American Journal of
Preventive Medicine

RESEARCH ARTICLE

Trends in the Prevalence of Diabetes Among U.S. Adults: 1999–2016

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Introduction: The prevalence of diabetes has increased substantially over the past three decades. This study sought to estimate recent trends in the prevalence of diabetes among U.S. adults.

Methods: This paper estimated trends in the prevalence of diagnosed, undiagnosed, and total diabetes among U.S. adults from 1999–2000 to 2015–2016 (analyzed in 2017). Data come from 42,554 respondents aged ≥20 years who participated in the National Health and Nutrition Examination Survey. Diagnosed diabetes was measured through self-report, undiagnosed diabetes was measured as never being diagnosed with diabetes but having glycated hemoglobin levels ≥6.5%, and total diabetes was measured as the sum of individuals with diagnosed and undiagnosed diabetes.

Results: In the overall U.S. adult population, the unadjusted prevalence of total diabetes increased from 7.7% in 1999–2000 to 13.3% in 2015–2016 ($p<0.001$ for trend). Growth was observed for all subgroups, though the rate of change was higher in older adults, racial minorities, and those who were obese compared with their peers. Increasing prevalence among Mexican-American adults was particularly pronounced, rising by 10.1 percentage points during the study period (8.3% to 18.4%, $p < 0.001$). Roughly 40% of the increase in total diabetes was accounted for by changes in the age and rates of obesity in the U.S. population.

Conclusions: From 1999 to 2016, the prevalence of diabetes among U.S. adults increased at a substantial rate. This growth occurred differentially across subgroups, particularly impacting Mexican-American adults, and was driven in large part by population aging and increasing obesity rates.

Am J Prev Med 2018;000(000):1–9.

INTRODUCTION

Diabetes is a group of metabolic disorders that stems from problems in insulin production or action and leads to hyperglycemia.[1] Diabetes is associated with numerous negative health consequences, including heart disease, kidney failure, blindness, and premature death.[2–7] The condition also carries a substantial economic burden, costing the U.S. an estimated $322 billion in lost productivity and medical costs in 2012.[8]

Within the U.S., the prevalence of diabetes has increased substantially over the past three decades among adults.[3,9–13] Between 1988 and 2012, rates of total diabetes (diagnosed and undiagnosed) increased from 8.6 to 12.3 cases per 100 U.S. adults.[9] The growth of diabetes has occurred unevenly across sociodemographic groups, increasing at a more pronounced rate among disadvantaged populations, such as racial/ethnic minorities and less educated individuals.[9,10,14] At the same time, two recent analyses found that the prevalence of total and diagnosed diabetes among adults may have stabilized between 2008 and 2012.[9,10] Several studies also showed that the share of all diabetes cases that are undiagnosed has declined substantially since the 1980s.[13–15] Taken together, existing trend analyses indicate that although important strides have been made, diabetes still remains an urgent public health concern, especially for disadvantaged populations.

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0749-3797/$36.00
https://doi.org/10.1016/j.amepre.2018.05.018

The primary aim of this study is to update national trends in diabetes among U.S. adults. Data were from the National Health and Nutrition Examination Survey (NHANES), collected from 1999–2000 to 2015–2016. The NHANES is the only national study that collects diabetes information through self-report and through blood samples, making it the only source available for estimating national trends in total diabetes. The analyses considered trends in undiagnosed, diagnosed, and total diabetes in the total population and across different sociodemographic groups.

METHODS

Study Sample

Details about the NHANES are available elsewhere.[16–18] In brief, the study consists of a series of nationally representative, cross-sectional surveys designed to monitor the health of individuals in the U.S. Beginning in 1999, the NHANES began collecting data in continuous, 2-year cycles. During each survey cycle, a nationally representative sample of respondents are selected from the U.S. non-institutionalized, civilian population using a complex, stratified, multistage probability cluster sampling design. After obtaining written informed consent from the participants, data are collected through in-home interviews and visits to a mobile examination center, where health examinations are administered by trained medical staff members. All data collection received approval from the National Center for Health Statistics research ethics review board.

For this study, all waves of data from the continuous NHANES were used to estimate trends in the prevalence of diabetes (1999–2000 to 2015–2016). Across these nine waves, response rates ranged from 61% to 84% for in-home interviews and 59% to 80% for the mobile center visits. Of the 92,062 respondents in these data, the author excluded respondents who were aged <20 years (n=42,550), women who were pregnant (n=1,486), and those with missing data for their diabetes status (n=4,654), weight or height (n=767), or sociodemographic characteristics (n=51). These restrictions yielded a final sample of 42,554 respondents.

Measures

During visits to the mobile examination center, trained phlebotomists drew samples of blood from respondents following a standardized protocol. These samples were subsequently analyzed to determine respondents' glycated hemoglobin (HbA1c) levels using high-performance liquid chromatography methods. The laboratory and tools used to measure HbA1c levels varied across survey years.[19] HbA1c testing was performed at University of Minnesota from 2007–2008 to 2011–2012 and at the University of Missouri from 2013–2014 to 2015–2016 using the Tosoh A1C 2.2 Plus Glycohemoglobin Analyzer (2007–2008), Tosoh G7 Glycohemoglobin Analyzer (2009–2010 and 2011–12), or Tosoh G8 Glycohemoglobin Analyzer (2011–2012 to 2015–2016).[20] A recent study suggests that these changes in laboratory methodology may have increased HbA1c levels,[14] and NHANES analytic guidelines advise researchers to compare HbA1c levels across survey years with caution.[19] As a sensitivity test, all prevalence rates were re-estimated using calibrated HbA1c values that account for these laboratory changes (Appendix Table 1, available online).

Three measures of diabetes were used for this study. The first was diagnosed diabetes. During the in-home interviews, respondents were asked if they had ever been told by a doctor or health professional that they had diabetes. Those who answered *yes* were coded as having diagnosed diabetes. The second was undiagnosed diabetes. Consistent with several prior studies,[14,21] respondents with HbA1c levels ≥6.5%[1] and who answered *no* to being diagnosed with diabetes by a health professional were coded as having undiagnosed diabetes. The third was total diabetes, measured as the total number of respondents who had either diagnosed or undiagnosed diabetes. The remaining participants (i.e., those who were never diagnosed with diabetes and who had HbA1c levels <6.5%) were coded as individuals without diabetes. Respondents with missing information for either diagnosed diabetes status or HbA1c were excluded from the analysis.

Height and weight were measured using standardized techniques and equipment during mobile examination visits. These measures were used to calculate respondents' BMI (calculated by dividing weight in kilograms by the square of height in meters). Those with BMI <25 were categorized as normal, those with BMI ≥25 but <30 were categorized as overweight, and those with BMI ≥30 were categorized as obese.

A standardized questionnaire was administered during the in-home visits to collect sociodemographic information from respondents, including sex (male, female), race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican American), age (20–44, 45–64, ≥65 years), and education (less than high school, high school graduate, some college, and college graduate). All sociodemographic measures were self-reported.

Statistical Analysis

This paper began by estimating the prevalence of diabetes across all nine waves of the continuous NHANES, from 1999–2000 to 2015–2016. Estimates were for the overall adult population and stratified by sex, age, race/ethnicity, educational level, and BMI category. Race-specific prevalence was only estimated for Mexican Americans, non-Hispanic blacks, and non-Hispanic whites due to small sample size for other racial/ethnic groups during the study period.

To test for time trends between 1999–2000 and 2015–2016, logistic regression models were estimated. In these models, diabetes status was regressed onto survey year, which was entered as a continuous variable. A statistically significant coefficient for the survey year variable was interpreted as a change in the prevalence of diabetes. Quadratic and cubic time trends were tested and found to be nonsignificant for the overall population and for different subgroups, therefore, linear terms were used to assess temporal trends.

The author then proceeded to investigate the factors that might explain changes in diabetes trends. To do this, a series of logistic regression models were estimated examining the relationship between survey cycle, entered as a continuous linear variable, and total diabetes. An unadjusted model was used and then potential mediators were added, including age, BMI category, sex, race/ethnicity, and education, in a stepwise fashion. The coefficient for the survey cycle in the adjusted models was compared with the coefficient in the