. Also, for all survey programs, self-reported diagnosed diabetes patients would not be asked whether they had a screening test; only participants who gave negative responses to the diagnosis question would be asked.

3. Other diabetes conditions

ADA’s guidelines consider the fasting plasma glucose (FPG) value, 2-hour plasma glucose (2-h PG) value during a 75-g oral glucose tolerance test (OGTT), and A1C criteria as diagnostic tests for diabetes [13]. Menke et.al (2015) indicated laboratory tests of NHANES data had all glucose measurements, but 2-h PG results were not available for all age groups and 2-h PG results were not in every year of NHANES data [59]. BRFSS and NHIS do not have the above tests data. Therefore, some diabetes conditions can be only identified in NHANES data.

a) Undiagnosed diabetes (can only be assessed in NHANES data): If a participant reported a negative response to diabetes diagnosis question but had the A1C test result 6.5% or greater, FPG 126 mg/dL [7.0 mmol/L] or greater, or 2hPG 200 mg/dL [11.1 mmol/L] or greater, then the participant can be defined as undiagnosed diabetes patient [71-74].

b) Prediabetes: prediabetes is defined by the self-reported affirmative response during the questionnaire interview. If a participant indicated they had ever been told of having prediabetes or borderline diabetes by a doctor, nurse, or other health professionals, then that participant is identified as prediabetes. This definition was used in previous research regardless of whether the data source was BRFSS [79,80], NHANES [81,82], or NHIS [83].

c) Undiagnosed prediabetes (can only be assessed in NHANES data): If a participant reported a negative response to prediabetes or borderline diabetes diagnosis question but had the A1C test result 5.7 – 6.4%, FPG 100 mg/dL [5.6 mmol/L] to 125 mg/dL [6.9 mmol/L], or 2hPG 140 mg/dL [7.8 mmol/L] to 199 mg/dL [11.0 mmol/L], then the participant can be defined as undiagnosed prediabetes [84].

However, adults with undiagnosed diabetes, prediabetes, and undiagnosed prediabetes were not the study population in this dissertation project. ADA suggested that prediabetes status only indicated the increased risk for diabetes and heart disease but should not be treated as a clinical entity [13]. Therefore, diabetes-related clinical care services may be not proper for prediabetes patients. Current questionnaires do not collect any information about diabetes-related clinical service among adults with prediabetes [68-70]. Additionally, the 2017 National Standards for Diabetes Self-Management Education and Support addressed self-care management education and support (DSMES) programs and National Diabetes Prevention Program (National DPP) lifestyle change programs are tailored for different participants with different needs and expectations; DPP is designed to provide more specific skills for prediabetes while DSMES works better for patients with diabetes [85]. Yet, no information about DPP was captured in BRFSS, NHANES, or NHIS. In addition, as mentioned previously, the screening test question is not asked if the participant self-reported as prediabetes patient

[77].

For undiagnosed diabetes patients, although they can be detected through NHANES lab tests, their information about diabetes-related healthcare activities was not captured in the questionnaire interview. If the participant reported a negative response to the diabetes diagnosis question, regardless of using BRFSS, NHANES, or NHIS questionnaire, follow-up questions such as the frequency of having blood sugar tests would be skipped; only the question of whether having screening tests would be asked when participants have negative responses [68-70]. Using self-reported diabetes diagnosis as a classification method may be not the most accurate definition; however, no information about diabetes-related healthcare service use among undiagnosed patients collected by nationally representative interviews is available yet. More details will be discussed later in the Discussion part of this dissertation.

Since the purpose of this project is to examine the racial/ethnic disparities in diabetes-related healthcare use, the study population of this project included diagnosed diabetes patients and individuals at risk of developing diabetes. For screening test utilization, NHANES data was analyzed in this project as an additional supplement to calibrate the result.

iv. Comparison of survey question design

Questionnaires of BRFSS, NHANES, and NHIS share very similar questions regarding the diabetes part. Table 2 shows examples of important questions in diabetes parts according to the most updated questionnaires of 2020 BRFSS, 2017-2018 NHANES, and 2021 NHIS [68-70]. This table indicates that questions related to the diabetes diagnosis in these three national surveys are all self-reported. Meanwhile, all questions are designed similarly. In addition, both NHIS and NHANES failed to cover all aspects of diabetes-related healthcare services. NHIS does not include questions related to diabetes healthcare use, which indicates that NHIS cannot be used as the data source for this dissertation project. NHANES does not include the diabetes education question and fails to collect information about DSMES, which is an important measure of diabetes-related healthcare. Both BRFSS and NHIS ask for test frequency of the HbA1c test while NHANES only needs affirmative or negative responses. ADA recommends diagnosed diabetes patients to have at least two HbA1c tests by clinical professionals annually. Information in NHANES data fails to include the number of tests, which may make it difficult to identify if a patient meets the ADA standard by using the NHANES questionnaire.

Table 2 Comparation of Survey Questions [68-70]

Question Category	BRFSS Question	NHANES Question	NHIS Question
Diabetes Diagnosis	"Has a doctor, nurse, or other health professional ever told you had diabetes?"	"Have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes?"	"Has a doctor or other health professional EVER told you that you had prediabetes or borderline diabetes?"
Insulin Intake	"Are you now taking insulin?"	"Are you now taking insulin?"	"Insulin can be taken by shot or pump. Are you NOW taking insulin?"
Diabetes Screening	"Have you had a test for high blood sugar or diabetes within the past three years?"	"Have you had a blood test for high blood sugar or diabetes within the past three years?"	"When was the last time you had a blood test for high blood sugar or diabetes by a doctor, nurse, or other health professional?"
HbA1C Test Frequency	"About how many times in the past 12 months has a doctor, nurse, or other health professional checked you for A-one-C?"	"During the past 12 months, has a doctor or other health professional checked your glycosylated hemoglobin or "A one C"?"	"About how many times in the past 12 months has a doctor, nurse, or other health professional checked your A-one-C?"

Self-check Blood Sugar	"About how often do you check your blood for glucose or sugar? by a family member or friend"	"How often do you check your blood for glucose or sugar? Include times when checked by a family member or friend, but do not include times when checked by a doctor or other health professional."	-
Foot Exam	"About how many times in the past 12 months has health professional checked your feet for any sores or irritations?"	"During the past 12 months, about how many times has a doctor or other health professional checked feet for any sores or irritations?"	-
Self-check Foot Status	"Including times when checked by a family member or friend, about how often do you check your feet for any sores or irritations?"	"How often do you check your feet for sores or irritations? Include times when checked by a family member or friend, but do not include times when checked by a doctor or other health professional."	-
Eye Exam	"When was the last time you had an eye exam in which the pupils were dilated, making you temporarily sensitive to bright light?"	"When was the last time had an eye exam in which the pupils were dilated? This would have made temporarily sensitive to bright light."	-
Doctor Visiting for Diabetes	"About how many times in the past 12 months have you seen a doctor, nurse, or other health professional for your diabetes?"	"How many times have you seen this doctor or other health professional in the past 12 months?"	-
Diabetes Education	"Have you ever taken a course or class in how to manage your diabetes yourself?"	-	-

v. Other strengths of BRFSS data

Due to the coronavirus disease 2019 (COVID-19) pandemic, NHANES suspended operations in March 2020, which led to the incompletion of the NHANES 2019-2020 cycle

[86]. Since the data collected from 2019 to March 2020 was not nationally representative, NHANES combined that data with the 2017-2018 cycle [86]. Thus, for some specific diseases or subgroups of the population, the sample size of this combined NHANES data may be small [86]. Similarly, NHIS also changed to conduct telephone interviews instead of original in-person interviews in March 2020 and reduced the sample [87]. However, as a telephone survey system, BRFSS continued interviewing during the pandemic and completed the 2020 data report. The total 5-year sample of BRFSS is 2,193,981, which is relatively large.

(3) Measures

Measures of this dissertation project were decided based on the conceptual model and previous literature. This dissertation project included two studies: healthcare service use of patients with diabetes and healthcare service use of individuals at risk of developing diabetes. Measures are described below.

a) Study 1: Diabetes-related Healthcare Service Use for Patients

i. Study population

Adults with diabetes, excluding adults with pre-diabetes/borderline diabetes and gestational diabetes (questionnaire question: “Has a doctor, nurse, or other health professionals ever told you that you had diabetes?”) [68]. This project created a binary variable (yes/no) to identify whether the respondent was diagnosed with diabetes.

ii. Independent variable

Self-reported race/ethnicity. This project used a calculated variable of BRFSS [68]. The original variable has 8 categories; this project combined non-Hispanic other race and non-Hispanic Multiracial race as one group [43] and combined the non-Mexican Hispanic and Mexican groups as Hispanic/Latino [77]. The final categories of race/ethnicity are non-Hispanic White, non-Hispanic Black, non-Hispanic Asian American (including Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, and other Asian), Hispanic or Latino (including Mexican, Mexican American, Chicano/a, Puerto Rican, Cuban, other Hispanic, Latino/a, or Spanish origins), non-Hispanic American Indian or Alaskan Native, non-Hispanic Pacific Islander (including Native Hawaiian, Guamanian or Chamorro, Samoan, and other Pacific Islander), and non-Hispanic multiracial and non-Hispanic others.

iii. Dependent variable

Diabetes-related healthcare service use. This project assessed two categories for the service use status, which are clinical diabetes care and self-care practice.

1. Clinical diabetes care service use: This project created three binary variables to determine the completion of annual clinical diabetes care in the past 12 months, including having ≥2 hemoglobin A1C tests by health professionals (yes/no), ≥1 eye examination by health professionals (yes/no), and ≥1 foot examination by health professionals (yes/no). Binary variables were recoded based on BRFSS questions “About how many times in the past 12 months has a doctor, nurse, or other health professional checked you for A-one-C?”, “When was the last time you had an eye exam in which the pupils were dilated, making you temporarily sensitive to bright light?”, and “About how many times in the past 12 months has a health professional checked your feet for any sores or irritations?” [68]. The completion status of annual clinical diabetes care use included three categories: fully completed (complete all three activities), partially completed (complete one or two activities), not completed (complete 0

activity).

2. Self-care practices completion: This project created 4 binary variables to determine the completion of self-care practices, including engaging in any physical activity or exercise during the leisure time in the past month (yes/no), self-monitoring blood glucose daily (yes/no), self-checking feet for sores or irritations daily (yes/no), and ever participating in any diabetes self-management education programs (yes/no). Specifically, in the BRFSS questionnaire, self-management education programs refer to the broad category as any classes or courses that provide diabetes management knowledge; no particular DSMES program is mentioned [68]. Binary variables were recoded based on BRFSS questions "During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?", "About how often do you check your blood for glucose or sugar?", "Including times when checked by a family member or friend, about how often do you check your feet for any sores or irritations?", and "Have you ever taken a course or class in how to manage your diabetes yourself?" [68]. The completion status of self-care activities included three categories: fully completed (complete all four activities), partially completed (complete one or two or three activities), not completed (complete 0 activity).

iv. Covariates

1. Demographic variables:

a) Age: this project used a calculated variable in BRFSS. Age groups were divided as 6 groups including ≥65, 55-64, 45-54, 35-44, 25-34, and 18-24.

b) Gender: male/female.

c) Marital status: this project created a binary variable including two categories, which were married or living with a partner and other (divorced, widowed, separated, or never married).

d) Annual household income: this project used a calculated variable in BRFSS. Income was divided as 5 groups including less than $15,000, $15,000 to less than $25,000, $25,000 to less than $35,000, $35,000 to less than $50,000, $50,000 or more.

e) Educational attainment: this project used a calculated variable in BRFSS. Educational levels were divided as 4 groups including did not graduate high school, graduated high school, attended college or technical school, graduated from college or technical school.

f) Employment status: this project created a three-categories variable including unemployed (out of work for 1 year or more, out of work for less than 1 year), not in the labor force (a homemaker, a student, retired, unable to work), and employed (employed for wages, self-employed).

2. Healthcare status:

a) Health insurance coverage: this project created a binary variable to assess coverage by health insurance (survey question: “Do you have any kind of health care coverage, including health insurance, prepaid plans such as HMOs, or government plans such as Medicare, or Indian Health Service?”) [68].

b) Whether having a routine annual checkup in the past 12 months: this project created a three-category variable including never, not within past year, and yes within past year (About how long has it been since you last visited a doctor for a routine checkup?”) [68].

c) Whether having a regular health care provider: this project created a binary variable (yes and no) to assess (survey question: “Do you have one person you think of as your personal doctor or health care provider?”) [68].

d) Unmet healthcare needs because of cost: this project created a binary variable (yes and no) to assess healthcare needs (survey question: “Was there a time in the past 12 months when you needed to see a doctor but could not because of cost?") [68].

3. General health status:

a) Self-rated general health status: this project created a three-category variable including poor, fair, good or better health to assess a participant's self-rated general health (survey question: "Would you say that in general your health is…") [68].

b) Self-rated physical health status in the past 30 days: this project used a calculated variable in BRFSS which was a binary variable, good (0-13 days) and poor (≥14 days), to assess a participant's self-rated physical health (survey question: "For how many days during the past 30 days was your physical health not good?") [68].

c) Self-rated mental health status in the past 30 days: this project used a calculated variable in BRFSS which was a binary variable, good (0-13 days) and poor (≥14 days), to assess a participant's self-rated mental health (survey question: "For how many days during the past 30 days was your mental health not good?") [68].

d) Days that poor health status affected usual activities in the past 30 days: this project created a binary variable to assess the health status, including not affected (0-13 days) and affected (≥14 days) (survey question: "During the past 30 days, for about how many days did poor physical or mental health keep you from doing your usual activities, such as self-care, work, or recreation?") [68].

e) Diagnosis with other key chronic health conditions (heart attack, heart disease, stroke, asthma, cancers except for skin cancer, chronic obstructive pulmonary disease COPD, arthritis, kidney disease, depressive disorder): this project created binary variables to assess the diagnosis status, yes and no.

f) Insulin use: created a binary variable to assess, yes and no.

g) Whether diabetes has affected eyes (referred as an indicator of poor diabetes control [23]): created a binary variable to assess, yes and no (survey question: "Has a doctor ever told you that diabetes has affected your eyes or that you have retinopathy") [68].

4. Health behaviors:

a) Smoking status: this project used a calculated variable in BRFSS which was a three-category variable including current smoker (every day smoker, someday smoker), former smoker, and non-smoker (never smoked).

b) Alcohol consumption: this project used a calculated variable in BRFSS to assess whether the participant was a heavy drinker. It was a binary variable, yes and no.

b) Study 2a: Diabetes-related Healthcare Service Use for Individuals at Risk

i. Study population

Adults who are not diagnosed with diabetes but should be screened for type 2 diabetes. This dissertation project defined respondents with high risks of developing diabetes as adults who are aged ≥45 years and aged <45 years with overweight and obese BMI (BMI ≥23 kg/m^2 for Asians and BMI ≥25 kg/m^2 for other races/ethnicities). BMI is a calculated variable in the BRFSS dataset. ADA guidelines recommend overweight and obese adults who are aged less than 45 years have screening tests if they have at least one additional risk factor (family history of diabetes, sedentary lifestyle, diagnosis of hypertension, etc.) [13]. Previous research found that the majority of adults who were overweight or obese also had one or more risk factors [43,88]. US Preventive Services Task Force also addressed obesity and overweight were the strongest risk factors for developing diabetes [89]. Thus, this project included all overweight and obese adults regardless of risk factors.

ii. Independent variable

Self-reported race/ethnicity, variable categories were same as Study 1.

iii. Dependent variable

Self-reported receipt of the diabetes screening test. This project created a binary variable to analyze whether respondents had the screening test (yes and no) based on the BRFSS question “Have you had a test for high blood sugar or diabetes within the past three years?” [68].

iv. Covariates

1. Demographic variables: age, gender, marital status, annual household income, educational attainment, and employment status. Variables categories were same as Study 1.
2. Healthcare status: health insurance coverage, whether having a routine annual checkup in the past 12 months, whether having a regular health care provider, and if having unmet healthcare needs because of cost. Variables categories were same as Study 1.
3. General health status: self-rated general health status, self-rated physical health status in the past 30 days, self-rated mental health status in the past 30 days, days that poor health status affected usual activities in the past 30 days, and other key chronic conditions. Variables categories were same as Study 1.
4. Health behaviors: smoking status, alcohol consumption, and leisure-time physical activity. Variables categories were same as Study 1. Study 2 also include leisure-time physical activity as a covariate, which was a calculated binary variable in BRFSS, yes and no.

c) Study 2b: Diabetes-related Healthcare Service Use for Individuals at Risk, 2017-March 2020 Pre-pandemic NHANES Data

i. Study population

Study population was the same as using BRFSS data. However, the BMI variable in NHANES data was collected by physical examination, which was not self-reported [90]. Additionally, since NHANES has both the interview and examination part, only participants who had been both interviewed and Mobile Examination Center examined were considered eligible. Criteria for defining adults who are at risk of developing diabetes were the same.

ii. Independent variable

Self-reported race/ethnicity. Due to a different design, the NHANES questionnaire identified race/ethnicity variable categories as Mexican American, other Hispanic, non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, and other Race - including multi-Racial [90]. NHANES data did not interview the subgroup information like BRFSS. Thus, some race/ethnicity details could not be captured in this dataset. As a result, in the additional analyses, Mexican Americans and Other Hispanic were combined as Hispanic/Latino; non-Hispanic American Indian or Alaskan Native, non-Hispanic Pacific Islander, and non-Hispanic multiracial and non-Hispanic others were combined as Other Race. The final race/ethnicity variable in the additional analyses included non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, Hispanic/Latino, and Other Race.

iii. Dependent variable

Self-reported receipt of the diabetes screening test. Additional analyses used the same binary variable to analyze whether respondents had the screening test (yes and no) based on the NHANES question “Have you had a test for high blood sugar or diabetes within the past three years?” [69].

iv. Covariates

Due to a different design, the NHANES questionnaire did not interview the same questions as BRFSS did. Thus, in the additional analyses, some covariates were not included. The variable list below described covariates included in the additional analyses using NHANES data.

1. Demographic variables:

a) Age: NHANES data interviewed participant’s age in years at the time of screening [90]. In NHANES data, it also interviewed participants who were aged less than 18 years old. To be in accordance with the main analyses, additional analyses only included adult participants (≥18 years old) and considered younger participants as missing. Additional analyses also used age groups instead of age in years. Age groups were divided into 6 groups including ≥65, 55-64, 45-54, 35-44, 25-34, and 18-24.

b) Gender: male/female.

c) Marital status: NHANES questionnaire interviewed participants for their marital status and categorized them as married/living with a partner, widowed/divorced/separated, and never married. To be in accordance with the main analyses, additional analyses combined widowed/divorced/separated and never married as “other”. Thus, these additional analyses also used a binary variable including two categories, which were married or living with a partner and other (divorced, widowed, separated, or never married).

d) Educational attainment: NHANES questionnaire interviewed participants for their educational levels and categorized them as less than 9th grade, 9-11th grade (including 12th grade with no diploma), high school graduate/GED or equivalent, some college or AA degree, and college graduate or above [90]. To be in accordance with the main analyses, additional analyses also used the variable that was divided into 4 groups including did not graduate high school (less than 9th grade, 9-11th grade (including 12th grade with no diploma)), graduated high school (high school graduate/GED or equivalent), attended college or technical school (some college or AA degree), graduated from college or technical school (college graduate or above).

2. Healthcare status:

Health insurance coverage: similar to the main analyses, the additional analyses used a binary variable to assess whether or not participants have health insurance (survey question: “Are you covered by health insurance or some other kind of health care plan?”) [90].

3. General health status:

a) Self-rated general health status: similar to the main analyses, the additional analyses used a three-category variable including poor, fair, good or better health to assess the general health status (survey question: “Would you say your health in general is . . .”) [90].

b) Diagnosis with other key chronic health conditions (heart attack, heart disease, stroke, asthma, cancers (all kinds of cancer), chronic obstructive pulmonary disease COPD, arthritis, kidney disease, depressive disorder): used binary variables to assess the diagnosis status, yes and no. Especially, NHANES data used the nine-item depression screening instrument (also called the Patient Health Questionnaire, PHQ-9) to detect if the participant had depressive disorder [90].

4. Health behaviors:

a) Smoking status: To be in accordance with the main analyses, additional analyses also used the variable that was divided as current smokers (every day smokers, someday smokers), former smokers, and non-smoker (never smoked). This variable was created based on NHANES questions "Have you smoked at least 100 cigarettes in your entire life?", and "Do you now smoke cigarettes?" [90]. Current smoker was defined as "Respondents who reported having smoked at least 100 cigarettes in their lifetime and now smoke every day" and "Respondents who reported having smoked at least 100 cigarettes in their lifetime and now smoke some days" [68]. Former smoker was defined as "Respondents who reported having smoked at least 100 cigarettes in their lifetime and currently do not smoke" [68]. Non-smoker was defined as "Respondents who reported they had not smoked at least 100 cigarettes in their lifetime" [68].

b) Leisure-time physical activity: To be in accordance with the main analyses, additional analyses also used a binary variable to describe if the participant had leisure-time physical activity. This variable was created based on NHANES questions "The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities. In a typical week do you do any vigorous-intensity sports, fitness, or recreational activities that cause large increases in breathing or heart rate like running or basketball for at least 10 minutes continuously?" and "In a typical week do you do any moderate-intensity sports, fitness, or recreational activities that cause a small increase in breathing or heart rate such as brisk walking, bicycling, swimming, or volleyball for at least 10 minutes continuously?" [90]. If any of these two questions were answered "yes", then the participant was considered as had leisure-time physical activity.

Some covariates variables were not included in the additional analyses. The list below described variables and reasons why they were included in the main analyses but not in the additional analyses.

a) Annual household income: the NHANES questionnaire used a different measure of income from BRFSS. In BRFSS, annual housed income was divided as 5 groups, less than

$15,000, $15,000 to less than $25,000, $25,000 to less than $35,000, $35,000 to less than $50,000, $50,000 or more. However, the NHANES questionnaire used the ratio of family income to poverty guidelines to describe the income level, which was calculated by “dividing total annual family (or individual) income by the poverty guidelines specific to the survey year” [90]. Due to the different calculation methods, it was difficult to compare the ratio and amount of income directly. Thus, the annual household income variable was not included in the additional analyses.

b) Employment status: NHANES questionnaire did not interview the employment status. This variable was not available in the NHANES dataset.

c) Alcohol consumption: NHANES questionnaire used a different measure from BRFSS. In BRFSS, it had a calculated variable for heavy drinkers (defined as “adult men having more than 14 drinks per week and adult women having more than 7 drinks per week”) [68]. This variable was calculated based on the BRFSS questions “During the past 30 days, how many days per week or per month did you have at least one drink of any alcoholic beverage such as beer, wine, a malt beverage or liquor?” and “During the past 30 days, on the days when you drank, about how many drinks did you drink on the average?” [68]. However, in the NHANES questionnaire, alcohol consumption information was collected for the whole year. It did not include any questions similar to “During the past 30 days, how many days per week or per month did you have at least one drink of any alcoholic beverage such as beer, wine, a malt beverage or liquor?”. It had a question asking, “During the past 12 months, on those days that you drank alcoholic beverages, on the average, how many drinks did you have?”; however, it may lead to bias if this number was simply divided by 52 (there are 52 weeks per year) to calculate the average number of drinks per week [90]. Thus, due to the different measurements, the alcohol consumption variable was not included in the additional analyses.

d) Whether having a routine annual checkup in the past 12 months: NHANES questionnaire did not collect information about routine checkups. This variable was not available in the NHANES dataset [90].

e) Whether having a regular health care provider: NHANES questionnaire did not collect information about a personal doctor or health care provider. This variable was not available in the NHANES dataset [90].

f) Unmet healthcare needs because of cost: NHANES questionnaire did not collect information about unmet healthcare needs. This variable was not available in the NHANES dataset [90].

g) Self-rated physical health status in the past 30 days: NHANES questionnaire did not collect information about self-rated physical health status. This variable was not available in the NHANES dataset [90].

h) Self-rated mental health status in the past 30 days: NHANES questionnaire did not collect information about self-rated mental health status. This variable was not available in the NHANES dataset [90].

i) Days that poor health status affected usual activities in the past 30 days: NHANES questionnaire did not collect information about poor health status affected usual activities. This variable was not available in the NHANES dataset [90].

(4) Statistical Analyses

a) Statistical Software

Statistical Analysis Software (SAS), version 9.4 (SAS Institute Inc., Cary, NC), will be used as statistical analyses software for this dissertation project.

b) Analyses Process

Statistical analyses were conducted to evaluate important characteristics of the study population as well as associations between dependent and independent variables. Descriptive statistical analyses were conducted using methods for analyzing complex sample design data [91]. For both studies, descriptive estimates were obtained from subpopulation analyses (patients with diabetes and individuals at risk) [91]. All analyses were weighted using the variables provided by BRFSS datasets including the weighting variable, the stratification variable, and the clustering variable [92]. In addition, second-order (Satterthwaite) Rao-Scott chi-square tests were used to explore associations between dependent and independent variables.

In addition, in order to examine the relationships between dependent and independent variables after controlling for covariates, weighted multivariable logistic regression models were conducted using PROC SURVEYLOGISTIC [91]. Logistic regressions provided relative odds ratios associated with all covariates included in the models. For both studies, 5 logistic regression models were conducted: Model 1 included demographic variables, Model 2 additionally included healthcare status variables, Model 3 additionally included general health status variables, Model 4 additionally included health behavior variables, and Model 5 included all variables. Model 5 was the final model. All analyses were weighted using the variables provided by BRFSS datasets including the weighting variable, the stratification variable, and the clustering variable [92].

For diabetes screening service use, as mentioned previously, 2017-March 2020 Pre-pandemic NHANES data was analyzed as an additional supplement to calibrate the result. Both descriptive analyses and multivariable logistic regression models were conducted. All analyses were weighted using the variables provided by the NHANES dataset including the weighting variable, the stratification variable, and the clustering variable [90].

Chapter 4. Results

a. Study 1: Diabetes-related Healthcare Service Use for Patients

(1) Included States

Table 3 shows states and territories included in this project. These states used Diabetes Optional Module and stored data in BRFSS core versions. 42 states and territories were included. Arkansas, California, Hawaii, Idaho, Kansas, Massachusetts, Nebraska, New York, Oklahoma, Oregon, Utah, and West Virginia were excluded since data of these states were in different versions.

Table 3. 42 U.S. States and Territories Implementing the Diabetes Module by Year

State	2016	2017	2018	2019	2020	State	2016	2017	2018	2019	2020
Alabama	X	X	X	X		Montana		X		X	
Alaska		X		X		Nebraska					
Arizona		X	X			Nevada		X			
Arkansas						New Hampshire		X		X	
California						New Jersey	X	X	X		
Colorado		X				New Mexico		X		X	
Connecticut				X		New York					
Delaware	X	X	X	X	X	North Carolina		X		X	
District of Columbia	X	X	X	X	X	North Dakota		X	X	X	X
Florida		X			X	Ohio		X			
Georgia		X	X		X	Oklahoma					
Guam	X	X		X		Oregon					

Hawaii					
Idaho					
Illinois				X	
Indiana		X		X	X
Iowa		X	X	X	
Kansas					
Kentucky		X		X	
Louisiana	X	X		X	
Maine			X	X	X
Maryland		X		X	
Massachusetts					
Michigan		X		X	
Minnesota		X		X	
Mississippi	X		X		X
Missouri		X		X	X
Pennsylvania		X		X	
Puerto Rico	X		X		X
Rhode Island		X			
South Carolina		X	X		
South Dakota	X		X		X
Tennessee			X		
Texas		X	X	X	
Utah					
Vermont		X			
Virgin Islands	X	X			X
Virginia	X	X	X	X	X
Washington		X			
West Virginia					
Wisconsin	X	X	X	X	X
Wyoming	X	X		X	
Total	13	35	17	26	14

(2) Sample Size

There are 296,691 patients with diabetes in the 2016–2020 BRFSS dataset, which counted for 13.6% of the total sample participants (2,189,805) excluding missing responses (4,176).

(3) Sample Characteristics of Patients with Diabetes

Table 4 presents characteristics of predisposing determinants (age, gender, marital status, educational attainment, and employment status) among patients with diabetes by racial and ethnic category from 2016 to 2020 enrolled in BRFSS data. Based on the results, over 75% of the patients with diabetes were aged ≥45 for all racial/ethnic groups, which indicates the consistency of previous research. Approximately 35% of the patients were diagnosed when they were ≤45 years old and more than 60% of patients were diagnosed when they were ≤55 years old. For non-Hispanic Asian American patients, there were approximately 12% more male patients (56.2% ± 3.4%) than female patients (43.8% ± 3.4%); non-Hispanic Black female patients (55.6% ± 1.1%) were 11% more than male patients (44.4% ± 1.1%). Over 50% of non-Hispanic White, non-Hispanic Asian American, Hispanic/Latino, and non-Hispanic Native Hawaiian/other Pacific Islander patients were married or living with a partner; while only 39.7% (± 1.1%) of non-Hispanic Black patients were married or living with a partner. The educational level of Hispanic/Latino patients was lower than other racial/ethnic groups; more than half of them did not graduate high school (52.0% ± 1.3%). Asian American patients with diabetes had a higher educational level than patients in other racial/ethnic groups; 46.6% (± 3.3%) of them were graduated from college or technical school. Meanwhile, the employment percentage of Asian American patients was the highest (48.8% ± 3.4%) among all patients.

Table 5 shows characteristics of enabling determinants (income level, health insurance coverage, routine annual checkup, regular health care provider, and unmet healthcare needs) among patients with diabetes by racial and ethnic category from 2016 to 2020 enrolled in BRFSS data. Based on the results, non-Hispanic Asian American patients had better income level than other patients: 50.1% (± 3.7%) of them had $50,000 or more annual household income. On the other hand, the annual household income level of Hispanic/Latino patients was lower than other groups; approximately 60% of them had less than $25,000 income. In addition, the results indicated that the majority of patients with diabetes for all racial/ethnic groups had good access to healthcare services since the most of them reported as having health insurance, annual routine health checkups, regular health care providers, and affordable health needs. However, non-Hispanic White patients had better rates than other groups in terms of insurance courage (95.5% ± 0.2%), healthcare providers (95.2% ± 0.2%), and affordable healthcare needs (89.4% ± 0.3%), which suggested the racial/ethnic disparities in healthcare access. Among all racial/ethnic groups, Hispanic/Latino had the lowest percentages of access to all types of healthcare services, including health insurance coverage, times of annual routine checkups, numbers of regular health care providers, and affordable health needs.

Table 6 shows characteristics of need determinants (insulin use, eyes status, self-rated health status, and various diseases/health conditions) among patients with diabetes by racial and ethnic category from 2016 to 2020 enrolled in BRFSS data. Results showed that non-Hispanic Asian American patients had a lower percentage of insulin use (25.6% ± 5.0%) than other racial/ethnic groups. Based on the results, compared to other patients, more Asian American patients (32.2% ± 6.7%) and Native Hawaiian/other Pacific Islander patients (35.9% ± 14.1%) reported their eyes were affected, which indicated they had poor control of diabetes. In addition, Hispanic/Latino patients and non-Hispanic AIAN patients self-evaluated that their overall health conditions were not good. Particularly, more AIAN patients reported poor status of both mental health and physical health conditions than other patients and about 40% of AIAN patients stated that poor health status had ever affected their daily lives. On the other hand, approximately 70% of non-Hispanic Asian American patients believed their health status was good; this percentage was higher than other patients. Besides, in terms of other related health conditions, the prevalence of arthritis among patients in all groups was the highest, which suggested that patients with diabetes should pay more attention to prevent joint diseases. Depressive disorder was another important health condition with higher prevalence. In addition, non-Hispanic AIAN patients and non-Hispanic Multiracial/ Other patients reported higher prevalence of asthma and COPD compared to other patients.

Table 7 shows characteristics of health behaviors (tobacco use and alcohol consumption) among patients with diabetes by racial and ethnic category from 2016 to 2020 enrolled in BRFSS data. Non-Hispanic AIAN patients had a larger tobacco use proportion than other patients; 24.3% (± 2.2%) of them were current smokers. Meanwhile, non-Hispanic Multiracial/

Other had a larger alcohol consumption proportion compared to other patients; 4.2% (± 1.3%) of them reported as heavy drinkers.

Table 8 describes the diabetes-related healthcare service utilization status by racial/ethnic groups. For annual clinical care services, fully completed patients were less than 50% for all racial/ethnic groups; participially, Hispanic/Latino patients (28.8% ± 2.2%) and Native Hawaiian/other Pacific Islander (28.7% ± 10.0%) reported lower full completion percentages than others. Non-Hispanic White patients (43.4% ± 0.6%) and non-Hispanic Black patients (43.6% ± 1.6%) had higher fully completion rates than others. The majority of patients in all racial/ethnic groups partially completed the annual clinical healthcare activities. Although non-Hispanic Native Hawaiian/other Pacific Islander patients (69.4% ± 10.2%) and Hispanic/Latino patients (68.3% ± 2.3%) had higher percentages of partially completing these service use, the rates of not using any type of service among these two racial groups were also high. The rate of completing 0 service for Hispanic/Latino patients was 2.9% (± 0.8%) and the rate for non-Hispanic Native Hawaiian/other Pacific Islander patients was 2.0% (± 1.3%). Also, the Rao-Scott chi-square test showed significant associations between clinical healthcare service use and race/ethnicity ($\chi^2_{R\text{-}S}$=172.7, DF=5.26, p<0.0001).

For self-care completion status, Asian American patients reported the lowest percentage of fully completing self-care activities (1.3% ± 0.5%) while Black patients had the highest (6.9% ± 0.7%). The majority of patients with diabetes partially completed the self-care activities, regardless of racial/ethnic groups. Asian American patients had the highest percentage of partially completed self-care activities which was 98.4% (± 0.6%). Hispanic/Latino patients (0.6% ± 0.3%) and non-Hispanic Native Hawaiian/other Pacific Islander patients (0.6% ± 0.5%) had higher rates of not completing any self-care activities. Rao-Scott chi-square test showed significant associations between self-care activities and race/ethnicity ($\chi^2_{R\text{-}S}$=162.4, DF=7.37 p<0.0001).

Table 9 shows the diabetes-related healthcare service use status by service type respectively among all racial/ethnic groups. Based on the results, the majority of patients in all racial/ethnic groups visited their doctors for diabetes at least once every year. Over 50% of patients in all groups can complete clinical tests, although not many patients reported use all services. Hispanic/Latino patients had low rates of taking these tests, including HbA1C test (63.6% ± 2.5%), eye examination (62.8% ± 2.5%), and foot examination (61.6% ± 2.5%). For self-care activities, fewer Asian American patients (40.4% ± 5.9%) and Hispanic/Latino patients (39.2% ± 2.3%) had participated in diabetes education programs. In addition, the percentage of daily self-monitoring blood glucose among non-Hispanic Asian American patients was the lowest, which was 46.3% (± 6.4%). Meanwhile, Hispanic/Latino patients had the lowest rate of daily self-checking feet, which was 35.9% (± 5.9%).

Table 10 shows the odds ratio of diabetes-related healthcare services use among patients with diabetes by racial/ethnic groups. For diabetes-related clinical healthcare services, compared to non-Hispanic White patients, non-Hispanic Asian patients (OR=0.57, 95% CI=0.21, 1.57), Hispanic/Latino patients (OR=0.12, 95% CI=0.08, 0.17), non-Hispanic Native Hawaiian/other Pacific Islander patients (OR=0.17, 95% CI=0.08, 0.36), and non-Hispanic Multiracial/ Other patients (OR=0.50, 95% CI=0.27, 0.95) had lower odds of achieving all clinical healthcare activities. These four racial/ethnic groups also had lower odds of partially completing clinical healthcare activities; especially for Hispanic/Latino patients (OR=0.21 95% CI=0.15, 0.30) and non-Hispanic Native Hawaiian/other Pacific Islander patients (OR=0.31, 95% CI=0.15, 0.67) had significant decreases. For diabetes-related self-care healthcare services, compared to non-Hispanic White patients, non-Hispanic Asian patients (OR=0.39, 95% CI=0.13, 1.16), Hispanic/Latino patients (OR=0.57, 95% CI=0.38, 0.86), and non-Hispanic Native Hawaiian/other Pacific Islander (OR=0.40, 95% CI=0.15, 1.09) had lower odds of achieving all self-care activities. Hispanic/Latino patients (OR=0.85, 95% CI=0.58, 1.23) and non-Hispanic Native Hawaiian/other Pacific Islander (OR=0.93, 95% CI=0.38, 2.31) also had lower odds of achieving self-care activities partially compared to non-Hispanic White patients.

Table 11 and Table 12 describe the results of the final multivariable logistic regression model predicting diabetes-related self-care activities completion and diabetes-related annual clinical activities completion, which only included variables that were significantly associated with the healthcare service use. For predicting diabetes-related self-care activities completion, the overall Wald test suggested that all possible factors in the final model had statistically significant impacts on the healthcare service use (F=9.41, p<0.0001). Based on the results, patients who used insulin (OR=22.76, 95% CI=12.88, 40.22) had significantly higher odds of completing all self-care activities. Patients who had eyes affected by diabetes were more likely to complete self-care activities fully (OR=2.50, 95% CI=1.61, 3.88). Self-rated general health status can also impact the achievement in self-care activities. Relative to those who believed their health conditions were good, patients who felt poor (OR=0.44, 95% CI=0.24, 0.81) and fair (OR=0.56, 95% CI=0.37, 0.85) had significantly lower odds of fully completing self-care activities. In terms of health behaviors, alcohol consumption plays a role: heavy drinkers were less likely to complete all self-care activities (OR=0.24, 95% CI=0.12, 0.46). In addition, patients who had healthcare insurance (OR=2.87, 95% CI=1.54, 5.36) and healthcare providers (OR=2.39, 95% CI=1.36, 4.20) also had significantly higher odds for full completions. Being graduated (OR=2.60, 95% CI=1.25, 5.42) or attended (OR=2.35, 95% CI=1.33, 4.16) college/technical school and married/living with a partner (OR=1.68, 95% CI=1.14, 2.48) was also positively associated with performing self-care activities.

For predicting diabetes-related annual clinical activities completion, the overall Wald test suggested that all possible factors in the final model had statistically significant impacts on the healthcare service use (F=14.28, p<0.0001). According to the final model, patients who used insulin (OR=3.63, 95% CI=1.84, 7.14) had significantly higher odds of taking all recommended clinical tests. Patients who had eyes affected by diabetes were more likely to complete annual clinical tests fully (OR=3.74, 95% CI=1.83, 7.63). Being diagnosed with arthritis was also positively related to completing all annual clinical tests (OR=2.35, 95% CI=1.41, 3.93). In terms of health behaviors, heavy drinkers were less likely to achieve all clinical care activities (OR=0.13, 95% CI=0.07, 0.26). Current smokers had lower odds of taking all recommended clinical tests although it was not statistically significant (OR=0.77, 95% CI=0.46, 1.32). Meanwhile, patients who had healthcare insurance (OR=2.75, 95% CI=1.41, 5.36), had a routine checkup within the past year (OR=8.41, 95% CI=2.35, 30.17), and healthcare providers (OR=5.70, 95% CI=3.10, 10.47) also had significantly higher odds for full completions. In addition, being older and educated, as well as having better annual household incomes were positively associated with annual clinical care service use.

Table 4 Sample Predisposing Determinants Characteristics by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance

Characteristics	**Non-Hispanic White N = 207,668 Weighted % (95% CI)**	**Non-Hispanic Black N = 34,793 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 5,045 Weighted % (95% CI)**	**Hispanic/Latino N = 25,659 Weighted % (95% CI)**	**Non-Hispanic AIAN [c] N = 7,631 Weighted % (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 1,538 Weighted % (95% CI)**	**Non-Hispanic Multiracial/ Other N = 8,377 Weighted % (95% CI)**	**P-value**
Age (Years)								<.0001
18-24	1.1 (0.9, 1.2)	1.2 (0.9, 1.4)	2.0 (1.1, 2.9)	1.6 (1.3, 1.9)	1.5 (0.8, 2.3)	1.8 (0.3, 3.2)	2.0 (1.3, 2.6)	
25-34	2.4 (2.2, 2.5)	3.7 (3.2, 4.1)	3.3 (2.3, 4.3)	5.2 (4.6, 5.8)	5.0 (3.4, 6.5)	4.7 (2.0, 7.5)	5.1 (3.9, 6.2)	
35-44	6.0 (5.7, 6.2)	9.6 (8.8, 10.3)	12.4 (10.3, 14.6)	11.8 (11.0, 12.7)	11.2 (9.4, 13.0)	16.9 (12.4, 21.4)	10.6 (9.0, 12.3)	
45-54	14.6 (14.3, 14.9)	19.6 (18.7, 20.5)	16.6 (14.4, 18.9)	21.8 (20.7, 23.0)	22.8 (20.2, 25.3)	30.0 (23.2, 36.8)	16.6 (14.9, 18.4)	
55-64	25.7 (25.4, 26.1)	29.0 (28.0, 30.0)	27.3 (24.3, 30.4)	27.4 (26.2, 28.6)	26.5 (24.2, 28.7)	21.1 (16.1, 26.0)	28.5 (26.3, 30.8)	
≥ 65	50.3 (49.8, 50.7)	37.0 (36.0 38.0)	38.3 (35.0, 41.6)	32.1 (30.9, 33.4)	33.1 (30.7, 35.5)	25.5 (19.3, 31.7)	37.2 (34.9, 39.4)	
Gender								<.0001
Male	52.0 (51.5, 52.4)	44.4 (43.3, 45.5)	56.2 (52.8, 59.6)	48.6 (47.3, 50.0)	50.4 (47.7, 53.1)	48.1 (41.2, 55.0)	48.2 (45.8, 50.6)	
Female	48.1 (47.6, 48.5)	55.6 (54.5, 56.7)	43.8(40.4, 47.2)	51.4 (50.0, 52.7)	49.6 (46.9, 52.3)	51.9 (45.0, 58.8)	51.8 (49.4, 54.2)	
Marital Status								<.0001
Married or Living with a partner	58.8 (58.3, 59.2)	39.7 (38.5, 40.8)	69.1 (65.9, 72.2)	57.1 (55.8, 58.4)	47.6 (44.9, 50.2)	58.9 (52.5, 65.4)	49.7 (47.3, 52.1)	
Other	41.2 (40.8, 41.7)	60.3 (59.2, 61.4)	30.9 (27.8, 34.1)	42.9 (41.6, 44.2)	52.4 (49.8, 55.1)	41.1 (34.6, 47.5)	50.3 (47.9, 52.7)	
Educational Attainment								<.0001
Did not graduate high school	12.8 (12.5, 13.1)	21.1 (20.2, 22.0)	8.4 (6.4, 10.5)	52.0 (50.7, 53.3)	26.6 (24.0, 29.2)	18.8 (13.6, 24.1)	17.1 (15.3, 19.0)	
Graduated high school	32.7 (32.3, 33.1)	32.8 (31.8, 33.7)	19.9 (17.1, 22.7)	21.9 (20.8, 22.9)	28.7 (26.5, 31.0)	37.0 (30.2, 43.7)	24.7 (22.7, 26.7)	

Attended college or technical school	33.9 (33.5, 34.3)	30.9 (29.8, 32.0)	25.0 (21.7, 28.2)	17.7 (16.7, 18.6)	32.4 (29.9, 35.0)	29.2 (22.8, 35.6)	38.4 (36.0, 40.8)	
Graduated from college or technical school	20.6 (20.3, 20.9)	15.2 (14.6, 15.9)	46.6 (43.3, 49.9)	8.5 (8.9, 9.0)	12.2 (10.5, 13.9)	15.0 (10.7, 19.3)	19.8 (18.1, 21.5)	
Employment Status								<.0001
Unemployed	4.1 (3.9, 4.3)	7.0 (6.3, 7.7)	6.2 (4.4, 7.9)	7.1 (6.4, 7.9)	6.9 (5.8, 8.0)	7.0 (4.5, 9.4)	4.8 (3.8, 5.8)	
Not in the labor force	64.4 (64.0, 64.8)	61.6 (60.4, 62.7)	45.1 (41.6, 48.5)	56.4 (55.1, 57.8)	63.0 (60.3, 65.7)	51.2 (44.3, 58.1)	61.8 (59.4, 64.2)	
Employed	31.5 (31.1, 31.9)	31.5 (30.4, 32.6)	48.8 (45.4, 52.2)	31.5 (35.2, 37.8)	30.1 (27.4, 32.9)	41.8 (35.0, 48.6)	33.4 (31.1, 35.7)	

[a] Numbers of all race/ethnicity do not add up to the total number of patients due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] AIAN = American Indian or Alaskan Native

[d] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 5 Sample Enabling Determinants Characteristics by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance System

Characteristics	**Non-Hispanic White N = 207,668 Weighted % (95% CI)**	**Non-Hispanic Black N = 34,793 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 5,045 Weighted % (95% CI)**	**Hispanic/Latino N = 25,659 Weighted % (95% CI)**	**Non-Hispanic AIAN [c] N = 7,631 Weighted % (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 1,538 Weighted % (95% CI)**	**Non-Hispanic Multiracial/ Other N = 8,377 Weighted % (95% CI)**	**P-value**
Annual Household Income								<.0001
Less than $15,000	11.4 (11.0, 11.7)	21.7 (20.7, 22.6)	13.0 (10.5, 15.6)	31.2 (29.8, 32.6)	26.0 (23.3, 28. 6)	15.2 (10.9, 19.4)	18.9 (16.9, 21.0)	
$15,000 to less than $25,000	19.5 (19.2, 19.9)	26.5 (25.4, 27.5)	16.1 (13.3, 18.8)	29.6 (28.2, 30. 9)	26.7 (24.3, 29.1)	25.8 (19.5, 32.1)	22.6 (20.5, 24.6)	
$25,000 to less than $35,000	11.9 (11.6, 12.2)	12.0 (11.2, 12.9)	11.4 (8.6, 14.1)	12.0 (11.0, 13.0)	10.2 (8.7, 11.8)	13.6 (8.3, 18.8)	9.9 (8.7, 11.0)	
$35,000 to less than $50,000	15.0 (14.7, 15.4)	12.5 (11.6, 13. 3)	9.4 (7.7, 11.1)	10.3 (9.4, 11.3)	10.4 (8.8, 12.1)	9.8 (6.8, 12.7)	13.3 (11.5, 15.1)	
$50,000 or more	42.2 (41.7, 42.7)	27.4 (26.2, 28.5)	50.1 (46.4, 53.8)	16.9 (15.8, 18.0)	26.6 (23.6, 29.7)	35.7 (27.8, 43.6)	35.4 (32.8, 38.0)	
Health Insurance Coverage								<.0001
Yes	95.5 (95.3, 95.7)	91.5 (90.8, 92.1)	93.9 (92.0, 95.9)	82.2 (81.2, 83.3)	93.6 (92.4, 94.9)	87.7 (83.8, 91.5)	93.4 (92.2, 94.5)	
Routine Annual Checkup								<.0001
Yes	92.3 (92.1, 92.6)	93.4 (92.7, 94.0)	90.7 (88.7, 92.8)	87.7 (86.7, 88.6)	88.5 (86.6, 90.5)	87.8 (83.8, 91.9)	90.0 (88. 7 91.3)	
Regular Healthcare Provider								<.0001
Yes	95.2 (95.0, 95.4)	93.0 (92.4, 93.6)	94.6 (93.4, 95.7)	84.4 (83.4, 85.5)	86.4 (84.5, 88.4)	86.8 (82.3, 91.2)	90.5 (89.2, 91. 9)	
Unmet Healthcare Needs because of Cost								<.0001
No	89.4 (89.1, 89.7)	84.5 (83.7, 85.3)	86.6 (84.2, 89. 1)	78.9 (77.8, 79.9)	81.6 (79.6, 83.7)	79.2 (73.7, 84.6)	83.4 (81.6, 85.1)	

[a] Numbers of all race/ethnicity do not add up to the total number of patients due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] AIAN = American Indian or Alaskan Native

[d] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 6 Sample Need Determinants Characteristics by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance System

Characteristics	**Non-Hispanic White N = 207,668 Weighted % (95% CI)**	**Non-Hispanic Black N = 34,793 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 5,045 Weighted % (95% CI)**	**Hispanic/Latino N = 25,659 Weighted % (95% CI)**	**Non-Hispanic AIAN [c] N = 7,631 Weighted % (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 1,538 Weighted % (95% CI)**	**Non-Hispanic Multiracial/ Other N = 8,377 Weighted % (95% CI)**	**P-value**
Insulin Use								<.0001
Yes	32.3 (31.6, 33.0)	36.3 (34.8, 37.8)	25.6 (20.7, 30.6)	33.9 (31.4, 36.4)	35.9 (31.6, 40.1)	33.4 (20.0, 46.9)	33.7 (30.1, 37.2)	
Affected Eye (Control Status)								<.0001
Yes	17.1 (16.4, 17.7)	23.0 (21.67, 24.3)	32.2 (25.6, 38.9)	24.0 (21.9, 26.1)	25.6 (21.4, 29.7)	35.9 (21.9, 50.0)	19.6 (16.6, 22.5)	
Self-rated General Health Status								<.0001
Poor	13.6 (13.3, 13.9)	13.2 (12.5, 13.9)	10.7 (8.5, 12.8)	18.9 (17.8, 20.0)	20.4 (18.2, 22.5)	13.3 (9.0, 17.7)	16.4 (14.7, 18.2)	
Fair	26.4 (26.0, 26.8)	31.4 (30.4, 32.3)	19.6 (16.9, 22.3)	41.5 (40.1, 42.8)	31.5 (29.0, 33.9)	32.4 (25.6, 39.2)	31.0 (28.8, 33.3)	
Good/Better	59.9 (59.5, 60.4)	55.4 (54.3, 56.5)	69.7 (66. 6, 72.8)	39.6 (38.3, 40.9)	48.1 (45.5, 50.9)	54.3 (47.4, 61. 2)	52.5 (50.1, 54.9)	
Self-report Physical Health Status								<.0001
Poor	10.4 (10.3, 10.5)	10.0 (9.8, 10.3)	4.6 (4.2, 5.0)	9.7 (9.4, 10.0)	16.5 (15.5, 17.5)	7.6 (6.5, 8.8)	13.6 (12.9, 14.2)	
Good	89.6 (89.5, 89.7)	90.0 (89.7, 90.2)	95.4 (95.0, 95.8)	90.3 (90.0 90.6)	83.5 (82.5, 84.5)	92.4 (91.2, 93.5)	86.4 (85.8, 87.1)	
Self-report Mental Health Status								<.0001
Poor	16.4 (16.1, 16.8)	16.7 (15.9, 17.6)	8.9 (7.0, 10.8)	16.5 (15.5, 17. 5)	25.7 (23.1, 28.2)	19.8 (13.7, 25.9)	22.0 (20.0, 23.9)	
Good	83.6 (83.2, 83.9)	83.3 (82.4, 84.1)	91.1 (89.2, 93.0)	83.5 (82.5, 84.5)	74.4 (71.8, 76.9)	80.2 (74.1, 86.3)	78.0 (76.1, 80.0)	
Poor Health Status Affected Usual Activities								<.0001

Yes	29.5 (29.0, 30.1)	27.7 (26.5, 28.9)	21.3 (16.9, 25.8)	28.4 (26.9, 29.8)	38.7 (35.6, 41.9)	29.1 (19.4, 38.8)	33.4 (30.7, 36.2)	
Diagnosis with Key Health Conditions								<.0001
Heart attack	15.4 (15.1, 15.7)	11.0 (10.4, 11.7)	8.0 (6.2, 9.8)	10.7 (9.9, 11.6)	18.2 (16.3, 20.1)	17.2 (10.7, 23.7)	15.5 (13.7, 17.3)	
Heart disease	16.1 (15.8, 16.5)	10.5 (9. 9 11.2)	9.8 (7.8, 11.7)	8.7 (8.0 9.4)	15.2 (13.4, 16.)	16.3 (9.6, 23.1)	15.2 (13.3, 17.1)	
Stroke	9.8 (9.5, 10.1)	11.4 (10.8, 12.0)	4.9 (3.7, 6.1)	6.7 (6.0, 7.3)	14.1 (12.2, 16.0)	11.8 (6.6, 17.0)	11.9 (10.3, 13.6)	
Asthma	18.2 (17.9, 18.6)	20.4 (19.5, 21.3)	12.2 (10.1, 14.3)	17.3 (16.3, 18.2)	26.1 (23.7, 28.5)	15.8 (11.9, 19.7)	28.0 (25.8, 30.3)	
Cancers (except for skin cancer)	14.8 (14.5, 15.1)	10.6 (10.0, 11.2)	8.0 (6.1, 9.9)	7.6 (7.0 8.2)	12.3 (10.8, 13.8)	7.2 (3.6, 10.8)	12.0 (10.7, 13.3)	
COPD	17.2 (16.9, 17.5)	13.4 (12.6, 14.1)	5.5 (4.0, 7.0)	8.8 (7.9, 9.6)	20.4 (18.3, 22.6)	9.2 (6.3, 12.1)	19.9 (18.0, 21.7)	
Arthritis	52.6 (52.2, 53.0)	48.1 (47.0, 49.2)	30.1 (26.9, 33.2)	36.0 (34.8, 37.2)	52.5 (49.8, 55.2)	36.9 (30.5, 43.3)	52.5 (50.1, 54.9)	
Kidney disease	10.8 (10.6, 11.1)	11.5 (10.8, 12.2)	8.5 (6.3, 10.6)	9.0 (8.2, 9.8)	10.4 (9.0, 11.7)	8.8 (6.3, 11.3)	10.3 (8.9, 11.6)	
Depressive disorder	26.9 (26.5, 27.3)	22.0 (21.1, 22.9)	14.4 (11.7, 17.1)	23.4 (22.2, 24.5)	32.0 (29.6, 34.5)	16.5 (12.4, 20.7)	32.1 (29.9, 34.3)	

[a] Numbers of all race/ethnicity do not add up to the total number of patients due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] AIAN = American Indian or Alaskan Native

[d] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 7 Sample Health Behavior Characteristics by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance System

Characteristics	**Non-Hispanic White N = 207,668 Weighted % (95% CI)**	**Non-Hispanic Black N = 34,793 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 5,045 Weighted % (95% CI)**	**Hispanic/Latino N = 25,659 Weighted % (95% CI)**	**Non-Hispanic AIAN [c] N = 7,631 Weighted % (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 1,538 Weighted % (95% CI)**	**Non-Hispanic Multiracial/ Other N = 8,377 Weighted % (95% CI)**	**P-value**
Tobacco Use								<.0001
Current smoker	14.9 (14.5, 15.2)	16.7 (15.8, 17.6)	7.6 (5.8, 9.4)	11.7 (10.8, 12.5)	24.3 (22.0 26.5)	19.9 (15.4, 24.4)	18.9 (17.1, 20.6)	
Former smoker	39.1 (38.6, 39.5)	26.5 (25.5, 27.5)	22.9 (20.0, 25.7)	26.3 (25.1, 27.5)	35.4 (32.6, 38.1)	26.9 (20.1, 33.7)	34.5 (32.2, 36.8)	
Non-smoker	46.1 (45.6, 46.5)	56.8 (55.7, 57.9)	69.6 (66.4, 72.7)	62.0 (60.7, 63.4)	40.4 (37.7, 43.0)	53.2 (46.2, 60.2)	46.6 (44.1, 49.0)	
Alcohol Consumption								0.0001
Heavy drinker	3.0 (2.9, 3.2)	2.7 (2.2, 3.1)	1.3 (0.7, 1.9)	2.7 (2.2, 3.1)	2.7 (2.0, 3.4)	2.6 (1.4, 3.8)	4.2 (3.0, 5.5)	

[a] Numbers of all race/ethnicity do not add up to the total number of patients due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] AIAN = American Indian or Alaskan Native

[d] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 8 Diabetes-related Healthcare Service Use by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance System

Diabetes-relate Healthcare Services	**Non-Hispanic White N = 207,668 Weighted % (95% CI)**	**Non-Hispanic Black N = 34,793 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 5,045 Weighted % (95% CI)**	**Hispanic/Latino N = 25,659 Weighted % (95% CI)**	**Non-Hispanic AIAN [c] N = 7,631 Weighted % (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 1,538 Weighted % (95% CI)**	**Non-Hispanic Multiracial/ Other N = 8,377 Weighted % (95% CI)**	**P-value**
Diabetes Clinical Care								<.0001
Fully completed	43.4 (42.6, 44.0)	43.6 (42.0, 45.2)	41.1 (35.2, 47.1)	28.8 (26.6, 31.0)	41.8 (37.3, 46.3)	28.7 (18.6, 38.7)	41.0 (37.1, 44.9)	
Partially completed	56.2 (55.5, 56.9)	55.9 (54.3, 57.5)	58.0 (52.0, 64.0)	68.3 (66.1, 70.6)	57.9 (53.4, 62.4)	69.4 (59.1, 79.6)	58.1 (54.2, 62.0)	
Not completed	0.5 (0.4, 0.6)	0.5 (0.3, 0.7)	0.8 (0.0, 1.6)	2.9 (2.1, 3.6)	0.3 (0.0, 0.6)	2.0 (0.6, 3.3)	0.9 (0.4, 1.5)	
Diabetes Self-care								<.0001
Fully ompleted	4.6 (4.4, 4.7)	6.9 (6.3, 7.6)	1.3 (0.8, 1.8)	3.1 (2.7, 3.6)	5.1 (3.7, 6.6)	2.0 (1.1, 2.9)	3.8 (3.1, 4.5)	
Partially completed	94.9 (94.7, 95.1)	92.6 (92.0, 93.3)	98.4 (97.7, 99.0)	96.2 (95.7, 96.8)	94.4 (93.0, 95.8)	97.4 (96.3, 98.5)	95.8 (95.0, 96.5)	
Not completed	0.5 (0.5, 0.6)	0.4 (0.3, 0.6)	0.4 (0.0, 0.8)	0.6 (0.4, 0.9)	0.5 (0.2, 0.8)	0.6 (0.1, 1.1)	0.4 (0.2, 0.7)	

[a] Numbers of all race/ethnicity do not add up to the total number of patients due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] AIAN = American Indian or Alaskan Native

[d] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 9 Diabetes-related Healthcare Service Use Characteristics by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance

Diabetes-relate Healthcare Services	**Non-Hispanic White N = 207,668 Weighted % (95% CI)**	**Non-Hispanic Black N = 34,793 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 5,045 Weighted % (95% CI)**	**Hispanic/Latino N = 25,659 Weighted % (95% CI)**	**Non-Hispanic AIAN [c] N = 7,631 Weighted % (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 1,538 Weighted % (95% CI)**	**Non-Hispanic Multiracial/ Other N = 8,377 Weighted % (95% CI)**	**P-value**
Annually ⩾2 Hemoglobin A1C tests by doctors	76.0 (75.3, 76.6)	72.7 (71.2, 74.2)	70.1 (63.0, 77.3)	63.6 (61.2, 66.1)	69.9 (65.1, 74.7)	61.2 (49.6, 72.9)	72.2 (68.5, 75.9)	<.0001
Annually ⩾1 Eye examination by doctors	69.6 (68.9, 70.3)	72.0 (70.6, 73.5)	75.2 (70.7, 79.7)	62.8 (60.2, 65.3)	68.7 (64.1, 73.4)	73.3 (65.1, 82.3)	66.4 (62.8, 70.1)	<.0001
Annually ⩾ 1 Foot examination by doctors	75.5 (74.8, 76.1)	79.5 (78.2, 80.9)	75.8 (70.9, 80.7)	61.6 (59.1, 64.1)	74.4 (69.6, 79.2)	68.4 (56.5, 80.3)	71.5 (67.7, 75.2)	<.0001
Having physical activity or exercise in past 30 days	60.7 (60.3, 61.1)	60.0 (58.9, 61.0)	71.5 (68.4, 74.6)	57.9 (56.6, 59.3)	60.2 (57.6, 62.7)	66.4 (59.4, 73.3)	63.8 (61.6, 66.0)	<.0001
Daily blood glucose self-monitoring	58.4 (57.7, 59.2)	65.4 (63.9, 66.9)	46.3 (40.0, 52.7)	63.0 (60.7, 65.3)	61.1 (56.6, 65.5)	58.5 (46.6, 70.3)	60.6 (56.7, 64.6)	<.0001
Daily feet self-check	56.2 (55.5, 57.0)	65.3 (63.8, 66.8)	56.0 (53.4, 58.5)	35.9 (30.1, 41.8)	62.7 (58.3, 67.2)	52.4 (39.4, 65.5)	57.6 (53.7, 61.6)	<.0001
Ever Take Diabetes self-management education	53.7 (52.9, 54.4)	56.5 (54.9, 58.0)	40.4 (34.5, 46.3)	39.2 (36.8, 41.5)	56.1 (51.6, 60.6)	49.1 (36.0, 62.1)	54.4 (50.4, 58.3)	<.0001
Annually ⩾1 Doctor visiting for diabetes	89.1 (88.7, 89.6)	90.9 (90.0, 91.9)	92.3 (89.9, 94.7)	87.8 (86.2, 89.4)	87.2 (83.1, 91.4)	86.2 (80.1, 92.4)	85.3 (82.2, 88.4)	0.0004

[a] Numbers of all race/ethnicity do not add up to the total number of patients due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] AIAN = American Indian or Alaskan Native

[d] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 10 Diabetes-related Healthcare Service Use Characteristics by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance

Diabetes-relate Healthcare Services	**Non-Hispanic White N = 207,668 OR (95% CI)**	**Non-Hispanic Black N = 34,793 OR (95% CI)**	**Non-Hispanic Asian American N = 5,045 OR (95% CI)**	**Hispanic/Latino N = 25,659 OR (95% CI)**	**Non-Hispanic AIAN [c] N = 7,631 OR (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander OR (95% CI)**	**Non-Hispanic Multiracial/ Other OR (95% CI)**
Diabetes Clinical Care							
Fully completed	Ref	1.00 (0.66, 1.51)	0.57 (0.21, 1.57)	0.12 (0.08, 0.17)	1.56 (0.64, 3.79)	0.17 (0.08, 0.36)	0.50 (0.27, 0.95)
Partially completed	Ref	0.99 (0.65, 1.49)	0.62 (0.23, 1.71)	0.21 (0.15, 0.30)	1.66 (0.69, 4.04)	0.31 (0.15 0.67)	0.55 (0.29, 1.03)
Diabetes Self-care							
Fully completed	Ref	1.92 (1.30, 2.83)	0.39 (0.13, 1.16)	0.57 (0.38, 0.86)	1.30 (0.63, 2.70)	0.40 (0.15, 1.09)	1.01 (0.59, 1.74)
Partially completed	Ref	1.23 (0.84, 1.80)	1.47 (0.53, 4.07)	0.85 (0.58, 1.23)	1.15 (0.59, 2.25)	0.93 (0.38, 2.31)	1.23 (0.74, 2.05)

[a] Numbers of all race/ethnicity do not add up to the total number of patients due to missing cases

[b] AIAN = American Indian or Alaskan Native

[c] CI= confidence interval; OR= odds ratio

Table 11 Results of Multivariable Analyses Predicting Diabetes-related Healthcare Service Use (Self-care) by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance

	Diabetes-related Self-care Activities Fully Completed Unweighted N= 6,411				**Diabetes-related Self-care Activities Partially Completed Unweighted N= 35,700**			
	β	**OR**	**95% CI**	***P***	**β**	**OR**	**95% CI**	***P***
Age (Years)				0.0003				
18-24	0.26	1.30	(0.29, 5.84)	0.73	0.35	1.42	(0.40, 4.98)	0.59
25-34	-0.11	0.90	(0.38, 2.13)	0.80	-0.64	0.53	(0.23, 1.12)	0.12
35-44	0.23	1.26	(0.66, 2.40)	0.48	-0.13	0.88	(0.48, 1.60)	0.67
45-54	0.20	1.23	(0.77, 1.95)	0.39	-0.03	0.97	(0.63, 1.50)	0.89
55-64	0.72	2.05	(1.35, 3.11)	0.00	0.48	1.16	(1.09, 2.40)	0.02
≥ 65 (Ref)								
Race/ethnicity				0.0003				
Non-Hispanic Black	0.55	1.73	(1.10, 2.72)	0.02	0.25	1.28	(0.83, 1.97)	0.26
Non-Hispanic Asian American	-0.39	0.68	(0.18, 2.55)	0.57	0.41	1.51	(0.50, 4.54)	0.45
Hispanic/Latino	0.09	1.10	(0.59, 2.03)	0.77	-0.07	0.93	(0.53, 1.62)	0.80
Non-Hispanic AIAN[b]	1.29	3.62	(1.15, 11.38)	0.03	0.99	2.69	(0.88, 8.26)	0.08
Non-Hispanic Native Hawaiian/other Pacific Islander	-1.75	0.17	(0.04, 0.73)	0.02	-1.00	0.37	(0.10, 1.30)	0.12
Non-Hispanic Multiracial/ Other	0.36	1.44	(0.52, 3.98)	0.48	0.21	1.24	(0.46, 3.35)	0.67
Non-Hispanic White (Ref)								
Marital Status				0.03				
Married or Living with a partner	0.52	1.68	(1.14, 2.48)	0.01	0.44	1.55	(1.08, 2.23)	0.02
Other (Ref)								
Educational Attainment				<.0001				
Graduated from college or technical school	0.96	2.60	(1.25, 5.42)	0.01	0.31	1.36	(0.68, 2.73)	0.39
Attended college or technical school	0.86	2.35	(1.33, 4.16)	0.00	0.22	1.25	(0.74, 2.10)	0.41
Graduated high school	0.50	1.65	(0.96, 2.82)	0.07	0.17	1.19	(0.73, 1.93)	0.49

Did not graduate high school (Ref)								
Health Insurance Coverage				0.0024				
Yes	1.06	2.87	(1.54, 5.36)	0.00	0.62	1.86	(1.09, 3.18)	0.02
No (Ref)								
Regular Healthcare Provider				0.0054				
Yes	0.87	2.39	(1.36, 4.20)	0.00	0.72	2.05	(1.30, 3.23)	0.00
No (Ref)								
Routine Checkup				0.0040				
Yes, within the past year	1.36	3.90	(0.80, 19.11)	0.09	-0.04	0.97	(0.27, 3.51)	0.96
Yes, but not within the past year	0.63	1.88	(0.37, 9.55)	0.45	-0.60	0.55	(0.15, 2.05)	0.37
Never (Ref)								
Insulin Use				<.0001				
Yes	3.13	22.76	(12.88, 40.22)	<.0001	2.21	9.14	(5.23, 15.98)	<.0001
No (Ref)								
Affected Eye (Control Status)				0.0002				
Yes	0.92	2.50	(1.61, 3.88)	<.0001	0.75	2.11	(1.39, 3.19)	0.00
No (Ref)								
Self-rated General Health Status				0.0081				
Poor	-0.83	0.44	(0.24, 0.81)	0.01	-0.54	0.59	(0.33, 1.04)	0.07
Fair	-0.58	0.56	(0.37, 0.85)	0.01	-0.49	0.61	(0.41, 0.91)	0.01
Good/Better (Ref)								
Alcohol Consumption, heavy drinker				<.0001				
Yes	-1.45	0.24	(0.12, 0.46)	<.0001	-0.91	0.40	(0.22, 0.75)	0.00
No (Ref)								

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[a] CI= confidence interval; OR= odds ratio

[b] AIAN = American Indian or Alaskan Native

Table 12 Results of Multivariable Analyses Predicting Diabetes-related Healthcare Service Use (Clinical Care) by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance

	Diabetes-related Clinical Care Activities Fully Completed Unweighted N= 19,410				**Diabetes-related Clinical Care Activities Partially Completed Unweighted N= 23,017**			
	β	**OR**	**95% CI**	***P***	**β**	**OR**	**95% CI**	***P***
Age (Years)				0.0002				
18-24	-2.10	0.12	(0.04, 0.42)	0.00	-1.63	0.20	(0.06, 0.63)	0.01
25-34	-1.28	0.28	(0.09, 0.89)	0.03	-0.93	0.39	(0.13, 1.22)	0.11
35-44	-1.59	0.21	(0.08, 0.52)	0.00	-1.35	0.26	(0.10, 0.65)	0.00
45-54	-1.11	0.33	(0.15, 0.71)	0.00	-0.98	0.37	(0.17, 0.80)	0.01
55-64	-0.27	0.76	(0.35, 1.66)	0.49	-0.31	0.74	(0.34, 1.60)	0.44
≥ 65 (Ref)								
Race/ethnicity				<.0001				
Non-Hispanic Black	0.54	1.72	(0.88, 3.33)	0.11	0.47	1.61	(0.83, 3.10)	0.16
Non-Hispanic Asian American	0.04	1.04	(0.26, 4.21)	0.95	0.20	1.22	(0.32, 4.70)	0.77
Hispanic/Latino	-0.99	0.37	(0.22, 0.64)	0.00	-0.86	0.42	(0.25, 0.72)	0.00
Non-Hispanic AIAN[b]	2.29	9.87	(0.97, 100.30)	0.05	2.16	8.70	(0.86, 87.81)	0.07
Non-Hispanic Native Hawaiian/other Pacific Islander	0.99	2.69	(0.25, 29.32)	0.42	1.84	0.37	(0.10, 1.30)	0.12
Non-Hispanic Multiracial/ Other	1.07	2.92	(0.85, 10.01)	0.09	1.17	3.21	(0.95, 10.88)	0.06
Non-Hispanic White (Ref)								
Annual Household Income				0.0001				
$50,000 or more	1.11	3.04	(1.11, 8.31)	0.03	0.72	2.05	(0.76, 5.53)	0.15
$35,000 to less than $50,000	0.85	2.34	(0.96, 5.68)	0.06	0.62	1.85	(0.77, 4.45)	0.17
$25,000 to less than $35,000	0.70	2.02	(0.77, 5.27)	0.15	0.58	1.79	(0.69, 4.62)	0.23
$15,000 to less than $25,000	0.15	1.17	(0.61, 2.22)	0.64	0.09	1.09	(0.58, 2.06)	0.79
Less than $15,000 (Ref)								
Educational Attainment				<.0001				
Graduated from college or technical school	0.54	1.72	(0.72, 4.13)	0.22	0.07	1.08	(0.45, 2.56)	0.87
Attended college or technical school	1.11	3.02	(1.57, 5.81)	0.00	0.73	2.07	(1.09, 3.94)	0.03
Graduated high school	0.90	2.46	(1.36, 4.42)	0.00	0.57	1.77	(1.00, 3.15)	0.05

Did not graduate high school (Ref)								
Employment Status				0.0480				
Employed	-0.29	0.75	(0.34, 1.65)	0.47	-0.27	0.76	(0.36, 1.64)	0.49
Not in the labor force	0.19	1.21	(0.55, 2.65)	0.64	0.04	1.04	(0.48, 2.25)	0.92
Unemployed (Ref)								
Health Insurance Coverage				0.0006				
Yes	1.01	2.75	(1.41, 5.36)	0.00	0.70	2.02	(1.06, 3.85)	0.03
No (Ref)								
Regular Healthcare Provider				<.0001				
Yes	1.74	5.70	(3.10, 10.47)	<.0001	1.15	3.16	(1.75, 5.69)	0.00
No (Ref)								
Unmet Healthcare Needs because of Cost				<.0001				
No	-0.09	0.91	(0.51, 1.65)	0.76	-0.41	0.66	(0.37, 1.18)	0.16
Yes (Ref)								
Routine Checkup				<.0001				
Yes, within the past year	2.13	8.41	(2.35, 30.17)	0.00	1.04	2.82	(0.85, 9.37)	0.09
Yes, but not within the past year	-0.08	0.92	(0.25, 3.34)	0.90	-0.48	0.62	(0.19, 2.05)	0.43
Never (Ref)								
Insulin Use				<.0001				
Yes	1.29	3.63	(1.84, 7.14)	0.00	0.54	1.72	(0.88, 3.37)	0.12
No (Ref)								
Affected Eye (Control Status)				<.0001				
Yes	1.32	3.74	(1.83, 7.63)	0.00	1.05	2.86	(1.41, 5.81)	0.00
No (Ref)								
Diagnosis with Arthritis				0.0002				
Yes	0.85	2.35	(1.41, 3.93)	0.00	0.72	2.06	(1.24, 3.44)	0.01
No (Ref)								
Diagnosis with Kidney disease				0.0009				
Yes	-0.74	0.48	(0.21, 1.08)	0.08	-0.92	0.40	(0.18, 0.89)	0.03
No (Ref)								

Tobacco Use				<.0001				
Current smoker	-0.26	0.77	(0.46, 1.32)	0.35	0.00	1.00	(0.60, 1.69)	0.99
Former smoker	0.60	1.83	(1.03, 3.25)	0.04	0.62	1.87	(1.05, 3.30)	0.03
Non-smoker (Ref)								
Alcohol Consumption, heavy drinker				<.0001				
Yes	-2.04	0.13	(0.07, 0.26)	<.0001	-1.72	0.18	(0.09, 0.35)	<.0001
No (Ref)								

[a] CI= confidence interval; OR= odds ratio

[b] AIAN = American Indian or Alaskan Native

b. Study 2a: Diabetes-related Healthcare Service Use for Individuals at Risk

(1) Included States

Table 13 shows states and territories included in this project. These states used Pre-diabetes Optional Module and stored data in BRFSS core versions. 50 states and territories were included. Colorado, Kansas, Massachusetts, and Ohio were excluded since data of these states were in different versions.

Table 13. 50 U.S. States and Territories Implementing the Pre-Diabetes Module by Year (using main version)

State	**2016**	**2017**	**2018**	**2019**	**2020**	**State**	**2016**	**2017**	**2018**	**2019**	**2020**
Alabama	X	X	X	X	X	Montana		X			X
Alaska	X	X	X		X	Nebraska	X				X
Arizona		X	X		X	Nevada	X	X		X	X
Arkansas		X				New Hampshire		X			X
California					X	New Jersey		X	X		X
Colorado						New Mexico	X	X	X	X	X
Connecticut	X				X	New York	X		X	X	
Delaware	X	X		X	X	North Carolina		X	X	X	
District of Columbia	X	X	X	X		North Dakota		X	X	X	X
Florida	X	X	X	X	X	Ohio					
Georgia		X	X	X	X	Oklahoma	X	X			
Guam	X	X	X	X	X	Oregon	X	X	X	X	X
Hawaii	X	X	X	X	X	Pennsylvania		X			X
Idaho	X		X	X	X	Puerto Rico	X		X		X
Illinois	X			X	X	Rhode Island		X			
Indiana			X	X	X	South Carolina	X	X	X		
Iowa	X	X			X	South Dakota	X	X	X	X	

Kansas					
Kentucky	X	X	X	X	X
Louisiana	X	X			
Maine		X	X	X	X
Maryland		X	X		X
Massachusetts					
Michigan		X			X
Minnesota		X			X
Mississippi	X	X	X	X	X
Missouri		X	X		X
Tennessee			X	X	
Texas		X	X	X	
Utah					X
Vermont		X		X	
Virgin Islands	X	X			X
Virginia	X	X	X	X	X
Washington		X	X	X	
West Virginia	X	X	X	X	X
Wisconsin	X	X	X	X	X
Wyoming			X		X
Total	27	39	31	26	37

(2) Sample Size

There are 1,566,937 adults considered as at risk of developing diabetes in the 2016–2020 BRFSS dataset, which counted for 75.0% of the total sample participants (2,090,757) excluding missing responses (103,224).

(3) Sample Characteristics of Individuals at Risk for Diabetes

Table 14 presents characteristics of predisposing determinants (age, gender, marital status, educational attainment, and employment status) among individuals at risk by racial and ethnic category from 2016 to 2020 enrolled in BRFSS data. Based on the results, the educational level of Hispanic/Latino individuals was lower than other racial/ethnic groups; 32.9% (± 0.6%) of them did not graduate high school, which was consistent with Study 1 results. Non-Hispanic Asian adults had better educational attainment than others: 57.1% (± 1.3%) of them were graduated from college or technical school. Meanwhile, over 50% of individuals at risk were employed among all groups. Non-Hispanic Native Hawaiian/other Pacific Islander adults had higher rates of employment, 69.7% (± 2.5%) of them were employed.

Table 15 shows characteristics of enabling determinants (income level, health insurance coverage, routine annual checkup, regular health care provider, and unmet healthcare needs) among individuals at risk by racial and ethnic category from 2016 to 2020 enrolled in BRFSS data. Adults at risk in the non-Hispanic White group and non-Hispanic Asian American group had higher income levels than others: 60.8% (± 0.3%) of non-Hispanic White adults and 65.5% (± 1.3%) of non-Hispanic Asian American adults reported they had ≥$50,000 annual household income. In addition, the majority (>70%) of adults at risk had good access to healthcare services; especially, non-Hispanic White adults reported higher percentages in healthcare insurance coverage (93.1% ± 0.1%), having healthcare providers (83.3% ± 0.1%), and affordable healthcare needs (90.7% ± 0.1%) than others. Hispanic/Latino adults had lowest percentages in healthcare insurance coverage (73.3% ± 0.5%), having a routine annual checkup (66.3% ± 0.6%), having healthcare providers (63.1% ± 0.6%), and affordable healthcare needs (81.8% ± 0.5%).

Table 16 shows characteristics of need determinants (self-rated general health status, and various diseases/health conditions) among individuals at risk by racial and ethnic category from 2016 to 2020 enrolled in BRFSS data. The majority (>70%) of adults at risk believed their general health status was good/better. However, more non-Hispanic AIAN adults felt their overall health conditions were poor (8.2% ± 0.8%). They also reported as having higher rates of poor physical health conditions (17.9% ± 1.2%) and mental health conditions (17.8% ± 1.1%) than other adults. The rate of feeling poor health status affected usual activities among non-Hispanic AIAN adults was the highest, which was 24.8% (± 1.8%). Also, compared to other comorbidities included in this project, the prevalence of arthritis among individuals at risk in all groups was highest, followed by depressive disorder.

Table 17 shows characteristics of health behaviors (tobacco use, alcohol consumption, leisure-time physical activity) among individuals at risk by racial and ethnic category from 2016 to 2020 enrolled in BRFSS data. Non-Hispanic AIAN adults had a larger tobacco use proportion than other adults: 28.8% (± 1.3%) of them were current smokers. Meanwhile, non-Hispanic Native Hawaiian/other Pacific Islanders had a larger alcohol consumption proportion: 8.5% (± 1.4%) of them reported as heavy drinkers. Non-Hispanic Asian American adults had a smaller current tobacco use proportion (8.2% ± 0.6%) and also a smaller alcohol consumption proportion (2.6% ± 0.4%) than others. In terms of leisure-time physical activity, more adults at risk in the Hispanic/Latino group (31.4 % ± 0.5%) reported they did not have any activities in the past month.

Table 18 presents the percentages of receiving diabetes screening tests by racial/ethnic groups. Asian American adults reported the lowest percentage of having screening tests; over half of them (53.9% ± 1.8%) were not screened for diabetes. More than 50% of adults at risk in other groups reported had screening tests; especially non-Hispanic Black adults with the largest proportion (61.9% ± 0.7%). Rao-Scott chi-square test showed significant associations between having screening tests and race/ethnicity ($\chi^2_{R\text{-}S}$=466.7, DF=4.25, p<0.0001).

Table 19 shows the odds ratio of diabetes screening healthcare services use by racial/ethnic groups. Compared to non-Hispanic White adults, all racial/ethnic groups had significantly lower odds ratios of having screening tests within the past three years except for non-Hispanic Black adults. Non-Hispanic Asian patients (OR=0.54, 95% CI=0.50, 0.58) had the significantly lowest odds of having screening tests. Respectively, odds of other groups were Hispanic/Latino (OR=0.89, 95% CI=0.86, 0.93), non-Hispanic AIAN (OR=0.89, 95% CI=0.82, 0.96), non-Hispanic Native Hawaiian/other Pacific Islander (OR=0.70, 95% CI=0.61, 0.79), and non-Hispanic Multiracial/Other (OR=0.88, 95% CI=0.83, 0.94).

Table 20 describes the results of the final multivariable logistic regression model predicting diabetes screening service completion, which only included variables that were significantly associated with healthcare service uses. The overall Wald test suggested that all possible factors in the final model had statistically significant impacts on healthcare service use (F=126.25, p<0.0001). Based on the results, adults who had healthcare insurance (OR=1.21, 95% CI=1.13, 1.30) and healthcare providers (OR=1.63, 95% CI=1.55, 1.72) had significantly higher odds of having diabetes screening tests. In addition, adults who ever had routine checkups in the past year were significantly more likely to have screening tests (OR=3.55, 95% CI=2.83, 4.46). Adults who were diagnosed with heart diseases (OR=1.27, 95% CI=1.17, 1.39), cancers (except for skin cancer) (OR=1.08, 95% CI=1.02, 1.15), arthritis (OR=1.34, 95% CI=1.29, 1.40), kidney diseases (OR=1.18, 95% CI=1.07, 1.29), and depressive disorders (OR=1.18, 95% CI=1.13, 1.23) also had significantly higher odds of having screening tests. In terms of health behaviors, heavy drinkers were less likely to have screening tests (OR=0.84, 95% CI=0.79, 0.89). Meanwhile, adults who did not have leisure-time physical activity (OR=0.89, 95% CI=0.85, 0.93) had significantly lower odds of taking screening tests. Being older and married or living with a partner, having an education beyond high school, and having higher incomes was positively associated with having diabetes screening tests.

Table 14 Sample Predisposing Determinants Characteristics by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance System

Characteristics	**Non-Hispanic White N = 1,218,903 Weighted % (95% CI)**	**Non-Hispanic Black N = 111,563 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 30,435 Weighted % (95% CI)**	**Hispanic/Latino N = 112,327 Weighted % (95% CI)**	**Non-Hispanic AIAN ^{c} N = 23,277 Weighted % (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 5,936 Weighted % (95% CI)**	**Non-Hispanic Multiracial/ Other N = 37,833 Weighted % (95% CI)**	**P-value**
Age (Years)								<.0001
18-24	5.7 (5.6, 5.8)	9.0 (8.6, 9.3)	12.6 (11.8, 13.3)	12.0 (11.6, 12.4)	8.1 (7.3, 8.9)	13.6 (11.8, 15.4)	10.8 (10.1, 11.5)	
25-34	11.4 (11.3, 11.5)	16.6 (16.2. 17.1)	18.6 (17.7, 19.4)	21.8 (21.3, 22.3)	16.5 (15.3, 17.6)	23.3 (20.9, 25.7)	17.0 (16.2, 17.7)	
35-44	11.8 (11.6, 11.9)	17.6 (17.2, 18.1)	19.2 (18.3, 20.1)	19.7 (19.3, 20.2)	15.6 (14.5, 16.7)	19.2 (17.1, 21.3)	16.2 (15.4, 17.1)	
45-54	20.6 (20.4, 20.7)	22.4 (22.0, 22.9)	22.4 (21.4, 23.5)	21.8 (21.3, 22.3)	22.7 (21.4, 23.9)	20.1 (17.8, 22.5)	19.3 (18.5, 20.2)	
55-64	21.9 (21.8, 22.1)	18.4 (17.9, 18.8)	15.3 (14.3, 16.3)	13.8 (13.3, 14.2)	19.5 (18.4, 20.6)	15.0 (12.4, 17.5)	17.9 (17.0, 18.7)	
≥ 65	28.6 (28.4, 28.7)	16.0 (15.6, 16.4)	11.9 (11.0, 12.9)	10.9 (10.5, 11.2)	17.7 (16.5, 18.9)	8.8 (7.4, 10.2)	18.8 (18.0, 19.6)	
Gender								<.0001
Male	49.8 (49.6, 50.0)	46.6 (46.0, 47.2)	55.9 (54.7, 57.2)	53.3 (52.7, 53.9)	51.3 (49.8, 52.8)	52.0 (49.1, 54.9)	52.7 (51.6, 53.8)	
Female	50.2 (50.0, 50.4)	53.4 (52.8, 54.0)	44.1 (42.8, 45.3)	46.7 (46.0, 47.2)	48.7 (47.2, 50.2)	48.0 (45.1, 50.9)	47.3 (46.2, 48.4)	
Marital Status								<.0001
Married or Living with a partner	63.3 (63.1, 63.4)	37.8 (37.2, 38.3)	64.1 (63.0, 65.3)	56.0 (55.4, 56.6)	46.3 (44.8, 47.8)	54.2 (51.4, 57. 1)	50.1 (49.0, 51.2)	
Other	36.7 (36.6, 36.9)	62.2 (61.7, 62.8)	35.9 (34.7, 37.0)	44.0 (43.4, 44.5)	53.7 (52.2, 55.2)	45.8 (42.9, 48.6)	49.9 (48.8, 51.0)	
Educational Attainment								<.0001
Did not graduate high school	7.2 (7.1, 7.3)	12.6 (12.2, 13.0)	4.4 (3.8, 5.1)	32.9 (32.3, 33.5)	18.0 (16.8, 19.1)	11.7 (9.5, 13.9)	10.3 (9.5, 11.0)	

Graduated high school	28.0 (27.8, 28.1)	30.9 (30.4, 31.4)	15.5 (14.6, 16.4)	27.6 (27.1, 28.2)	34.5 (33.1, 36.0)	34.5 (31.8, 37.2)	25.8 (24.8, 26.7)	
Attended college or technical school	32.7 (32.5, 32.8)	33.4 (32.9, 34.0)	23.0 (21.8, 24.2)	24.3 (23.7, 24.8)	31.7 (30.4, 33.1)	32.2 (29.5, 35.0)	37.0 (36.0, 38.0)	
Graduated from college or technical school	32.1 (32.0, 32.3)	23.1 (22.7, 23.5)	57.1 (55.8, 58.4)	15.2 (14.8, 15.5)	15.8 (14.9, 16.7)	21.6 (19.4, 23.8)	26.9 (26.1, 27.8)	
Employment Status								<.0001
Unemployed	4.2 (4.1, 4.2)	8.3 (8.0, 8.6)	5.4 (4.9, 6.0)	7.6 (7.2, 7.9)	8.7 (8.0, 9.5)	8.1 (6.7, 9.5)	6.3 (5.8, 6.8)	
Not in the labor force	38.6 (38.4, 38.7)	32.4 (31.9, 32.9)	27.0 (25.8, 28.1)	29.2 (28.6, 29.7)	38.2 (36.8, 39.6)	22.2 (20.0, 24.4)	35.8 (34.7, 36.9)	
Employed	57.3 (57.1, 57.5)	59.3 (58.7, 59.8)	67.6 (66.4, 68.8)	63.3 (62.7, 63.9)	53.1 (51.6, 54.5)	69.7 (67.2, 72.2)	57.9 (56.8, 59.0)	

[a] Numbers of all race/ethnicity do not add up to the total number of adults at risk due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] AIAN = American Indian or Alaskan Native

[d] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 15 Sample Enabling Determinants Characteristics by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance System

Characteristics	**Non-Hispanic White N = 1,218,903 Weighted % (95% CI)**	**Non-Hispanic Black N = 111,563 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 30,435 Weighted % (95% CI)**	**Hispanic/Latino N = 63,979 Weighted % (95% CI)**	**Non-Hispanic AIAN [c] N = 23,277 Weighted % (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 5,936 Weighted % (95% CI)**	**Non-Hispanic Multiracial/ Other N = 37,833 Weighted % (95% CI)**	**P-value**
Annual Household Income								<.0001
Less than $15,000	5.9 (5.8, 6.0)	15.0 (14.6, 15.4)	6.5 (5.7, 7.2)	17.8 (17.3, 18.3)	17.9 (16.7, 19.0)	10.3 (8.6, 12.0)	11.9 (11.0, 12.8)	
$15,000 to less than $25,000	11.7 (11.5, 11.8)	21.3 (20.81, 21.8)	10.6 (9.8, 11.4)	24.9 (24.3, 25.4)	22.8 (21.6, 24.01)	16.5 (14.3, 18.7)	15.9 (15.1 16.7)	
$25,000 to less than $35,000	8.6 (8.5, 8.7)	11.6 (11.2, 11.9)	7.5 (6.8, 8.2)	13.4 (13.0, 13.9)	11.6 (10.6, 12.5)	12.2 (9.7, 14.6)	10.3 (9.6, 10.9)	
$35,000 to less than $50,000	13.1 (13.0, 13.2)	13.9 (13.5, 14.3)	10.0 (9.1, 10.8)	13.5 (13.0, 14.0)	12.8 (11.7, 14.0)	14.2 (12.2 16.2)	13.0 (12.2, 13.78)	
$50,000 or more	60.8 (60.6, 61.1)	38.3 (37.7, 38.9)	65.5 (64.2, 66.8)	30.4 (29.7, 31.0)	34.9 (33.3, 36.5)	46.9 (43.7, 50.0)	49.0 (47.8, 50.2)	
Health Insurance Coverage								<.0001
Yes	93.1 (93.0, 93.2)	86.6 (86.2, 87.0)	91.9 (91.3, 92.5)	73.3 (72.7, 73.8)	87.4 (86.4, 88.4)	83.3 (81.0, 85.5)	88.7 (88.1, 89.4)	
Routine Annual Checkup								<.0001
Yes	75.0 (74.8, 75.1)	81.0 (80.6, 81.5)	70.6 (69.4, 71.8)	66.3 (65.7, 66.9)	70.1 (68.7, 71.5)	70.2 (67.6, 72.7)	70.7 (69.8, 71.7)	
Regular Healthcare Provider								<.0001
Yes	83.3 (83.1, 83.4)	78.4 (77.9, 78.9)	78.3 (77.3, 79.23)	63.1 (62.5, 63.7)	71.1 (69.8, 72.4)	72.5 (70.0, 74.9)	75.2 (74.2, 76.1)	
Unmet Healthcare Needs because of Cost								<.0001
No	90.7 (90.6, 90.8)	85.0 (84.6, 85.4)	91.0 (90.3, 91.7)	81.8 (81.3, 82.3)	83.1 (82.0 84.2)	86.0 (84.3, 87.8)	84.4 (83.6, 85.3)	

[a] Numbers of all race/ethnicity do not add up to the total number of adults at risk due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] AIAN = American Indian or Alaskan Native

[d] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 16 Sample Need Determinants Characteristics by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance System

Characteristics	**Non-Hispanic White N = 1,218,903 Weighted % (95% CI)**	**Non-Hispanic Black N = 111,563 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 30,435 Weighted % (95% CI)**	**Hispanic/Latino N = 63,979 Weighted % (95% CI)**	**Non-Hispanic AIAN[c] N = 23,277 Weighted % (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 5,936 Weighted % (95% CI)**	**Non-Hispanic Multiracial/ Other N = 37,833 Weighted % (95% CI)**	**P-value**
Self-rated General Health Status								<.0001
Poor	3.7 (3.6, 3.7)	3.8 (3.5, 4.0)	1.9 (1.5, 2.3)	3.6 (3.4, 3.8)	8.2 (7.4, 9.0)	2.8 (2.1, 3.5)	5.4 (5.0, 5.9)	
Fair	10.2 (10.1, 10.3)	14.4 (14.0, 14.8)	6.4 (5.8, 7.0)	18.5 (18.1, 19.0)	16.2 (15.2, 17.1)	11.2 (9.4, 13.1)	12.3 (12.6, 13.9)	
Good/Better	86.1 (86.0 86.2)	81.9 (81.4, 82.3)	91.7 (91.0, 92.4)	77.9 (77.4, 78.4)	75.6 (74.5, 76.8)	86.0 (84.0, 87.9)	81.3 (80.6, 82.1)	
Self-report Physical Health Status								<.0001
Poor	11.3 (11.2, 11.5)	11.2 (10.8, 11.5)	5.1 (4.5, 5.6)	10.7 (10.4, 11.1)	17.9 (16.6, 19.1)	8.2 (6.9, 9.6)	15.4 (14.5, 16.2)	
Good	88.7 (88.5, 88.8)	88.9 (88.5, 89.2)	94.9 (94.4, 95.5)	89.3 (88.9, 89.6)	82.1 (80.9, 83.4)	91.8 (90.4, 93.1)	84.6 (83.8, 85.5)	
Self-report Mental Health Status								<.0001
Poor	11.5 (11.4, 11.6)	12.5 (12.1, 12.9)	6.7 (6.1, 7.2)	11.2 (10.8, 11.6)	17.8 (16.7, 18.9)	11.5 (10.0, 13.1)	17.8 (16.9, 18.7	
Good	88.5 (88.4, 88.6)	87.5 (87.1, 87.9)	93.3 (92.8 93.9)	88.8 (88.4, 89.2)	82.2 (81.1, 83.3)	88.5 (86.9, 90.0)	82.2 (81.3, 83.1)	
Poor Health Status Affected Usual Activities								<.0001
Yes	15.4 (15.2, 15.5)	16.7 (16.1, 17.2)	8.5 (7.5, 9.6)	14.7 (14.1, 15.4)	24.8 (23.1, 26.6)	14.0 (11.4, 16.6)	20.0 (18.8, 21.1)	
No	84.6 (84.5, 84.8)	83.3 (82.7, 83.9)	91.5 (90.4, 92.5)	85.3 (84.6, 85.9)	75.2 (73.4, 76.9)	86.0 (83.4, 88.6)	80.0 (78.9 81.2)	
Diagnosis with Key Health Conditions								<.0001
Heart attack	4.4 (4.3, 4.4)	3.2 (3.0, 3.3)	1.5 (1.2, 1.8)	2.6 (2.4, 2.8)	6.0 (5.5, 6.6)	3.0 (2.1, 3.9)	4.7 (4.1, 5.3)	
Heart disease	4.3 (4.2, 4.3)	2.6 (2.5, 2.8)	1.5 (1.2, 1.8)	2.1 (1.9, 2.2)	4.7 (4.1, 5.2)	1.9 (1.2, 2.5)	3.8 (3.4, 4.1)	

Stroke	3.1 (3.1, 3.2)	3.9 (3.7, 4.2)	1.1 (0.8, 1.5)	1.9 (1.7, 2.0)	5.0 (4.5 5.5)	2.1 (1.3, 2.8)	4.2 (3.7, 4.6)
Asthma	13.1 (13.0, 13.3)	15.6 (15.2, 16.0)	9.3 (8.5, 10.0)	12.1 (11.7, 12.4)	19.3 (18.0, 20.6)	15.3 (13.3, 17.3)	19.6 (18.7, 20.4)
Cancers (except for skin cancer)	8.9 (8.9, 9.0)	5.3 (5.0, 5.5)	3.0 (2.5, 3.5)	3.5 (3.3, 3.7)	8.2 (7.2, 9.1)	3.3 (2.4, 4.2)	6.9 (6.4, 7.4)
COPD	7.5 (7.4, 7.6)	5.8 (5.5, 6.0)	1.9 (1.5, 2.3)	3.2 (3.0, 3.4)	10.5 (9.6, 11.3)	3.9 (2.9, 5.0)	9.4 (8.7, 10.2)
Arthritis	30.8 (30.7, 31.0)	24.1 (23.6, 24.5)	11.0 (10.2, 11.8)	15.0 (14.6, 15.4)	30.6 (29.3, 31.9)	16.8 (14.7, 19.0)	28.2 (27.3, 29.1)
Kidney disease	2.6 (2.5, 2.6)	2.6 (2.4, 2.7)	1.2 (0.9, 1.5)	2.1 (1.9, 2.3)	2.9 (2.5, 3.3)	2.4 (1.4, 3.4)	2.8 (2.4, 3.1)
Depressive disorder	18.9 (18.7, 19.0)	14.6 (14.1, 15.0)	7.0 (6.4, 7.7)	13.3 (12.9, 13.7)	22.4 (21.3, 23.6)	11.3 (9.7, 13.0)	23.3 (22.4, 24.2)

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[a] Numbers of all race/ethnicity do not add up to the total number of adults at risk due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] AIAN = American Indian or Alaskan Native

[d] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 17 Sample Health Behavior Characteristics by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance System

Characteristics	**Non-Hispanic White N = 1,218,903 Weighted % (95% CI)**	**Non-Hispanic Black N = 111,563 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 30,435 Weighted % (95% CI)**	**Hispanic/Latino N = 63,979 Weighted % (95% CI)**	**Non-Hispanic AIAN [c] N = 23,277 Weighted % (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 5,936 Weighted % (95% CI)**	**Non-Hispanic Multiracial/ Other N = 37,833 Weighted % (95% CI)**	**P-value**
Tobacco Use								<.0001
Current smoker	16.0 (15.9, 16.2)	18.4 (18.0 18.9)	8.2 (7.5, 8.8)	12.9 (12.5, 13.3)	28.8 (27.5, 30.1)	20.3 (17.9, 22.6)	22.5 (21.6, 23.4)	
Former smoker	30.1 (30.0, 30.3)	15.6 (15.2, 16.0)	13.4 (12.5, 14.2)	18.1 (17.6, 18.5)	25.3 (24.0, 26.7)	19.3 (17.2 21.5)	25.0 (24.0, 25.9)	
Non-smoker	53.8 (53.6, 54.0)	66.0 (65.4, 66.5)	78.5 (77.5, 79.5)	69.1 (68.5, 69.6)	45.9 (44.4 47.3)	60.4 (57.6, 63.2)	52.5 (51.4, 53.6)	
Alcohol Consumption								<.0001
Heavy drinker	7.7 (7.6, 7.8)	5.2 (4.9, 5.5)	2.6 (2.3, 3.0)	5.5 (5.3, 5.8)	7.9 (7.1, 8.7)	8.5 (7.1, 9.9)	6.9 (6.4, 7.5)	
Leisure-time Physical Activity								<.0001
No	22.3 (22.2, 22.5)	28.4 (27.9, 28.9)	18.3 (17.3, 19.3)	31.4 (30.8, 31.9)	27.8 (26.4, 29.2)	22.1 (19.7, 24.4)	22.1 (21.2, 22.9)	

[a] Numbers of all race/ethnicity do not add up to the total number of adults at risk due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] AIAN = American Indian or Alaskan Native

[d] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 18 Diabetes Screening Service Use by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance System

Characteristics	**Non-Hispanic White N = 1,218,903 Weighted % (95% CI)**	**Non-Hispanic Black N = 111,563 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 30,435 Weighted % (95% CI)**	**Hispanic/Latino N = 63,979 Weighted % (95% CI)**	**Non-Hispanic AIAN [c] N = 23,277 Weighted % (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 5,936 Weighted % (95% CI)**	**Non-Hispanic Multiracial/ Other N = 37,833 Weighted % (95% CI)**	**P-value**
Diabetes Screening Test								<.0001
No	38.7 (38.4, 38.9)	38.1 (37.4, 38.8)	53.9 (52.1, 55.7)	41.4 (40.5, 42.3)	41.5 (39.6, 43.3)	47.5 (44.4, 50.7)	41.7 (40.3, 43.1)	
Yes	61.3 (61.1, 61.6)	61.9 (61.2, 62.6)	46.1 (44.3, 47.9)	58.6 (57.7, 59.5)	58.5 (56.7, 60.4)	52.5 (49.3, 55.6)	58.3 (56.9, 59.7)	

[a] Numbers of all race/ethnicity do not add up to the total number of adults at risk due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] AIAN = American Indian or Alaskan Native

[d] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 19 Diabetes Screening Service Use Characteristics by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance

Diabetes Screening	**Non-Hispanic White N = 1,218,903 OR (95% CI)**	**Non-Hispanic Black N = 111,563 OR (95% CI)**	**Non-Hispanic Asian American N = 30,435 OR (95% CI)**	**Hispanic/Latino N = 63,979 OR (95% CI)**	**Non-Hispanic AIAN [c] N = 23,277 OR (95% CI)**	**Non-Hispanic Native Hawaiian/other Pacific Islander N = 5,936 OR (95% CI)**	**Non-Hispanic Multiracial/ Other N = 37,833 OR (95% CI)**	**P-value**
Diabetes Screening Test								<.0001
Yes	Ref	1.02 (0.99, 1.06)	0.54 (0.50, 0.58)	0.89 (0.86, 0.93)	0.89 (0.82, 0.96)	0.70 (0.61, 0.79)	0.88 (0.83, 0.94)	

[a] Numbers of all race/ethnicity do not add up to the total number of patients due to missing cases

[b] AIAN = American Indian or Alaskan Native

[c] CI= confidence interval; OR= odds ratio

Table 20 Results of Multivariable Analyses Predicting Diabetes Screening Service Use by Racial and Ethnic Category, 2016–2020, Behavioral Risk Factor Surveillance

	Diabetes Screening Service Ever Taken Screening Test within the Past 3 Years Unweighted N= 185,891			
	β	**OR**	**95% CI**	***P***
Age (Years)				<.0001
18-24	-0.86	0.42	(0.38, 0.46)	<.0001
25-34	-0.45	0.64	(0.59, 0.68)	<.0001
35-44	-0.18	0.83	(0.78, 0.89)	<.0001
45-54	-0.09	0.91	(0.86, 0.97)	0.00
55-64	0.11	1.12	(1.06, 1.18)	0.00
≥ 65 (Ref)				
Race/ethnicity				<.0001
Non-Hispanic Black	0.30	1.35	(1.27, 1.43)	<.0001
Non-Hispanic Asian American	-0.42	0.66	(0.57, 0.76)	<.0001
Hispanic/Latino	0.35	1.42	(1.32, 1.53)	<.0001
Non-Hispanic AIAN[b]	0.29	1.33	(1.17, 1.51)	<.0001
Non-Hispanic Native Hawaiian/other Pacific Islander	0.06	1.07	(0.89, 1.28)	0.50
Non-Hispanic Multiracial/ Other	0.11	1.12	(1.01, 1.24)	0.04
Non-Hispanic White (Ref)				
Marital Status				<.0001
Married or Living with a partner	0.14	1.15	(1.11, 1.20)	
Other (Ref)				
Educational Attainment				<.0001
Graduated from college or technical school	0.35	1.42	(1.31, 1.54)	<.0001
Attended college or technical school	0.29	1.34	(1.24, 1.45)	<.0001
Graduated high school	0.15	1.16	(1.07, 1.25)	0.00
Did not graduate high school (Ref)				
Annual Household Income				<.0001

$50,000 or more	0.19	1.21	(1.12, 1.31)	<.0001
$35,000 to less than $50,000	0.16	1.17	(1.08, 1.27)	0.00
$25,000 to less than $35,000	0.16	1.17	(1.08, 1.28)	0.00
$15,000 to less than $25,000	0.13	1.14	(1.06, 1.22)	0.00
Less than $15,000 (Ref)				
Health Insurance Coverage				<.0001
Yes	0.19	1.21	(1.13, 1.30)	
No (Ref)				
Regular Healthcare Provider				<.0001
Yes	0.49	1.63	(1.55, 1.72)	
No (Ref)				
Routine Checkup				<.0001
Yes, within the past year	1.27	3.55	(2.83, 4.46)	<.0001
Yes, but not within the past year	0.50	1.65	(1.32, 2.08)	<.0001
Never (Ref)				
Self-rated General Health Status				<.0001
Poor	0.01	1.02	(0.93, 1.11)	0.75
Fair	0.11	1.12	(1.06, 1.19)	<.0001
Good/Better (Ref)				
Diagnosis with Heart Disease				<.0001
Yes	0.24	1.27	(1.17, 1.39)	
No (Ref)				
Diagnosis with Cancer (except for skin cancer)				0.01
Yes	0.08	1.08	(1.02, 1.15)	
No (Ref)				
Diagnosis with Arthritis				<.0001
Yes	0.29	1.34	(1.29, 1.40)	
No (Ref)				

Diagnosis with Kidney Disease				0.0008
Yes	0.16	1.18	(1.07, 1.29)	
No (Ref)				
Diagnosis with Depressive Disorder				<.0001
Yes	0.16	1.18	(1.13, 1.23)	
No (Ref)				
Leisure-time Physical Activity				<.0001
No	-0.12	0.89	(0.85, 0.93)	
Yes (Ref)				
Tobacco Use				<.0001
Current smoker	-0.03	0.98	(0.93, 1.03)	0.33
Former smoker	0.09	1.09	(1.05, 1.14)	<.0001
Non-smoker (Ref)				
Alcohol Consumption, heavy drinker				<.0001
Yes	-0.17	0.84	(0.79, 0.89)	<.0001
No (Ref)				

c. Study 2b: Diabetes-related Healthcare Service Use for Individuals at Risk Additional Analyses Using 2017-March 2020 Pre-pandemic NHANES Data

(1) Sample Size

There are 6,267 adults considered as at risk of developing diabetes in the NHANES 2017-March 2020 Pre-pandemic dataset, which counted for 85.0% of the total sample participants (8,965) excluding missing responses (1,631).

(2) Sample Characteristics of Individuals at Risk for Diabetes

Table 21 presents characteristics of predisposing determinants (age, gender, marital status, educational attainment) among individuals at risk by racial and ethnic category from 2017 to March 2020 Pre-pandemic enrolled in NHANES data. Based on the results, the educational level of Hispanic/Latino individuals was lower than other racial/ethnic groups; 27.5% (± 4.2%) of them did not graduate high school, which was consistent with BRFSS study results. Non-Hispanic Asian adults had better educational attainment than others: 54.3% (± 12%) of them were graduated from college or technical school, which was also consistent with BRFSS study results. Among adults who were considered at risk in the non-Hispanic White group, over 50% of them were aged 45 years or older. However, for adults in other minority groups, about half of them were younger (18-44 years old). Particularly, in the Hispanic/Latino group, approximately 60% were adults aged 18-44.

Table 22 shows characteristics of enabling determinants (health insurance coverage) among individuals at risk by racial and ethnic category in 2017 to March 2020 Pre-pandemic NHANES data. Most of the individuals at risk in the non-Hispanic White group (92.2% ± 2.5%) and the non-Hispanic Asian group (91.2% ± 2.3%) had healthcare insurance. Hispanic/Latino adults had a lower rate of insurance coverage than others; only 69.8% (± 3.2%) of them reported they had healthcare insurance. This finding was consistent with BRFSS study results, which both indicated the Hispanic/Latino group may have more barriers to access the healthcare services than other racial/ethnic groups.

Table 23 shows characteristics of need determinants (self-rated general health status and various diseases/health conditions) among individuals at risk by racial and ethnic category from 2017 to March 2020 Pre-pandemic enrolled in NHANES data. The majority (>70%) of adults at risk believed their general health status was good/better. However, among all individuals at risk, those in the Hispanic/Latino group reported lower percentages of self-rating better health (73.6% ± 2.5%) than others. Also, compared to other comorbidities included in this project, the prevalence of arthritis among individuals at risk in all groups was highest, followed by asthma. Unlike the BRFSS results, the diagnosis of kidney diseases was not statistically significant (p=0.08).

Table 24 shows characteristics of health behaviors (tobacco use and physical activity) among individuals at risk by racial and ethnic category in the 2017 to March 2020 Pre-pandemic NHANES data. Non-Hispanic Other adults had a larger tobacco use proportion than other adults; approximately 65% of them were current or former smokers. Non-Hispanic Asian Americans reported the lowest rate of tobacco use: more than 80% of them were non-smokers. In terms of leisure-time physical activity, more adults at risk in the Hispanic/Latino group (50.3% ± 3.3%) and non-Hispanic Black group (51.1% ± 3.8%) reported they did not have any physical exercise.

Table 25 presents the percentages of receiving diabetes screening tests by racial/ethnic groups. Asian American adults reported the lowest percentage of having screening tests; nearly half of them (49.5% ± 5.4%) were not screened for diabetes. Thus, both BRFSS and NHANES data showed fewer Asian American adults had screening tests. More than 50% of adults at risk in other groups reported having screening tests; especially among non-Hispanic White (57.5% ± 3.1%) and non-Hispanic Other (57.7% ± 8.4%) adults with the larger proportions. Rao-Scott chi-square test showed significant associations between having screening tests and race/ethnicity ($\chi^2_{R\text{-}S}$=11.8, DF=3.36, p=0.01).

Table 26 shows the odds ratio of diabetes screening healthcare services use by racial/ethnic groups. Compared to non-Hispanic White adults, all racial/ethnic groups had significantly lower odds ratios of having screening tests within the past three years except for non-Hispanic Black adults. Non-Hispanic Asian patients (OR=0.79, 95% CI=0.66, 0.95) had the significantly lowest odds of having screening tests. Respectively, odds of other groups were Hispanic/Latino (OR=0.83, 95% CI=0.73, 0.95), Non-Hispanic Other (OR=0.83, 95% CI=0.74, 0.93).

Table 27 describes the results of the final multivariable logistic regression model predicting diabetes screening service completion, which only included variables that were significantly associated with healthcare service uses. Due to the small sample size, in the logistic regression model, the degree of freedom was set to infinity. The overall Wald test suggested that all possible factors in the final model had statistically significant impacts on healthcare service use (p<0.0001). Based on the results, adults who had healthcare insurance (OR=1.96, 95% CI=1.60, 2.40) had significantly higher odds of having diabetes screening tests. In addition, adults who were diagnosed with arthritis (OR=1.42, 95% CI=1.15, 1.77) also had significantly higher odds of having screening tests. In terms of health behaviors, former smokers were more likely to have screening tests (OR=1.29, 95% CI=1.10, 1.52). Being older and having an education beyond high school was positively associated with having diabetes screening tests.

Table 21 Sample Predisposing Determinants Characteristics by Racial and Ethnic Category, 2017-March 2020 Pre-pandemic, National Health and Nutrition Examination Survey

Characteristics	**Non-Hispanic White N = 2,215 Weighted % (95% CI)**	**Non-Hispanic Black N = 1,640 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 736 Weighted % (95% CI)**	**Hispanic/Latino N = 1,385 Weighted % (95% CI)**	**Other N = 291 Weighted % (95% CI)**	**P-value**
Age						<.0001
18-24	7.4 (6.0, 8.9)	9.2 (7.3, 11.1)	7.4 (3.7, 11.2)	15.7 (12.7, 18.7)	9.5 (5.4, 13.7)	
25-34	13.0 (11.1, 14.9)	20.1 (18.1, 22.1)	23.8 (19.3, 28.2)	19.9 (16.2, 23.6)	22.8 (13.1, 32.4)	
35-44	13.2 (11.0, 15.3)	18.4 (15.7, 21.1)	18.5 (13.0,24.0)	23.9 (20.5, 27.4)	17.1 (11.6, 22.6)	
45-54	18.2 (14.9, 21.4)	18.7 (16.3, 21.1)	20.2 (16.6, 23.8)	17.9 (15.8, 20.0)	19.4 (8.5, 30.3)	
55-64	22.6 (19.3, 25.9)	19.4 (16.5, 22.3)	16.4 (13.1, 19.7)	13.5 (11.3, 15.6)	17.0 (9.5, 24.5)	
≥ 65	25.7 (22.6, 28.8)	14.2 (11.9, 16.5)	13.7 (9.7, 17.7)	9.1 (7.0, 11.2)	14.2 (8.3, 20.1)	
Gender						0.01
Male	47.0 (44.4, 49.5)	43.4 (40.7, 46.2)	49.0 (44.1, 53.9)	51.4 (48.6, 54.2)	54.5 (46.9, 62.2)	

Female	53.0 (50.5, 55.6)	56.6 (53.8, 59.3)	51.0 (46.1, 55.9)	48.6 (45.8, 51.4)	45.5 (37.8, 53.1)	
Marital Status						<.0001
Married or Living with a partner	66.8 (63.6, 69.9)	46.0 (41.6, 50.5)	72.7 (67.2, 78.2)	64.3 (60.3, 68.2)	51.9 (40.0, 63.7)	
Other	33.2 (30.1, 36.4)	54.0 (49.5, 58.4)	27.3 (21.8, 32.8)	35.7 (31.8, 39.7)	48.1 (36.3, 60.0)	
Educational Attainment						<.0001
Did not graduate high school	6.1 (4.5, 7.6)	11.0 (8.6, 13.5)	12.5 (8.9, 16.0)	27.5 (23.3, 31.7)	11.7 (6.9, 16.5)	
Graduated high school	25.5 (21.4, 29.6)	31.5 (29.1, 34.0)	16.3 (10.5, 22.1)	28.9 (24.8, 33.1)	21.6 (14.4, 28.8)	
Attended college or technical school	31.7 (28.7, 34.7)	33.8 (31.3, 36.3)	16.9 (12.2, 21.6)	26.1 (22.0, 30.2)	44.4 (36.0, 52.7)	
Graduated from college or technical school	36.7 (30.8, 42.6)	23.6 (20.7, 26.5)	54.3 (42.3, 66.3)	17.5 (13.5, 21.6)	22.4 (12.8, 32.0)	

[a] Numbers of all race/ethnicity do not add up to the total number of adults at risk due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 22 Sample Enabling Determinants Characteristics by Racial and Ethnic Category, 2017-March 2020 Pre-pandemic, National Health and Nutrition Examination Survey

Characteristics	**Non-Hispanic White N = 2,215 Weighted % (95% CI)**	**Non-Hispanic Black N = 1,640 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 736 Weighted % (95% CI)**	**Hispanic/Latino N = 1,385 Weighted % (95% CI)**	**Other N = 291 Weighted % (95% CI)**	**P-value**
Health Insurance Coverage						<.0001
Yes	92.2 (89.8, 94.7)	81.9 (79.6, 84.1)	91.2 (89.0, 93.5)	69.8 (66.6, 73.0)	84.0 (76.9, 91.1)	

[a] Numbers of all race/ethnicity do not add up to the total number of adults at risk due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 23 Sample Need Determinants Characteristics by Racial and Ethnic Category, 2017-March 2020 Pre-pandemic, National Health and Nutrition Examination Survey

Characteristics	**Non-Hispanic White N = 2,215 Weighted % (95% CI)**	**Non-Hispanic Black N = 1,640 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 736 Weighted % (95% CI)**	**Hispanic/Latino N = 1,385 Weighted % (95% CI)**	**Other N = 291 Weighted % (95% CI)**	**P-value**
Self-rated General Health Status						<.0001
Poor	1.7 (1.2, 2.3)	3.0 (2.1, 3.8)	1.1 (0.2, 2.1)	2.6 (1.9, 3.3)	4.6 (1.7, 7.6)	
Fair	11.9 (9.9, 13.9)	16.5 (13.9, 19.2)	11.3 (8.3, 14.3)	23.8 (21.4, 26.1)	17.3 (10.2, 24.4)	
Good/Better	86.4 (84.5, 88.2)	80.5 (77.7, 83.3)	87.5 (84.6, 90.5)	73.6 (71.1, 76.1)	78.1 (70.0, 86.1)	
Diagnosis with Key Health Conditions						
Heart attack	3.2 (2.0, 4.3)	2.5 (1.5, 3.4)	1.0 (0.2, 1.8)	1.5 (0.8, 2.2)	5.0 (2.4, 7.6)	0.00
Heart disease	4.0 (2.7, 5.3)	1.2 (0.6, 1.7)	1.4 (0.3, 2.5)	1.3 (0.6, 2.0)	2.6 (0.4, 4.9)	<.0001
Stroke	3.4 (2.7, 4.2)	4.4 (3.2, 5.7)	1.3 (0.3, 2.4)	1.6 (1.1, 2.2)	6.2 (2.6, 9.8)	0.01
Asthma	14.0 (12.2, 15.8)	19.3 (16.3, 22.2)	9.8 (7.6, 12.0)	14.1 (10.8, 17.3)	22.4 (13.6, 31.1)	0.02

Cancers	15.2 (13.0, 17.4)	6.5 (4.9, 8.1)	4.4 (2.6, 6.1)	3.6 (2.5, 4.7)	8.5 (3.8, 13.1)	<.0001
COPD	9.4 (8.1, 10.8)	6.9 (4.8, 9.0)	1.9 (0.8, 2.9)	4.1 (2.8, 5.5)	14.7 (10.0, 19.5)	<.0001
Arthritis	32.2 (28.5, 36.0)	26.2 (23.9, 28.5)	12.5 (9.6, 15.4)	17.2 (14.8, 19.6)	34.7 (25.2, 44.2)	<.0001
Kidney disease	2.7, (1.8, 3.5)	3.2 (2.0, 4.4)	1.4 (0.5, 2.2)	1.7 (0.7, 2.8)	0.9 (0.0, 2.1)	0.08[d]
Depressive disorder	7.0 (5.6, 8.5)	8.4 (6.8, 10.0)	4.2 (2.5, 5.9)	8.1 (6.0, 10.1)	13.2 (8.2, 18.3)	0.01

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[a] Numbers of all race/ethnicity do not add up to the total number of adults at risk due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

[d] Not statistically significant

Table 24 Sample Health Behavior Characteristics by Racial and Ethnic Category, 2017-March 2020 Pre-pandemic, National Health and Nutrition Examination Survey

Characteristics	**Non-Hispanic White N = 2,215 Weighted % (95% CI)**	**Non-Hispanic Black N = 1,640 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 736 Weighted % (95% CI)**	**Hispanic/Latino N = 1,385 Weighted % (95% CI)**	**Other N = 291 Weighted % (95% CI)**	**P-value**
Tobacco Use						<.0001
Current smoker	15.4 (12.7, 18.1)	20.5 (16.8, 24.1)	6.4 (3.8, 9.1)	12.4 (9.9, 15.0)	30.2 (21.7, 38.7)	
Former smoker	29.8 (27.4, 32.2)	15.2 (12.7, 17.6)	11.4, (8.3, 14.4)	18.3 (15.7, 20.9)	34.4 (27.1, 41.7)	
Non-smoker	54.8 (51.5, 58.1)	64.4 (60.1, 68.6)	82.2 (77.3, 87.0)	69.3 (66.1, 72.5)	35.4 (27.6, 43.3)	
Leisure-time Physical Activity						0.00
No	42.1 (38.7, 45.5)	51.1 (47.2, 54.9)	41.4 (35.7, 47.0)	50.3 (46.9, 53.6)	45.3 (35.9, 54.7)	

[a] Numbers of all race/ethnicity do not add up to the total number of adults at risk due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 25 Diabetes Screening Service Use by Racial and Ethnic Category, 2017-March 2020 Pre-pandemic, National Health and Nutrition Examination Survey

Characteristics	**Non-Hispanic White N = 2,215 Weighted % (95% CI)**	**Non-Hispanic Black N = 1,640 Weighted % (95% CI)**	**Non-Hispanic Asian American N = 736 Weighted % (95% CI)**	**Hispanic/Latino N = 1,385 Weighted % (95% CI)**	**Other N = 291 Weighted % (95% CI)**	**P-value**
Diabetes Screening Test						0.01
No	42.5 (39.4, 45.6)	46.3 (42.8, 49.7)	49.5 (44.1, 54.9)	48.7 (44.9, 52.5)	42.3 (33.9, 50.7)	
Yes	57.5 (54.4, 60.6)	53.7 (50.3, 57.2)	50.5 (45.1, 55.9)	51.3 (47.5, 55.1)	57.7 (49.3, 66.1)	

[a] Numbers of all race/ethnicity do not add up to the total number of adults at risk due to missing cases

[b] Percentages may not add up equal to 100% due to rounding

[c] Determined by Second-order (Satterthwaite) Rao-Scott chi-square test

Table 26 Diabetes Screening Service Use by Racial and Ethnic Category, 2017-March 2020 Pre-pandemic, National Health and Nutrition Examination Survey

Characteristics	**Non-Hispanic White N = 2,215 OR (95% CI)**	**Non-Hispanic Black N = 1,640 OR (95% CI)**	**Non-Hispanic Asian American N = 736 OR (95% CI)**	**Hispanic/Latino N = 1,385 OR (95% CI)**	**Other N = 291 OR (95% CI)**	**P-value**
Diabetes Screening Test						<.0001
Yes	Ref	1.01 (0.77, 1.35)	0.79 (0.66, 0.95)	0.83 (0.73, 0.95)	0.83 (0.74, 0.93)	

[a] Numbers of all race/ethnicity do not add up to the total number of adults at risk due to missing cases

[b] CI= confidence interval; OR= odds ratio

Table 27 Results of Multivariable Analyses Predicting Diabetes Screening Service Use by Racial and Ethnic Category, 2017-March 2020 Pre-pandemic, National Health and Nutrition Examination Survey

	Diabetes Screening Service Ever Taken Screening Test within the Past 3 Years Unweighted N= 185,891			
	β	**OR**	**95% CI**	***P***
Age (Years)				<.0001
18-24	-1.36	0.26	(0.17, 0.40)	<.0001
25-34	-0.63	0.53	(0.38, 0.75)	0.00
35-44	-0.47	0.63	(0.48, 0.82)	0.00
45-54	-0.13	0.88	(0.64, 1.22)	0.44
55-64	-0.01	0.99	(0.72, 1.36)	0.95
≥ 65 (Ref)				
Race/ethnicity				0.00
Non-Hispanic Black	0.13	1.13	(0.97, 1.33)	0.12
Non-Hispanic Asian American	-0.03	0.97	(0.82, 1.15)	0.72
Hispanic/Latino	0.33	1.39	(1.14, 1.69)	0.00
Other	0.30	1.35	(0.99, 1.84)	0.06
Non-Hispanic White (Ref)				
Educational Attainment				<.0001
Graduated from college or technical school	0.47	1.61	(1.24, 2.09)	0.00
Attended college or technical school	0.37	1.44	(1.11, 1.87)	0.01
Graduated high school	0.17	1.18	(0.89, 1.56)	0.25
Did not graduate high school (Ref)				
Health Insurance Coverage				<.0001
Yes	0.67	1.96	(1.60, 2.40)	
No (Ref)				
Self-rated General Health Status				<.0001
Poor	0.58	1.78	(0.96, 3.30)	0.07
Fair	0.48	1.62	(1.35, 1.95)	<.0001

Good/Better (Ref)				
Diagnosis with Arthritis				0.00
Yes	0.35	1.42	(1.15, 1.77)	
No (Ref)				
Tobacco Use				0.00
Current smoker	-0.20	0.82	(0.65, 1.02)	0.07
Former smoker	0.26	1.29	(1.10, 1.52)	0.00
Non-smoker (Ref)				

Chapter 5. Conclusions

In conclusion, racial and ethnic disparities in diabetes-related healthcare service use (including clinical care, self-care, and screening care) still exists. The purposes of this dissertation project are to compare differences in diabetes-related healthcare service use among patients with diabetes as well as individuals who are at risk to develop diabetes in different racial/ethnic groups and examining how potential factors are associated with racial/ethnic disparities in diabetes-related healthcare service use. This project found the overall achievements of all type of diabetes-related healthcare service use were not as high as expected, especially in some specific racial/ethnic groups. The results of the project confirmed the hypothesis that compared to non-Hispanic White people, racial/ethnic minority groups had lower diabetes-related healthcare service use. For some specific services, one specific minority group may have a higher rate of use; however, the overall rates of diabetes-related healthcare service use are lower among racial/ethnic minority groups.

In addition, the findings of this project further confirmed that multiple factors can influence diabetes-related healthcare service uses. For diabetes-related self-care use among patients with diabetes, demographic factors (such as age, marital status, educational level), healthcare insurance status (insurance coverage, care providers, routine checkups), insulin use as well as affected eyes, self-rated health status, and alcohol consumption all play important roles in the completions of self-care activities. On the other hand, factors associated with diabetes-related clinical care use among patients with diabetes were slightly different. Demographic factors (such as age, annual household income, educational level, employment status), healthcare insurance status (insurance coverage, care providers, routine checkups, affordable healthcare cost), insulin use as well as affected eyes, diagnosis with arthritis as well as kidney disease, tobacco use, and alcohol consumption can influence clinical care use.

For adults who are at risk of developing diabetes, they are recommended to have regular diabetes screening tests. Demographic factors (such as age, marital status, annual household income, educational level), healthcare insurance status (insurance coverage, care providers, routine checkups), self-rated health status, diagnosis with other chronic diseases (heart disease, cancers, arthritis, kidney disease, depressive disorder), health behaviors (tobacco use, alcohol consumption, physical activity) can impact such service use.

Chapter 6. Discussion and Implications

Diabetes has been a serious public health issue for several decades. Efforts had been made to prevent developing diabetes and reduce the medical and economic burden caused by this chronic disease. However, many patients with diabetes and adults who are at risk of developing diabetes, especially those who are racial/ethnic minorities, are still struggling with the unaffordable cost of healthcare and other barriers, which makes it relatively more difficult for them to complete recommended healthcare activities.

The findings of this project demonstrated the importance of factors related to healthcare insurance, such as insurance coverage and having regular healthcare providers. Healthcare insurance coverage is significant to both patients with diabetes and individuals who are at risk of developing diabetes. Both BRFSS data and NHANES data indicated people had better healthcare service use if they had insurance. For all types of healthcare service use, insurance-related factors are significantly associated with achieving care activities. With healthcare insurance, patients with diabetes or adults who are at risk can relatively reduce the economic burden, which would encourage them to have examinations and tests. Thus, improve healthcare coverage is an important step to reduce the prevalence and mortality of diabetes. The Affordable Care Act (ACA) is an example for protecting public health by improving healthcare coverage. Certain population subgroups have been found to be more likely to have chronic diseases like diabetes. Thus, several ACA provisions developed specific guidelines to ensure those groups (such as racial/ethnic minority groups) have equitable access to health insurance coverage as well as to patient-centered medical homes which provide them with low or no cost evidence-based preventive services [93]. With the expansion of the Affordable Care Act Medicaid, more patients had access to health insurance. Compared to newly insured non-Hispanic Whites, newly insured Hispanic patients were reported to have better control of their diabetes; newly insured non-Hispanic Blacks also reported to have faster control of diabetes than non-Hispanic Whites among patients [94].

In addition, the results of this project indicated diagnosis with other diseases, such as arthritis, heart diseases, kidney diseases, cancers, and depressive disorder, can be positively associated with diabetes-related healthcare utilization. One possible reason can be their healthcare providers' recommendations. For example, previous studies found patients with severe mental illnesses also have a higher risk of developing type 2 diabetes [95, 96]. Health care professionals who provide care to patients with mental disorders may be familiar with diagnosis features of diabetes and recommend screening tests to their patients, which can encourage those patients to detect their blood sugar levels in early stage [97]. From this perspective, collaborative care can play an important role in increasing diabetes-related healthcare utilization. Primary care teams should have basic training in knowledge and skills to identify and manage diabetes. For healthcare professionals who work in general hospitals and already have the essential knowledge to identify other health needs, they should be able to refer patients to specialized diabetes doctors, which can help patients to access related diabetes care services or encourage them to have screening tests.

In terms of the utilization of specific racial/ethnic groups, non-Hispanic Asian American patients had the lowest percentage of fully completing self-care activities and adults in this racial/ethnic group also reported the lowest percentage of having screening tests, which was consistent with previous studies [28,43]. Hispanic/Latino patients reported lower full completion percentages of annual clinical care use. Also, both BRFSS and NHANES results stated individuals at risk in the Hispanic/Latino group were reported as young, with lower educational level, without healthcare insurance, and self-rated poor health. As mentioned previously, healthcare insurance is one of the most important factors of healthcare service use. Among all racial/ethnic groups, Hispanic/Latino people had the lowest percentages of accessing to all types of healthcare services, including health insurance coverage, times of annual routine checkups, numbers of regular health care providers, and affordable health needs. Additionally, Hispanic/Latino adults had lower annual household incomes as well as educational levels. A lack of education may make them feel that it’s difficult to understand related healthcare service instructions, which leads to the fear of using these services. These socioeconomic barriers can relatively explain the low rates of diabetes-related healthcare service utilization among Hispanic/Latino adults. Therefore, future healthcare policies should focus more on helping Hispanic/Latino population to improve their insurance coverage and providing affordable, straightforward healthcare services.

However, the case of non-Hispanic Asian Americans may be different. Their levels of education, income, employment, and healthcare service access were all above the average. Despite the fact that this project did not focus on identifying why non-Hispanic Asian Americans had lower utilization specifically, some insights can be obtained from the results. Self-rated general health status can impact the achievement of screening tests. Compared to adults who felt their health conditions were not good, adults who believed their health conditions were good would be less likely to have screening tests. Approximately 90% of non-

Hispanic Asian American adults believed their health status was good, although they were qualified as “at risk of developing diabetes” by ADA guidelines. Besides, a previous study indicated language barrier can be another reason for the low rate of self-care achievement [98]. Since some self-care activities (such as self-monitoring blood sugar levels) may require basic trainings, it can be difficult for them to understand that information in English. Therefore, fluency in English and familiarity with the U.S. healthcare environment can be other factors that influence service utilization. More research to investigate why non-Hispanic Asian Americans had lower service utilization is needed.

Race/ethnic differences in diabetes-related healthcare service utilization are complex. Different racial/ethnic groups may have different barriers to accessing and using healthcare services. Policymakers and intervention designers should take culture, traditions, and specific factors associated with these differences into account. For example, healthcare policies that aimed to improve healthcare coverage may be more effective for Hispanic/Latino adults to improve their diabetes-related healthcare utilization. For non-Hispanic Asian Americans, culturally tailored interventions or self-management pragmas with bilingual staff may be more helpful. Therefore, tailored health policies and tailored diabetes-related interventions/self-management programs that are based on specific race/ethnic group’s needs are significant to reducing the burden caused by diabetes.

This project had some limitations, which mainly result from the BRFSS data source. As a cross-sectional, self-report, publicly published survey system, BRFSS has challenges that may cause limitations of this project.

a. Lack of Information about Racial/ethnic Subgroups

Minority racial/ethnic groups are heterogeneous; different racial/ethnic subgroups can have disparities in educational levels, income, English fluency levels, culture, and health behaviors. All these factors can influence the patterns of healthcare service use. Although the

BRFSS questionnaire includes the responses to collect the subgroup information for participants who reported themselves as Asians (Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, etc.), Pacific Islanders (Native Hawaiian, Guamanian or Chamorro, Samoan, etc.), and Hispanics (Mexican, Mexican American, Chicano/a, Puerto Rican, Cuban, etc.), this data cannot be accessed in the public dataset. In order to protect participants' privacy, most of the national health interview surveys including NHANES do not publish subgroup information in their public datasets [99]. Only NHIS includes racial/ethnic subgroup data [99]; however, as stated previously, NHIS does not have information for diabetes-related healthcare service use. Therefore, future research can focus on racial/ethnic subgroups and disclose different healthcare service use patterns among different subgroups.

b. Lack of Information about Duration of Diagnosis and Type of Diabetes

Whether the patient is newly diagnosed can be an important covariate for the completion of diabetes-related healthcare activities. ADA guidelines recommend all patients with diabetes have regular tests and examinations at diagnosis and maintain throughout their lifetime; however, newly diagnosed patients and patients who have been diagnosed for a long time may follow the guideline differently in accordance with how long they have been diagnosed. Taking the diabetes self-management as an example, previous research indicated that completions of patients with different duration of diabetes diagnosis (less than 1 year, 1-5 years, 6-10 years, 10-15 years, and more than 15 years) were significantly different [100]. However, BRFSS fails to include a question about the diagnosis duration. Although it has a survey question that asks patients "How old were you when you were told you have diabetes?", it does not have detailed information about respondents' age. To protect participants' privacy, BRFSS only has the age group information. Therefore, the duration of diagnosis cannot be calculated. Besides, BRFSS only collected diagnosis information (yes or no) but did not distinguish the type of diabetes. Patients with Type 1 diabetes are accounted for 5% of all patients with diabetes in the U.S.; the healthcare recommendations for them may be different [13]. Previous studies using BRFSS data treated all patients with diabetes as patients with Type 2 diabetes. Thus, this project decided to follow the method that was used before to keep consistency.

c. Bias Due to BRFSS Design

Despite the proven reliability and validity of the BRFSS system, it still has some limitations [101]. One limitation is the selection bias. As a telephone survey system, it cannot cover people who do not have a cell phone or landline phone in their houses. Generally, these people may have lower incomes than people who have phones. As a result, BRFSS data may understate real healthcare use.

Another limitation is using self-reported diabetes diagnosis and healthcare service use. Participants who recalled inaccurately or were not aware of healthcare service use may lead to underreporting. Collins et al. (1985) also found recall of past behavior could be biased by current behavior, which may also result in overreporting or underreporting [102]. It is difficult to assess the reliability of self-report information directly using BRFSS data; however, previous studies provide insights into the validity. Schneider et al. (2012) found the reliability of self-reported diagnosis of diabetes was greater than 92% at all time points [103]. Other research also indicated self-report diabetes status as one classification measurement had high sensitivity and specificity [104,105]. For self-reported recipients of screening tests, research to assess the validity was limited. Kiefer et al. (2015) used the cholesterol screening test as a reference since both tests shared analogous mechanisms [77] and the accuracy was fairly reliable [106]. In order to reduce the uncertainty caused by bias, this dissertation project conducted additional analyses using NHANES data to justify BRFSS results. Consistent findings were observed from the analyses with NHANES and BRFSS data. Future research can use medical records as the data source for a more accurate and valid assessment of related patterns.

Non-response is also a limitation. Even though BRFSS continued to collect data during the pandemic, it still had a declining response rate. By applying weighting methods when conducting analyses, the impact of bias can be decreased.

d. Changes in 2022 ADA Standards of Medical Care in Diabetes

Due to the increasing prevalence of diabetes among younger adults, ADA adjusted the recommendation for individuals at risk and aimed to encourage more younger adults to take a screening test. The new age for the recommended-screening group is now 35 [107]. ADA recommended all adults aged 35 years or older as well as adults who are overweight or have obesity who are aged <35 years and have one or more of risk factors to have regular screening tests [107]. This dissertation project was conducted in 2021 so the inclusion criteria were based on ADA 2021 guidelines. Future research using 2022 or later data should follow the ADA 2022 guidelines and consider updating age criterion as 35 years.

Despite these limitations, the findings of this project highlighted the racial/ethnic disparities in diabetes-related healthcare service utilization. Also, results identified possible factors associated with the utilization. Future studies are needed to continually monitor the racial/ethnic disparities and trends of healthcare service utilization among different racial/ethnic groups. Substantial efforts should be made to reduce such disparities and improve the overall utilization of diabetes-related healthcare services, which can eventually promote public health.

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