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Educational Disparities in the Prevalence of

Diabetes and Prediabetes in the United States, 2001-2020

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Educational disparities in the prevalence of diabetes and prediabetes in the United States, 2001-2020

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An abstract of
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Abstract

Educational disparities in the prevalence of diabetes and prediabetes in the United States, 2001-2020

By Ji Young Choi

This study aims to examine whether the prevalence of diabetes and prediabetes varied by education level and whether these patterns changed over the past two decades in the United States. Data were from adults aged 30 to 79 in the National Health and Nutrition Examination Survey, 2001-2020 (n=33,200). Diabetes was defined based on self-reported diagnosis of diabetes, elevated glycated hemoglobin (HbA1c$\geq$6.5%) or the use of diabetes medications. Prediabetes was defined as HbA1c of 5.7-6.4%. We estimated the age-standardized prevalence of diabetes and prediabetes by educational attainment (less than high school, high school diploma and some college or higher) and survey period. Adjusted associations between educational attainment and diabetes and prediabetes were estimated using multiple logistic regression models. The prevalence of diabetes increased from 10.8% to 16.2% and prediabetes increased from 14.0% to 23.3% between 2001-2004 and 2017-2020. Less-educated adults consistently had a higher prevalence of diabetes and prediabetes than college-educated. The odds of having diabetes and prediabetes among those with less than high school were significantly higher than that of college-educated (diabetes: OR=1.37 [1.23-1.52]; prediabetes: OR=1.2 [1.1-1.3]). The absolute magnitude of disparity between adults with less than a high school education and the college-educated group was similar in 2001-2004 (3.9 percentage points) and 2017-2020 (4.3 percentage points). In conclusion, substantial disparities in diabetes by educational attainment were observed in the United States in 2001-2020, with evidence of unchanging magnitude of disparities over time. Therefore, novel intervention strategies focusing on diabetes prevention in individuals with lower educational attainment are urgently warranted.

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Chapter 1: Introduction

1.1 Introduction and Rationale

Since the late-1990s, the prevalence of diabetes has increased rapidly in US adults, from 9.5% in 1999-2002 to 12.0% in 2013-2016. In 2019, 37.1 million US adults had diabetes, which accounts for 14.7 % of all US adults [1]. Diabetes was the eighth leading cause of death in the country in 2020 [2]. Prediabetes prevalence among US adults also increased from 33.6% in 2005-2008 to 36.5% in 2017-2020, and about 96 million adults were living with prediabetes in 2019 [3]. Prediabetes is a significant risk factor for the development of type 2 diabetes and chronic cardiovascular diseases (CVDs) that lead to serious health complications and reduced quality of life [4]. Without early intervention, 70% of prediabetes cases will progress to diabetes within ten years, and 8 in 10 adults are unaware of existing prediabetes [5,6].

Several studies have demonstrated that socioeconomically underserved people are at higher risk of diabetes, prediabetes, and mortality from hyperglycemia [7–9]. The minority groups characterized by low levels of education and income and high levels of poverty are affected by disparities in health and access to healthcare [10]. As a reliable and valid measure of individuals' socioeconomic status (SES), educational attainment has been shown to influence a person's access to health-promoting resources, lifestyle choices, health behaviors and environment [7,11,12]. For example, people with higher education tend to have greater access to and utilization of preventive services and make healthier choices, such as engaging in regular physical activity and maintaining a healthy diet [12–14]. A study of national representative data reported that adults with college graduation have a 30% lower risk of diabetes than those with less than a high school education [15]. To address the disproportionate burden of these diseases among disadvantaged subpopulations, a comprehensive understanding of the long-term trends of SES disparities in diabetes and prediabetes is needed.

1.2 Problem Statement

Public health organizations, policymakers and medical and social service providers have implemented action plans and interventions to address health disparities related to diabetes (e.g., REACH 2010 and Healthy People 2020) [10,16,17]. However, despite the multisectional efforts, the disproportionate burdens of diabetes and prediabetes among underserved subpopulations remain substantial [9,18,19]. Previous scientific research has suggested potential mechanisms that may influence persistent diabetes disparities [20,21]. For example, diabetes prevention programs, such as lifestyle interventions and medication treatment, were more likely to have greater efficacy among highly educated individuals, possibly resulting in a lower transition from prediabetes to diabetes in the most educated segment of the US population [22]. Given the complexity of SES differences in the diseases, there is a vital need to assess the long-term trends in SES disparities in the prevalence of diabetes and prediabetes to identify a population at higher risk for the conditions. Although there have been several previous studies evaluating the prevalence of diabetes or prediabetes, little is known about long-term trends in both diabetes and prediabetes by different socioeconomic groups using recent data [15,18,19]. Thus, a comprehensive understanding of the current state of national-level socioeconomic disparities in diabetes, and whether these disparities have reduced over time. Such investigation could help assess whether prior policies and interventions have been successful in mitigating disparities in diabetes and aid in informing future public health policies and interventions to reduce diabetes-related disparities and diabetes burdens through the identification of subpopulations at the greatest risk for diabetes and prediabetes.

1.3 Purpose Statement

To fill those research gaps, this study applies individuals’ SES based on their educational attainment and assesses trends in educational disparities in diabetes and prediabetes between 2001 and 2020 among the US adult population using large and nationally representative data. In particular, the current study aims to answer the question of whether and to what extent disparities in diabetes and prediabetes prevalence across educational attainment have changed over two decades.

Chapter 2: Comprehensive Review of the Literature

This chapter will review the literature regarding the definitions of diabetes and prediabetes, trends in the prevalence of diabetes and prediabetes in the US and SES disparities in diabetes and prediabetes. In addition, this chapter will provide an overview of the National Health and Nutrition Examination Survey (NHANES).

2.1 Definitions of Diabetes and Prediabetes

Diabetes is a chronic medical condition characterized by high blood glucose levels, which occurs when the body cannot produce or use insulin, a hormone that regulates blood sugar levels. Type 2 diabetes is the most common form of diabetes and accounts for about 90-95% of all diagnosed cases of diabetes [23]. Uncontrolled diabetes can lead to a range of health problems, including cardiovascular diseases (CVDs), nerve damage, kidney damage, and vision problems [24]. Prediabetes, also known as impaired glucose tolerance, is a condition in which blood glucose levels are higher than normal but not high enough to be classified as diabetes. Without early intervention, 70% of prediabetes cases will progress to diabetes within ten years, and 8 in 10 adults are unaware of existing prediabetes [4,5].

According to the guidelines of the American Diabetes Association (ADA), diabetes and prediabetes are diagnosed using a glycohemoglobin (HbA1c) test, which measures the average blood glucose level over the past 2-3 months [25]. Diabetes is diagnosed when the HbA1c level is equal to or higher than 6.5%, and prediabetes is diagnosed when the HbA1c level is between 5.7% and 6.4%. Additionally, diagnosed diabetes is based on self-reported of a previous diagnosis by a physician or other health professional, and undiagnosed diabetes is based on HbA1c level among people self-reporting no diabetes [26].

2.2 Trends in the Prevalence of Diabetes and Prediabetes

Since the late-1990s, the prevalence of diabetes has increased rapidly in US adults, from 9.5% in 1999-2002 to 12.0% in 2013-2016. According to the Center for Disease Control and Prevention (CDC), the prevalence of diabetes in 2021 was estimated to be more than 37 million (10.5% of the population) in the US [24]. Previous research using the NHANES data presented that the unadjusted prevalence of total diabetes (diagnosed plus undiagnosed cases) among US adults increased from 7.7% in 1999–2000 to 13.3% in 2015–2016 [27]. In the study using data from the National Health Interview Survey (NHIS), age-adjusted prevalence and incidence of diagnosed diabetes doubled between 1990 and 2008 and reached a plateau between 2008 and 2012, while there appear to be continued increases in the prevalence or incidence of diabetes among subgroups, including non-Hispanic black and Hispanic subpopulations and those with a high school education or less [28]. Age-adjusted prevalence of prediabetes also increased from 33.6% (95% CI: 31.9-35.2) in 2005-2008 to 36.5% (95% CI: 34.3-38.7) in 2017-2020, showing no significant change over the period [29,30]. A study of patients with heart failure in the US documented that the prevalence of the prediabetes among the study population did not change significantly between 2005 and 2016 [31].

Several factors have been suggested for the increasing trends in diabetes and prediabetes, including widespread screening tests [32,33], increasing obesity and overweight prevalence [34–36] and lifestyle changes (e.g., increasing sedentary behavior and poor dietary habits) [37–39]. Although diabetes-related complications in the United States have been reduced due to substantial improvements in preventive care [40,41], the increase in the proportion of US adults living with diabetes and prediabetes could pose escalating burden of diabetes costs and public health concerns given that diabetes is a major cause of CVDs, hospitalization and excess death [42–44].

2.3 Socioeconomic Status (SES) and Diabetes and Prediabetes

The measurement of SES varies across studies and can be based on a variety of indicators, such as income, education, occupation, and/or neighborhood characteristics [12,21,45]. It is crucial to note that no single measure of SES is perfect and each measure has its own limitations. Among socioeconomic indicators, educational attainment is considered a reliable and valid measure of individuals' SES in health research [7–9]. Educational attainment has been shown to influence individuals' access to health resources, lifestyle choices, health behaviors and the environment, which is suggested as a potential mechanism leading to disease disparities [7,11].

The association between SES and health outcomes is well known [31,46,47]. Previous literatures have revealed that dysglycemia, including diabetes and prediabetes, affects all segments of the US population, but socioeconomically underserved population are disproportionately affected [15,42,46]. Several scientific literatures have reported that people with lower socioeconomic status (SES) levels, measured by education attainment and income, experienced greater prevalence of diabetes [15,31,48]. In a study of a US representative sample from NHIS, the age-standardized prevalence of diagnosed diabetes among adults with less than high school increased from 7.8% (95% CI: 7.5-8.2) in 1999-2002 to 11.0% (95% CI: 10.6-11.5) in 2011-2014, and that among those with college or higher education increased from 3.6% (95% CI: 3.4-3.9) to 5.0% (95% CI: 4.8-5.3) in the same periods. This study demonstrated the widened absolute disparities between the least and most educated groups between two periods [48]. In a recent research using 2015-2018 NHANES, compared with adults with less than high school, those with college education had an adjusted prevalence ratio of 0.71 (95% CI: 0.58-0.88) for total diabetes and 0.94 (95% CI: 0.83-1.06) for prediabetes. Additionally, the research also demonstrated that disparities persisted with higher prevalence among populations that have been marginalized, including racial and ethnic minorities, low-income, less educated Americans, and those living in food-insecure households in 2015-2018 [15].

Despite the increasing evidence of SES disparities in diabetes and prediabetes, little research was showed recent and long-term trends of the disparities, which is vital to identify a subpopulation at higher risk of the diseases.

2.4 Data Source - National Health and Nutrition Examination Survey

National Health and Nutrition Examination Survey (NHANES) is a cross-sectional, continuous, stratified, nationally representative survey of the noninstitutionalized civilian population in the US conducted by the National Center for Health Statistics (NCHS). In the early 1960s, the NHANES was launched, and it has since been conducted as a sequence of surveys that have concentrated on diverse population segments and health topics. In 1999, NHANES became a continuous, ongoing survey conducted in two-year cycles. This change allowed for more frequent updates on the health status of the US population and the ability to monitor trends over time. NHANES collects data through a combination of household interviews and physical examinations conducted in mobile examination centers. The NHANES interview consists of demographic, socioeconomic, dietary, and health-related questions. The examination component includes medical, dental, and physiological measurements. Laboratory tests on blood and other specimens are performed by trained medical personnel [49]. NHANES has been an essential source of data for researchers and policymakers seeking to understand the health and nutritional status of the US population, as well as the factors that contribute to health disparities and chronic disease, including diabetes.

Chapter 3: Manuscript

Title

Educational Disparities in the Prevalence of Diabetes and Prediabetes in the United States, 2001-2020

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Abstract

Purpose

To examine disparities in prevalent diabetes and prediabetes by education level in the United States from 2001 to 2020.

Methods

Data were from the National Health and Nutrition Examination Survey, 2001-2020 (n=33,200). Diabetes was defined based on self-reported diagnosis of diabetes, elevated glycated hemoglobin (HbA1c≥6.5%) or the use of diabetes medications. Prediabetes was defined as HbA1c of 5.7-6.4%. We estimated the age-standardized prevalence of diabetes and prediabetes by educational attainment (less than high school, high school diploma and some college or higher) and survey period among adults aged 30 to 79. Adjusted associations between educational attainment and diabetes and prediabetes were estimated using multiple logistic regression models.

Results

The prevalence of diabetes increased from 10.8% to 16.2% and prediabetes increased from 14.0% to 23.3% between 2001-2004 and 2017-2020. Less-educated adults consistently had a higher prevalence of diabetes and prediabetes than college-educated. The odds of having diabetes and prediabetes among those with less than high school were significantly higher than that of college-educated (OR for diabetes: 1.37 [1.23-1.52] and OR for prediabetes: 1.2[1.1-1.3]). The absolute magnitude of disparity between adults with less than high school education and the college educated group remained similar between 2001-2004 and 2017-2020, at 3.9 and 4.3 percentage points, respectively.

Conclusions

Substantial disparities in diabetes by educational attainment were consistently observed in the United States across the 2001 to 2020 period, with evidence of unchanging magnitude of disparities over time.

Highlights

- Increasing prevalence of dysglycemia in all education groups from 2001 to 2020
- Persistent educational disparities in diabetes and prediabetes
- A rapid increase in the prevalence of diabetes among people with high school diploma

Keywords

Diabetes; prediabetes; educational disparities; SES; national trend; NHANES

List of abbreviations

ACA, Affordable Care Act; BMI, Body Mass Index; CVD, Cardiovascular Diseases; FPL, Federal poverty level; GED, general education development; HbA1c, glycated hemoglobin; NHANES, National Health and Nutrition Examination Survey; NCHS, National Center for Health Statistics; SES, socioeconomic status;

Introduction

The association between socioeconomic status (SES) and health outcomes is well known [1–6]. Several studies have demonstrated that socioeconomically underserved people are at higher risk of diabetes, prediabetes, and mortality from hyperglycemia [7–9]. Since the late-1990s, the prevalence of diabetes has increased rapidly in US adults, from 9.5% in 1999-2002 to 12.0% in 2013-2016. In 2019, 37.1 million US adults had diabetes, which accounts for 14.7 % of all US adults [10]. Diabetes was the eighth leading cause of death in the country in 2020 [12]. Prediabetes prevalence among US adults also increased from 33.6% in 2005-2008 to 36.5% in 2017-2020, and about 96 million adults were living with prediabetes in 2019 [13]. Prediabetes is a significant risk factor for the development of type 2 diabetes and chronic cardiovascular diseases (CVDs) that lead to serious health complications and reduced quality of life [14]. Without early intervention, 70% of prediabetes cases will progress to diabetes within ten years, and 8 in 10 adults are unaware of existing prediabetes [15,16].

Among socioeconomic indicators, educational attainment is considered a reliable and valid measure of individuals' SES in health research [7–9]. Educational attainment has been shown to influence a person's access to health resources, lifestyle choices, health behaviors and environment [7,17]. For example, people with higher education tend to have greater access to and utilization of preventive services and make healthier choices, such as engaging in regular physical activity and maintaining a healthy diet [18,19]. Individuals with low educational attainment have a higher risk of having diabetes and prediabetes and are more affected by diabetes-related complications than those with higher educational attainment [20–22]. In addition, diabetes prevention programs, such as lifestyle interventions and medication treatment, were more likely to have greater efficacy among highly educated individuals, possibly resulting in lower transition from prediabetes to diabetes in the most educated segment of the US population [23].

Addressing health equity in diabetes requires an understanding of the current state of national-level socioeconomic disparities in diabetes, and whether these disparities have reduced over time. Such investigation could help assess whether prior policies and interventions have been successful in mitigating disparities in diabetes and aid in informing future public health policies and interventions to reduce diabetes-related disparities and diabetes burdens through the identification of subpopulations at the greatest risk for diabetes and prediabetes. Therefore, this study assesses trends in educational disparities in diabetes and prediabetes between 2001 and 2020 using large and nationally representative data. In particular, the current study aims to answer the question of whether and to what extent disparities in diabetes and prediabetes prevalence across educational attainment have changed over two decades.

Methods

Data

We utilized data from the public-use National Health and Nutrition Examination Survey (NHANES), nationally representative surveys of the noninstitutionalized civilian population in the U.S. conducted by the National Center for Health Statistics (NCHS) [24]. We used data from 9 consecutive cycles of NHANES from 2001 to 2020. We categorized nine consecutive survey cycles into five periods: 2001-2004, 2005-2008, 2009-2012, 2013-2016 and 2017-2020. Since data collection for the NHANES 2019-2020 cycle was not completed due to the impact of the coronavirus disease 2019, we followed recommended weighting procedures to create nationally representative 2017-March 2020 pre-pandemic data [25]. The NCHS ethics review board approved the surveys, and participants signed the informed consent [24]. Data were collected through a combination of interviews (demographics, healthcare accessibility, smoking status and medical history), physical and medical examinations (weight and height) and laboratory tests (HbA1c) [24].

This study was restricted to respondents aged 30 to 79 to account for the possibility that those under 30 might still be completing formal education and that educational attainment information in this age group better reflect their socioeconomic position than at older ages [26]. Our analysis included only adults who completed the interview and examination components (n=39,990). We excluded respondents with incomplete information on education (n=39, 0.10%), income-to-poverty ratio (n=3,465, 8.92%), healthcare accessibility (n=2, 0.01%), smoking status (n=29, 0.07%), body mass index (BMI) (n=703, 1.81%) and glycated hemoglobin (HbA1c; n=1,853, 4.77%), yielding an analytic sample size of 33,220 across the survey cycles.

Measurements

The outcomes of this study were diabetes and prediabetes. Based on the American Diabetes Association guidelines, we defined diabetes as having glycated hemoglobin (HbA1c) of 6.5% or more and prediabetes as having HbA1c between 5.7% and 6.4% [10]. We further classified individuals who reported a physician diagnosis of diabetes or the use of oral hypoglycemic agents or insulins as having diabetes [21,27]. HbA1c was measured by a high-performance liquid chromatographic method using whole blood specimens collected during laboratory tests [28]. We used a validated statistical calibration approach to account for changes in laboratory equipment and analytic methods throughout the study period [23].

We measured individuals' SES based on their educational attainment [7,29]. Highest educational attainment was classified into three groups as follows: less than high school (individuals without a high school diploma or general education development (GED) test or equivalent), high school (high school diploma, GED test or equivalent), and some college or higher (some college, associate degree, college diploma, or higher).

We included other covariates to address potential confounders that may affect the relationship between education and diabetes and prediabetes: age, sex, race and ethnicity, healthcare accessibility, smoking status, and BMI. We also included the income-to-poverty ratio as a potential mediator. Combined race and ethnicity was categorized as non-Hispanic White, non-Hispanic Black, Hispanic, and others (non-Hispanic Asian and multi-racial). The family income-to-poverty ratio was classified into four categories based on the federal poverty level (FPL): High (≥400% FPL), middle income (200-399% FPL), near poor (100-199% FPL), poor (<100% FPL). Healthcare accessibility was measured by the presence or absence of places regularly visited for healthcare. BMI was calculated by dividing weight by kilogram per height in meters squared.

Statistical Analysis

We presented demographic characteristics of the sample for each of the five survey periods. Age-standardized prevalence of diabetes and prediabetes and their 95% confidence intervals were calculated by direct method to the 2010 Census population [30,31]. We then calculated the absolute change in estimates between 2017-2020 and 2001-2004.

To examine temporal trends in educational disparities in diabetes and prediabetes after adjustment for potential confounders, we implemented multiple logistic regression models. We built three regression models. We first estimated associations between educational attainment and diabetes and prediabetes, separately, after adjusting for potential confounders (Model 1). We then introduced interaction terms of education and survey periods to examine whether the period effect of having diabetes and prediabetes observed in Model 1 differ across education groups (Model 2). Lastly, we examined whether the interactive effect between education and survey periods observed in Model 2 changed independent of BMI, a biological risk factor for both diabetes and prediabetes (Model 3) [32,33]. In Model 1, we included educational attainment, survey periods, age, sex, race and ethnicity, income-to-poverty ratio, healthcare accessibility, and smoking status. In Model 2, we additionally included interaction terms between education level and survey periods. We further adjusted both linear and quadratic terms for BMI in Model 3. After performing Model 3, we calculated predicted probability of the outcomes by educational attainment and survey periods using coefficients from Model 3. We then tested the differences in the estimated probability of the outcomes for each educational level within the survey period using F-statistics at an alpha of 0.05.

We performed two sensitivity analyses. First, we examined the effect of missing information on our results. To do that, estimated prevalence of diabetes and prediabetes in all adults, including those with missing values of BMI and income (n=36,900). Second, it is possible that disparities in diagnosed diabetes differ from total diabetes due to changes in diabetes diagnosis environment (e.g., screening methods and diagnosis threshold for diabetes) over time affects our results. Therefore, we also conducted an analysis for diabetes based solely on previous diagnosis of the condition.

All results incorporated appropriate sampling weights to produce national population estimates and to account for unequal probabilities of sample selection, non-response and post-stratification adjustments [24]. All analyses were performed using STATA software, version 17.0

Results

Table 1 shows characteristics of the US population aged 30 to 79 years by survey period from 2001-2020. The percentage of non-Hispanic whites, non-Hispanic blacks, and Hispanics in the population changed from 75.2%, 10.0%, and 10.3% in 2001-2004, respectively, to 64.9%, 10.2% and 15.0% in 2017-2020, respectively. The percentage of individuals with less than a high school education decreased from 17.7% in 2001-2004 to 10.5% in 2017-2020, whereas those with a college education increased from 56.7% to 65.3% in the same period. The mean BMI and HbA1c of the US adult population increased over time from 28.8 kg/m2 to 30.5 kg/m2 and from 5.7% to 6.0%, respectively, in the study period.

Table 2 presents the age-standardized prevalence of diabetes and prediabetes by educational attainment across survey periods. Among 30-79-year-old US adults, diabetes prevalence increased from 10.8% (95% CI: 9.8-11.8) in 2001-2004 to 16.2% (95% CI: 14.8-17.6) in 2017-2020. Stratified by educational attainment, notably, diabetes prevalence in those with less than a high school education (17.2% [15.3-19.3]) was nearly twice as high as those with high school (9.9 [8.7-11.3]) or college education (9.2 [7.8-10.7]) in 2001-2004. Over the period, diabetes prevalence significantly increased in all education categories, but the increase was most rapid in the high school group at 10.5% (95% CI: 6.3-14.9), which was twice as large as that for less than high school (5.6 percentage point increase) and college groups (4.2 percentage point increase). Prediabetes prevalence also increased during the study period among 30-79-year-old US adults, from 14.0% (95% CI: 12.9-15.2) in 2001-2004 to 23.3% (95% CI: 21.8-24.8) in 2017-2020. Unlike diabetes, there were no educational differences in prediabetes prevalence in 2001-2004. However, the rapid increase in prediabetes appeared to occur to the greatest extent among those with less than high school education at 11.8% (95% CI: 7.4-16.2) over the period, resulting in widening prediabetes differences by education groups in recent years.

Logistic regression evaluated relative disparities in prevalent diabetes and prediabetes accounting for several demographic and health differences across educational groups (Table 3). Model 1 suggests that lower education was significantly associated with a higher risk of having diabetes after adjusting for social and demographic factors in the pooled sample. Compared to those with a college education, individuals with a high school diploma (OR: 1.20, 95% CI: 1.07-1.34) and those with less than a high school (OR: 1.37, 95% CI: 1.23-1.52) were more likely to have diabetes. In addition, Model 1 shows a period effect of diabetes, such that the risk of having diabetes significantly increased over time compared to those adults surveyed in 2001-2004. Model 2 introduced interaction terms between educational attainment and survey periods and we found a significant interactive effect. This implies that the period effect between 2001-2004 and 2017-2020 observed in model 1 was greater among those with high school education than those with college education. The significant interactive effect remained even after controlling for BMI and BMI squared in Model 3.

Table 4 shows the results from logistic models examining prediabetes. The risks of having prediabetes among those with high school (OR: 1.20, 95% CI: 1.09-1.32) and less than high school education (OR: 1.20, 95% CI: 1.08-1.34) were significantly higher than among those with college education after adjustment for social and demographic factors (Model 1). In addition, compared to 2001-2004, the relative odds of having prediabetes were significantly higher in the later survey periods. However, there was no evidence that the period effect in prediabetes differed for any of the education groups in Model 2 and Model 3.

We further investigated the predicted probability of diabetes (A) and prediabetes (B) across survey periods using regression coefficients from Model 3 (Figure 1e). Overall, the prevalence of diabetes gradually increased among all educational groups during the study periods. In 2001-2004, which is the baseline year, both high school (10.5%) and college (10.9%) groups had a significantly lower probability of diabetes compared to less than high school group (14.8%) ($p<0.05$). Nevertheless, we observed a steeply increase in the probability among high school groups over time, resulting in a widening diabetes disparities between high school (16.3 %) vs. college groups (12.8%) and attenuation of difference between the less than high school (17.1%) vs. high school (16.3%) groups in the most recent period. As a result, the probabilities of having diabetes in those with less than high school and high school were significantly higher than those with college education in 2017-2020 ($p<0.05$).

For prediabetes, all educational groups experienced an increased risk of the disease from 2001-2004 to 2009-2012, and the patterns plateaued in more recent periods. In 2001-2004, there was no significant difference in the probability of having prediabetes between the three educational groups. However, we observed a significantly higher probability of prediabetes in less than high school and high school groups compared to those with a college education in 2009-2012 and 2013-2016, in conjunction with a rapid increase in the probability of prediabetes among lower education groups. These disparities disappeared in the most recent period. In the initial period, the predicted probability of prediabetes among less than high school, high school and college were 17.8%, 18.8% and 16.6%, while in 2017-2020, the corresponding probabilities were 29.0, 25.0 and 26.1%.

The sensitivity analysis of missing information showed that our estimates of diabetes remained the same even when we analyzed adults that were excluded from primary analytic sample because of missing BMI and income data (Table 1e). The second sensitivity analysis of diagnosed diabetes revealed that there were very similar patterns of educational disparities in prevalent diabetes, such that those with high school showed the highest increase in prevalent diagnosed diabetes over time followed by less than high school and some college when diabetes is defined based on self-reported diagnosis of diabetes (Table 2e).

Discussion

Our analyses of nationally representative data of US adults aged 30 to 69 showed that the age-standardized prevalence of diabetes and prediabetes substantially increased from 2001 to 2020. Individuals without a high school education, the lowest educational group, consistently had the highest prevalence of both diabetes and prediabetes over the study period. In the most recent 2017-2020 survey, adults with less than high school education and adults with high school education had significantly higher prevalence of diabetes compared with college-educated adults. The data show sustained educational disparities in diabetes and prediabetes over the last two decades. Furthermore, we demonstrated that US adults with high school diplomas showed a disproportionate increase in the risk of diabetes compared to the college education group as well as the lowest education group after adjustment for demographics, behavioral and biological factors.

The temporal increase in prevalent diabetes and prediabetes in the United States found in our study are consistent with previous findings [22,27,34–36]. Several factors have been suggested for the increasing trends in diabetes and prediabetes, including widespread screening tests [37,38], increasing obesity and overweight prevalence [36,39,40] and lifestyle changes (e.g., increasing sedentary behavior and poor dietary habits) [41–43]. In our data, we also observed that the average BMI and the prevalence of current smokers increased over the study periods, which may drive the increasing prevalence of the outcomes [44]. Although diabetes-related complications in the United States have been reduced due to substantial improvements in preventive care [20,45], the increase in the proportion of US adults living with diabetes and prediabetes could pose escalating burden of diabetes costs and public health concerns given that diabetes is a major cause of CVDs, hospitalization and excess death [6,21,46]. Therefore, more comprehensive and systematic diabetes research are needed to better understand the complex interplay of social, economic, cultural and behavioral factors contributing to the increasing diabetes trends and its complications [22,27].

Furthermore, we demonstrated that educational disparities in diabetes and prediabetes among US adults persisted, which were aligned with previous research [1,6,22,27,29]. To mitigate this gap, clinical and population-level interventions have been implemented, which suggested that tailored approaches to the unique needs and cultural context of minority populations in the US can potentially reduce the disproportionate burden of diabetes and prediabetes [47–50]. For example, research showed that culturally appropriate diabetes education and community-based programs have led to positive outcomes, including improved glycemic control and increased diabetes knowledge in underserved populations [47,49]. However, further investigation is needed to comprehensively understand the factors behind the sustained inequalities and the various social determinants of health that influence diabetes outcomes.

Interestingly, we observed that it was adults with high school education (+10.6% [6.3-14.9]) showed the greatest increase in diabetes compared to those with less than high school education (+5.6% [1.2-10.0]) and college education (+4.2% [2.3-6.0]) between 2001-2004 and 2017-2020. For example, in 2001-2004, there was a large gap in the prevalence of diabetes between less than high school (17.2% [15.3-19.3]) and high school groups (9.9% [8.7-11.3]), but this gap substantially reduced with less than high school (22.8% [18.9-27.2]) and high school groups (20.5% [16.5-25.1]). One potential explanation for the findings is that US adults with high school diplomas may have better access to tests for diabetes than the least educated adults. For instance, scientific literature on healthcare spending of beneficiaries in Medicaid showed that minority populations had lower utilization and adherence to healthcare services, including primary preventive care and screening for diabetes, than their counterparts, which suggested that health resources and benefits could be differentially delivered to receivers [51,52].

Over the past two decades, there has been more testing because of the screening guideline threshold decreasing, increased availability of the tests and improved awareness of the importance of diabetes screening [38,53,54]. The environmental changes in access to diabetes screening may have particularly helped those with high school to get tests and detect the disease versus those with less than high school. In addition, based on the results from the sensitivity analysis, the increase in the prevalence of diagnosed diabetes among people with high school is more prominent than among those with less than high school education, which implies that those with high school in our sample may have a greater chance of detecting their existing diabetes. These observations suggested that more than current efforts to eliminate diabetes inequity are needed, and that future implementation should carefully consider underlying disadvantaged determinants of health that may increase the risks of having diseases among less educated people [55]. Moreover, multifaceted strategies that take into account the unique needs of individuals across the socioeconomic spectrum are warranted.

There are limitations of the study. First, while education is one of the most important measure of individual’s SES in health research [5,7–9], one’s occupation and wealth (e.g., home ownership) might better reflect social and environmental factors that influence the diabetes risk factors, such as health insurance, healthcare accessibility, availability of healthy food and walkability of neighborhoods [56–59]. Despite this, education is more comparable across time than income or occupation, and there were fewer missing data in NHANES than income. Additionally, this public data source lacks detailed information on employment and wealth. Second, misclassification of diabetes and prediabetes was possible because of reliance on single-occasion laboratory measurement and the use of self-reported diagnosis. In addition, we did not account for levels of severity of diabetes. It is possible that the least educated group have suffered from more severe diabetes and complications than the more educated group in recent years, which would not be captured by the data presented here.

Conclusion

Our study showed that less educated people have a higher prevalence of having diabetes and prediabetes than more educated people after adjustment for social and demographic factors. Despite outreach and awareness campaigns about healthy diet and weight and physical activity and public policy efforts to achieve health equity, educational disparities in diseases and prediabetes have not narrowed in the past decades. As a result of these patterns, the US society may face an escalating economic burden through required long-term management, high prevalence of complications, lost productivity, premature mortality, and intangible costs in the form of reduced quality of life [60]. Therefore, multifaceted intervention strategies focusing on the determinants attributed to an individual's educational attainment are urgently warranted.

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Tables and Figures

Table 1. Descriptive information of US adults aged 30-79 by survey periods, NHANES, 2001-2020.

	2001-2004 (n=6,176)	2005-2008 (n=6,841)	2009-2012 (n=7,401)	2013-2016 (n=7,391)	2017-2020 (n=5,411)
Age (in years), mean	52.1	52.3	52.0	52.1	53.5
Race/Ethnicity, %					
Non-Hispanic White	75.2	73.1	70.7	67.3	64.9
Non-Hispanic Black	10.0	10.4	10.4	10.5	10.2
Hispanic	10.3	10.7	12.3	13.7	15.0
Others	4.5	5.8	6.6	8.5	9.9
Education, %					
Less than high school	17.7	17.6	17.0	14.1	10.5
High school	25.6	24.8	21.2	20.6	24.2
Some college or higher	56.7	57.6	61.8	65.3	65.3
Income to poverty ratio[§], %					
High	41.3	41.8	39.9	39.6	43.6
Middle	30.7	29.8	27.9	28.0	27.5
Near poor	17.9	18.0	19.5	19.0	17.3
Poor	10.1	10.4	12.7	13.4	11.6
Smoking Status, %					
Current	47.5	50.5	53.5	54.4	55.6
Former	23.2	22.2	19.8	19.2	17.2
Never	29.3	27.3	26.7	26.4	27.2
BMI (kg/m^2), mean	28.8	29.4	29.6	29.9	30.5
BMI category (kg/m^2), %					
Less than 24.9	30.2	28.5	26.9	24.9	22.2
25 to 29.9	36.3	34.7	34.8	33.2	33.3
30 to 34.9	20.3	20.9	21.4	23.0	23.1
More than 35	13.2	15.9	16.9	18.9	21.4
HbA1c (%), mean	5.7	5.7	5.9	5.9	6.0

Abbreviations: NHANES, National Health and Nutrition Examination Survey, BMI, body mass index, HbA1c, glycated hemoglobin. [§]Based on the federal poverty level (FPL). Poor: <100% FPL, near poor: 100-199% FPL, middle income: 200-399% FPL, high income: ≥400% FPL. All estimates are weighted and account for complex survey design.

Table 2. Age-standardized prevalence of diabetes and prediabetes among US adults aged 30-79 by educational attainment and survey periods, NHANES, 2001-2020.

	2001-2004 (n=6,176)	2005-2008 (n=6,841)	2009-2012 (n=7,401)	2013-2016 (n=7,391)	2017-2020 (n=5,411)	Δ 2017-2020 to 2001-2004
Diabetes prevalence†, %						
Overall	10.8 (9.8-11.8)	12.2 (10.9-13.6)	13.0 (11.9-14.3)	14.7 (13.5-16.1)	16.2 (14.8-17.6)	5.4 (3.7-7.0)
Educational attainment						
Less than high school	17.2 (15.3-19.3)	18.3 (16.4-20.3)	19.8 (17.4-22.5)	20.4 (18.7-22.3)	22.8 (18.9-27.2)	5.6 (1.2-10.0)
High school	9.9 (8.7-11.3)	13.1 (10.6-16.1)	13.4 (11.0-16.2)	15.8 (14.0-17.8)	20.5 (16.5-25.1)	10.6 (6.3-14.9)
Some college or higher	9.2 (7.8-10.7)	9.8 (8.5-11.1)	11.2 (9.9-12.6)	13.1 (11.6-14.8)	13.3 (12.1-14.7)	4.2 (2.3-6.0)
Prediabetes prevalence‡, %						
Overall	14.0 (12.9-15.2)	19.1 (17.8-20.5)	25.0 (23.8-26.3)	21.7 (20.4-23.0)	23.3 (21.8-24.8)	9.2 (7.4-11.1)
Education level						
Less than high school	16.6 (14.0-19.6)	23.5 (21.2-26.1)	31.5 (29.0-34.1)	28.1 (24.7-31.8)	28.4 (25.0-32.1)	11.8 (7.4-16.2)
High school	15.2 (13.4-17.1)	21.7 (19.2-24.4)	29.3 (25.2-33.8)	25.0 (22.6-27.5)	23.6 (20.9-26.6)	8.4 (5.2-11.7)
Some college or higher	12.7 (11.0-14.5)	17.1 (15.8-18.6)	21.9 (20.0-23.9)	19.3 (17.9-20.7)	22.3 (20.4-24.4)	9.7 (7.2-12.2)

Abbreviations: NHANES, National Health and Nutrition Examination Survey. 95% confidence intervals are in parentheses. All estimates are weighted and account for complex survey design.

† Diabetes was defined based on 1) HbA1c level of 6.5% or higher, 2) the use of diabetes medication, and 3) self-reported diagnosis of diabetes.

‡ Prediabetes was defined using HbA1c threshold between 5.7-6.4%

Table 3. Adjusted associations between educational attainment and diabetes and changes in the associations across survey periods, NHANES, 2001-2020.

	Model 1		Model 2		Model 3	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Educational attainment						
Some college or higher	1.00		1.00		1.00	
High school	1.20**	1.07-1.34	0.99	0.79-1.23	0.96	0.76-1.20
Less than high school	1.37***	1.23-1.52	1.45**	1.14-1.85	1.51***	1.21-1.87
Survey periods						
2001-2004	1.00		1.00		1.00	
2005-2008	1.18*	1.00-1.40	1.11	0.88-1.39	1.04	0.83-1.31
2009-2012	1.28**	1.10-1.48	1.25*	1.00-1.55	1.14	0.92-1.42
2013-2016	1.49***	1.30-1.71	1.51***	1.21-1.88	1.31*	1.04-1.64
2017-2020	1.65***	1.41-1.92	1.49***	1.21-1.82	1.23	1.00-1.53
Interaction terms						
Less than high school × 2005-2008			0.99	0.75-1.32	0.99	0.75-1.31
Less than high school ×2009-2012			0.97	0.73-1.30	0.93	0.71-1.22
Less than high school × 2013-2016			0.82	0.60-1.11	0.85	0.63-1.14
Less than high school × 2017-2020			0.96	0.67-1.38	0.99	0.71-1.41
High school × 2005-2008			1.30	0.95-1.78	1.27	0.91-1.77
High school × 2009-2012			1.12	0.79-1.58	1.10	0.77-1.56
High school × 2013-2016			1.12	0.85-1.47	1.07	0.79-1.45
High school × 2017-2020			1.50*	1.05-2.15	1.48*	1.01-2.17

Abbreviations: BMI, body mass index; NHANES, National Health and Nutrition Examination Survey
[§]Based on the federal poverty level (FPL). Poor: <100% FPL, near poor: 100-199% FPL, middle income: 200-399% FPL, high income: ≥400% FPL.
[†]Based on self-reported on the presence or absence of places regularly visited for health care.
Model 1 includes age, sex, race/ethnicity, income to poverty ratio, healthcare accessibility and smoking status.
Model 2: Model 1 + education categories × survey period.
Model 3: Model 2 + BMI and BMI squared.
All estimates are weighted and account for complex survey design.
***p < 0.001; ** < 0.01; *p < 0.05

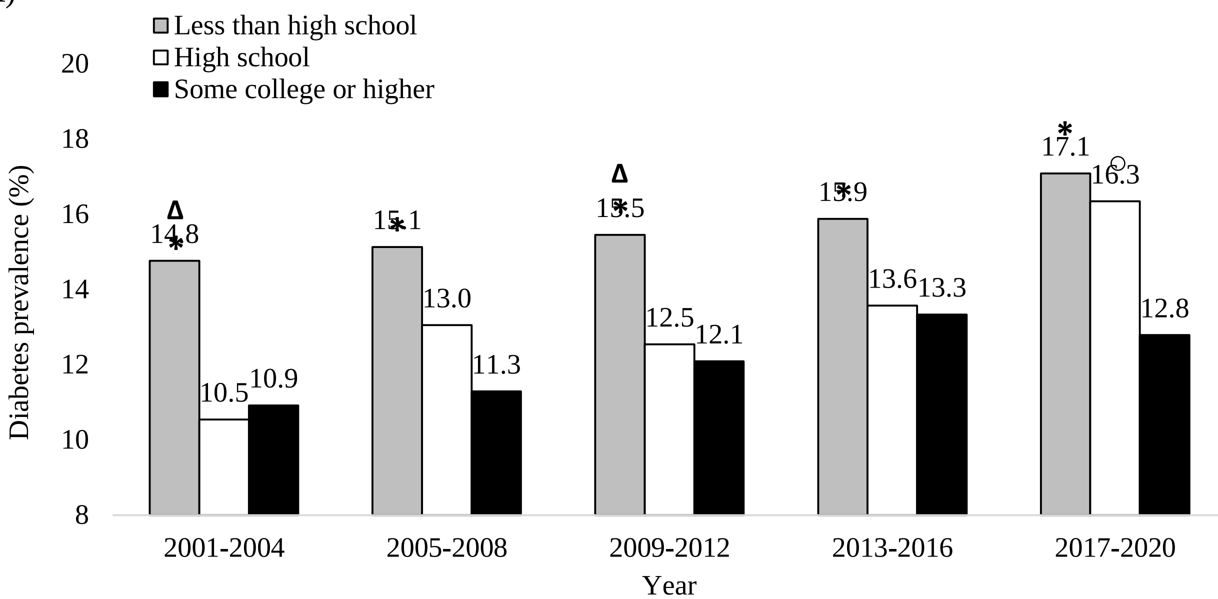
Table 4. Adjusted associations between educational attainment and prediabetes and changes in the associations across survey periods, NHANES, 2001-2020.

	Model 1		Model 2		Model 3	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Educational attainment						
Some college or higher	1.00		1.00		1.00	
High school	1.20***	1.09-1.32	1.20	0.94-1.52	1.18	0.93-1.49
Less than high school	1.20**	1.08-1.34	1.09	0.85-1.41	1.10	0.85-1.42
Survey periods						
2001-2004	1.00		1.00		1.00	
2005-2008	1.49***	1.32-1.69	1.46***	1.22-1.74	1.44***	1.20-1.72
2009-2012	2.18***	1.94-2.45	2.05***	1.69-2.48	2.01***	1.66-2.44
2013-2016	1.78***	1.59-1.99	1.70***	1.43-2.02	1.62***	1.37-1.93
2017-2020	1.91***	1.68-2.17	1.99***	1.64-2.42	1.87***	1.54-2.29
Interaction terms						
Less than high school × 2005-2008			1.05	0.77-1.44	1.05	0.76-1.44
Less than high school ×2009-2012			1.17	0.84-1.64	1.15	0.82-1.61
Less than high school × 2013-2016			1.20	0.88-1.63	1.22	0.89-1.66
Less than high school × 2017-2020			1.06	0.75-1.48	1.07	0.76-1.51
High school × 2005-2008			1.04	0.79-1.38	1.04	0.78-1.37
High school × 2009-2012			1.14	0.79-1.62	1.12	0.78-1.60
High school × 2013-2016			1.04	0.79-1.36	1.03	0.78-1.34
High school × 2017-2020			0.81	0.59-1.10	0.80	0.59-1.09

Abbreviations: BMI, body mass index; NHANES, National Health and Nutrition Examination Survey
§Based on the federal poverty level (FPL). Poor: <100% FPL, near poor: 100-199% FPL, middle income: 200-399% FPL, high income: ≥400% FPL.
†Based on self-reported on the presence or absence of places regularly visited for health care.
Model 1 includes age, sex, race/ethnicity, income to poverty ratio, healthcare accessibility and smoking status.
Model 2: Model 1 + education categories × survey period.
Model 3: Model 2 + BMI and BMI squared.
All estimates are weighted and account for complex survey design.
***p < 0.001; ** < 0.01; *p < 0.05

Supplemental Figures and Tables

(A)



(B)

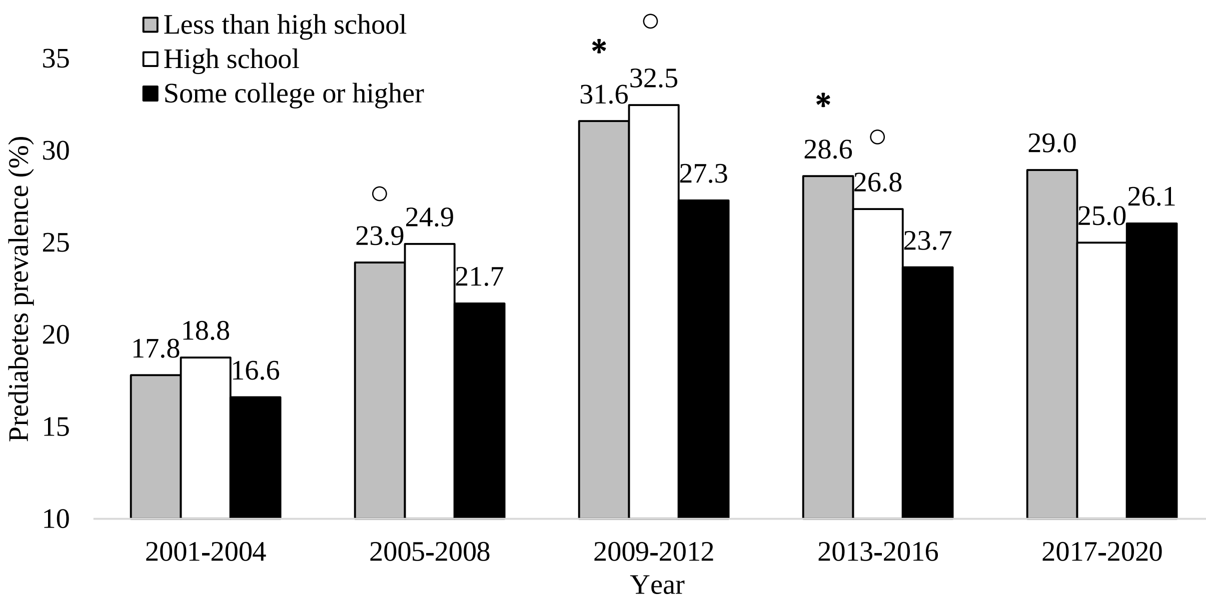


Figure 1e. Predicted prevalence of diabetes (A) and prediabetes (B) by education across survey years.

All estimates were from Model 3 in Table 3 and Table 4.

* $P < 0.05$, difference between less than high school and college within the survey period.

Δ $P < 0.05$, difference between less than high school and high school within the survey period.

○ $P < 0.05$, difference between high school and college within the survey period.

Table 1e. Sensitivity analysis for missing information on BMI and income. Age-standardized prevalence of diabetes and prediabetes, NHANES, 2001-2020 (n=36,900).

	2001-2004 (n=6,753)	2005-2008 (n=7,416)	2009-2012 (n=8,218)	2013-2016 (n=8,182)	2017-2020 (n=6,331)
Diabetes prevalence, %					
Overall	11.2 (10.2-12.3)	12.4 (11.1-13.8)	13.1 (12.0-14.3)	14.9 (13.6-16.2)	16.2 (14.8-17.6)
Educational attainment					
Less than high school	17.2 (15.4-19.3)	18.5 (16.7-20.5)	19.7 (17.6-21.9)	20.4 (18.8-22.1)	22.5 (19.4-26.0)
High school	10.0 (8.8-11.4)	13.2 (10.7-16.2)	13.6 (11.3-16.2)	15.9 (14.2-17.8)	19.8 (15.8-24.5)
Some college or higher	9.7 (8.3-11.4)	9.8 (8.7-11.2)	11.2 (9.9-12.6)	13.2 (11.7-14.9)	13.6 (12.3-14.9)
Prediabetes prevalence, %					
Overall	14.0 (12.9-15.2)	19.4 (18.1-20.8)	25.4 (24.1-26.6)	22.0 (20.8-23.3)	23.7 (22.2-25.2)
Education level					
Less than high school	16.5 (14.0-19.5)	23.5 (21.2-26.1)	31.5 (29.1-34.0)	28.4 (25.4-31.6)	28.7 (25.9-31.7)
High school	15.1 (13.4-16.9)	22.4 (19.9-25.0)	29.4 (25.3-33.7)	25.3 (23.1-27.7)	24.9 (22.6-27.5)
Some college or higher	12.7 (11.1-14.4)	17.3 (15.9-18.7)	22.3 (20.4-24.3)	19.5 (18.2-20.8)	22.4 (20.3-24.6)

Abbreviations: NHANES, National Health and Nutrition Examination Survey. 95% confidence intervals are in parentheses. All estimates are weighted and account for complex survey design.

For a sensitivity analysis, people with missing values of BMI and income data were included in the analysis presented in Table 2 (n=33,220)

Table 2e. Age-standardized prevalence of total diabetes and diagnosed diabetes among US adults aged 30-79 by educational attainment and survey periods, NHANES, 2001-2020 (n=33,220).

	2001-2004 (n=6,176)	2005-2008 (n=6,841)	2009-2012 (n=7,401)	2013-2016 (n=7,391)	2017-2020 (n=5,411)	Δ 2017-2020 to 2001-2004
Total diabetes, %						
Overall	10.8 (9.8-11.8)	12.2 (10.9-13.6)	13.0 (11.9-14.3)	14.7 (13.5-16.1)	16.2 (14.8-17.6)	5.4 (3.7-7.0)
Educational attainment						
Less than high school	17.2 (15.3-19.3)	18.3 (16.4-20.3)	19.8 (17.4-22.5)	20.4 (18.7-22.3)	22.8 (18.9-27.2)	5.6 (1.2-10.0)
High school	9.9 (8.7-11.3)	13.1 (10.6-16.1)	13.4 (11.0-16.2)	15.8 (14.0-17.8)	20.5 (16.5-25.1)	10.6 (6.3-14.9)
Some college or higher	9.2 (7.8-10.7)	9.8 (8.5-11.1)	11.2 (9.9-12.6)	13.1 (11.6-14.8)	13.3 (12.1-14.7)	4.2 (2.3-6.0)
Diagnosed diabetes, %						
Overall	8.7 (7.8-9.6)	9.4 (8.2-10.7)	10.1 (9.2-11.0)	11.9 (10.8-13.1)	12.8 (11.6-14.1)	4.1 (2.6-5.6)
Educational attainment						
Less than high school	13.5 (12.0-15.2)	14.9 (13.4-16.6)	15.0 (12.9-17.4)	16.7 (15.3-18.3)	17.4 (13.9-21.5)	3.9 (-0.1-7.9)
High school	8.4 (7.3-9.5)	9.5 (7.4-12.1)	10.6 (8.5-13.1)	12.6 (10.8-14.7)	16.0 (12.4-20.3)	7.6 (3.7-11.5)
Some college or higher	7.3 (6.2-8.7)	7.5 (6.4-8.7)	8.6 (7.5-9.8)	10.5 (9.3-11.9)	10.6 (9.5-11.9)	3.3 (1.6-4.9)

Abbreviations: NHANES, National Health and Nutrition Examination Survey. 95% confidence intervals are in parentheses. All estimates are weighted and account for complex survey design.
Total diabetes was defined as those with HbA1c level of 6.5% or higher and who reported the use of diabetes medication and diagnosis of diabetes. Diagnosed diabetes was defined as those who reported diagnosed of diabetes.

Chapter 4: Conclusion and Public Health Recommendations

Our analyses of nationally representative data collected from 2001 to 2020 showed that the age-standardized prevalence of diabetes and prediabetes substantially increased among US adults. Individuals without a high school education, the lowest educational group, consistently had the highest prevalence of both diabetes and prediabetes over the study period. In the most recent 2017-2020 survey, adults with less than high school education and adults with high school education had significantly higher prevalence of diabetes compared with college-educated adults. The data showed sustained educational disparities in diabetes and prediabetes over the last two decades. Furthermore, we demonstrated that US adults with high school diplomas showed a disproportionate increase in the risk of diabetes compared to the college education group as well as the lowest education group after adjustment for demographics, behavioral and biological factors.

Despite outreach and awareness campaigns about healthy diet and weight and physical activity and public policy efforts to achieve health equity, educational disparities in diabetes and prediabetes have not narrowed in the past decades. As a result of these patterns, the US society may face an escalating economic burden through required long-term management, a high prevalence of complications, lost productivity, premature mortality, and intangible costs in the form of reduced quality of life [50]. Therefore, more than current efforts to eliminate diabetes inequity are urgently needed.

The findings of this study suggest public health recommendations to improve disparities in diabetes and prediabetes. First, future implementations should carefully consider underlying determinants of health that may increase the risks of diabetes and prediabetes among less educated people. To do this, evaluating the unique needs and barriers of individuals across the socioeconomic spectrum is required, and this can be achieved through collaborative efforts between various sectors, including public health organizations, healthcare providers, and researchers. The insights gathered can then be utilized to develop targeted interventions toward socially disadvantaged people. Second, more research is needed to comprehend the underlying mechanisms that connect an individual's socioeconomic status to dysglycemia. It is imperative to explore the relationship between a range of socioeconomic indicators, including but not limited to poverty, food insecurity and geographic location, and the outcomes. Identifying and accounting for any unmeasured factors that may influence these associations is also essential. Lastly, it is necessary to continuously assess and monitor the prevalence trends of diabetes and prediabetes by SES to determine the effectiveness of these inputs and guide future directions to improve health inequity.

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