Diabetic retinopathy is well established.9,10 Detection and treatment of diabetic retinopathy is important because it is a key indicator of systemic diabetic microvascular complications, and as such, a sentinel indicator of the impact of diabetes. Despite the documented increase in the prevalence of diabetic retinopathy in the US population,11 national population-based data on the prevalence and severity of diabetic retinopathy remain scarce, with previous nationwide prevalence estimates dating back to 1988-1994 (National Health and Nutrition Examination Surveys III [NHANES III]).12 In 2004, the Eye Diseases Prevalence Research Group estimated the prevalence of diabetic retinopathy from the compilation of 8 separate national surveys, including the National Health and Nutrition Examination Surveys (NHANES) III.13

**Context** The prevalence of diabetes in the United States has increased. People with diabetes are at risk for diabetic retinopathy. No recent national population-based estimate of the prevalence and severity of diabetic retinopathy exists.

**Objectives** To describe the prevalence and risk factors of diabetic retinopathy among US adults with diabetes aged 40 years and older.

**Design, Setting, and Participants** Analysis of a cross-sectional, nationally representative sample of the National Health and Nutrition Examination Survey 2005-2008 (N=1006). Diabetes was defined as a self-report of a previous diagnosis of the disease (excluding gestational diabetes mellitus) or glycated hemoglobin A1c of 6.5% or greater. Two fundus photographs were taken of each eye with a digital nonmydriatic camera and were graded using the Airlie House classification scheme and the Early Treatment Diabetic Retinopathy Study severity scale. Prevalence estimates were weighted to represent the civilian, noninstitutionalized US population aged 40 years and older.

**Main Outcome Measurements** Diabetic retinopathy and vision-threatening diabetic retinopathy.

**Results** The estimated prevalence of diabetic retinopathy and vision-threatening diabetic retinopathy was 28.5% (95% confidence interval [CI], 24.9%-32.5%) and 4.4% (95% CI, 3.5%-5.7%) among US adults with diabetes, respectively. Diabetic retinopathy was slightly more prevalent among men than women with diabetes (31.6%; 95% CI, 26.8%-36.8%; vs 25.7%; 95% CI, 21.7%-30.1%; P=.04). Non-Hispanic black individuals had a higher crude prevalence than non-Hispanic white individuals of diabetic retinopathy (38.8%; 95% CI, 31.9%-46.1%; vs 26.4%; 95% CI, 21.4%-32.2%; P=.01) and vision-threatening diabetic retinopathy (9.3%; 95% CI, 5.9%-14.4%; vs 3.2%; 95% CI, 2.0%-5.1%; P=.01). Male sex was independently associated with the presence of diabetic retinopathy (odds ratio [OR], 2.07; 95% CI, 1.39-3.10), as well as higher hemoglobin A1c level (OR, 1.45; 95% CI, 1.20-1.75), longer duration of diabetes (OR, 1.06 per year duration; 95% CI, 1.03-1.10), insulin use (OR, 3.23; 95% CI, 1.99-5.26), and higher systolic blood pressure (OR, 1.03 per mm Hg; 95% CI, 1.02-1.03).

**Conclusion** In a nationally representative sample of US adults with diabetes aged 40 years and older, the prevalence of diabetic retinopathy and vision-threatening diabetic retinopathy was high, especially among non-Hispanic black individuals.
rate population-based studies from the United States and elsewhere conducted in the late 1980s or early 1990s. Their report recommended that more recent estimates of diabetic retinopathy prevalence be obtained from the nationally representative sample of NHANES.

Moreover, several other population-based studies reported a decrease in the prevalence and incidence of severe diabetic retinopathy and related visual impairment. However, these findings were limited to regional cohorts and the status of diabetic retinopathy at the national level remains unknown. Thus, the principal aim of this study is to describe the most recent prevalence and risk factors of diabetic retinopathy in the US population aged 40 years and older using NHANES 2005-2008.

**METHODS**

**Study Population**

NHANES are national representative surveys conducted by the National Center for Health Statistics, part of the Centers for Disease Control and Prevention. The data consist of samples of the US noninstitutionalized civilian population, which were obtained using a stratified multistage probability design with planned oversampling of certain age and racial/ethnic groups. There were 6797 individuals aged 40 years and older interviewed for socio-demographic, medical, and family information and had a full medical examination at the medical examination center in NHANES 2005-2008. The NHANES 2005-2008 response rate for the interview sample aged 40 years and older was 71% and 69% for the examined sample. The NHANES protocol was approved by a human subjects review board and written informed consent was obtained from all participants.

**Fundus Photography**

NHANES 2005-2008 used the Canon CR6-45NM ophthalmic digital imaging system and Canon EOS 10D digital camera (Canon, Tokyo, Japan) to take 2 digital images per eye (total 4 images per participant) through a non-pharmacologically dilated pupil. Participants were seated in a windowless room with the lights turned off to allow the pupils to dilate naturally in preparation for the retinal imaging examination. One image was centered on the macula and the second on the optic nerve. The digital images were graded by masked photo graders at the University of Wisconsin Ocular Epidemiologic Reading Center, Madison, using a modification of the Airlie House classification system. Capture and grading of digital images and quality control by the Wisconsin group have been described in detail previously.

Survey participants who had no light perception or severe visual impairment in both eyes or had a severe infection in one or both eyes were excluded (n=13). Complete data of fundus photographs of both eyes were obtained for 5371 (79%) participants aged 40 years and older who had full medical examinations.

Reasons for having incomplete data (n=1426, 21%) included insufficient time to finish the examination (ie, arrived late or left early; n=514; 42%), physical limitation (n=238; 19%), eyespecific limitation (n=193; 16%), participant’s refusal (n=119; 10%), communication problems (n=40; 3%), and others. Those individuals with incomplete data were more likely to be older, non-Hispanic black, with less than a high school education, higher systolic blood pressure, higher glycated hemoglobin A1c level, and a history of using insulin than participants with complete gradable photographs (all P<.001). We further examined the potential influence of nonresponse bias due to the exclusion of participants without complete gradable photographs by adjusting the original sampling weights using the standard weighting–class method. Findings using these adjusted weights led to only minor differences in point and variance estimates (0%-0.5%), indicating minimal impact of nonresponse; therefore, we present all estimates using the original sampling weights.

Diabetic retinopathy was defined as the presence of 1 or more retinal microaneurysms or retinal blot hemorrhages with or without more severe lesions (hard exudates, soft exudates, intraretinal microvascular abnormalities, venous beading, retinal new vessels, preretinal and vitreous hemorrhage, and fibroproliferans) using the Early Treatment Diabetic Retinopathy Study (ETDRS) grading standards. Diabetic retinopathy was further categorized as nonproliferative and proliferative determined by assessment of the presence of retinal neovascularization or abnormal growth of new retinal blood vessels into the vitreous. Vision-threatening diabetic retinopathy, a level that may soon result in vision loss if left untreated, was defined as the presence of severe nonproliferative diabetic retinopathy, proliferative diabetic retinopathy, or clinically significant macular edema. Clinically significant macular edema was considered present when edema involved the fovea or was within 500 microns of the fovea, or when a 1 disc area of edema was present with at least a portion of it within the macula. Outcomes for this study were defined on the basis of the worse of the 2 eyes.

**Other Measurements**

Diabetes was defined as self-report of a previous diagnosis of the disease by a clinician (excluding gestational diabetes mellitus) or hemoglobin A1c of 6.5% or greater (American Diabetes Association’s new diagnostic criterion for undiagnosed diabetes). Although hemoglobin A1c does not capture completely the increased risk of microvascular complications due to diabetes, the diagnostic hemoglobin A1c cut point of 6.5% was determined to be an inflection point for retinopathy prevalence, as is also true for the diagnostic thresholds of the glucose-based test. The final analytic sample consisted of 1006 individuals with diabetes aged 40 years and older (n=795 for diagnosed diabetes; n=211 for undiagnosed diabetes).
All participants were asked about their age, sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, and others [including those who selected multiple races and non-Mexican American Hispanics]), educational attainment (less than high school, high school education, or higher), and health insurance status. Consistent with previous epidemiologic studies,22,23 risk factors for diabetic retinopathy and vision-threatening diabetic retinopathy (hemoglobin A1c, duration of diabetes, insulin use [yes/no], systolic and diastolic blood pressure, body mass index [BMI, calculated as weight in kilograms divided by height in meters squared], current smoking status [yes/no], and history of cardiovascular diseases [CVD; yes/no]) were examined. Hemoglobin A1c, duration of diabetes, and systolic and diastolic blood pressure were used as continuous variables. Hemoglobin A1c was used as the surrogate for blood glucose level and measured by a high-performance liquid chromatographic assay as used in the Diabetes Control and Complications Trial.7 Insulin therapy indicated that the participant had type 1 diabetes or their diabetes could not otherwise be controlled without insulin. We used measured height and weight to calculate BMI and divided respondents into 3 groups: normal/underweight (BMI <25), overweight (BMI 25-<30), and obese (BMI ≥30). Prior history of CVD was ascertained by self-report of coronary heart disease, angina, myocardial infarction, stroke, or congestive heart failure.

**Statistical Methods**

Statistical analyses were conducted using SAS version 9.2 (SAS Institute, Cary, North Carolina) and SUDAAN version 10.1 software (Research Triangle Institute, Research Triangle Park, North Carolina) to calculate national estimates and their standard errors while accounting for the complex survey design of the survey. Taylor series linearization was used for variance estimation.31 The NHANES 2005-2008 study has sufficient sample size to detect a relative difference of 6% (effective sample size = sample size/design effect = 1006/1.7 = 591) at 85% power and an α level of .05.

Characteristics of the study population are described using means for continuous variables and percentages for categorical variables. For continuous variables, t tests were used and for categorical variables the χ2 test. We estimated the crude prevalence of diabetic retinopathy and vision-threatening diabetic retinopathy by age, sex, and race/ethnicity in the diabetic and overall US population. Multiple logistic regressions were used to assess the association between diabetic retinopathy and vision-threatening diabetic retinopathy, vs clinical potential risk factors for diabetic retinopathy and vision-threatening diabetic retinopathy after controlling for age, sex, race/ethnicity, and education attainment.

**RESULTS**

In 2005-2008, the estimated (weighted) crude prevalence of diabetic retinopathy and vision-threatening diabetic retinopathy was 28.5% (95% CI, 24.9%-32.5%) and 4.4% (95% CI, 3.5%-5.7%), respectively, among persons with diabetes aged 40 years and older (TABLE 1). Extrapolating to the overall US population in the same period, the prevalence nation wide would be 3.8% (95% CI, 3.2%-4.5%) and 0.6% (95% CI, 0.5%-0.8%). Approximately 1.3% (95% CI, 1.1%-2.2%) of adults with diabetes had proliferative diabetic retinopathy and 2.7% (95% CI, 1.8%-4.0%) had clinically significant macular edema. In other words, approximately 0.2% (95% CI, 0.1%-0.3%) of adults aged 40 years or older had proliferative diabetic retinopathy and 0.4% (95% CI, 0.2%-0.5%) had clinically significant macular edema.

Among individuals with diabetes, no significant difference was found in the prevalence of diabetic retinopathy between those aged 40 to 64 years and those aged 65 years and older (28.0%; 95% CI, 23.0%-33.6%; vs 29.5%; 95% CI, 25.4%-33.9%; P=.64). Approximately 31.6% (95% CI, 26.8%-36.8%) of men with diabetes had diabetic retinopathy and approximately 25.7% (95% CI, 21.7%-30.1%) of women with diabetes had diabetic retinopathy (P=.04). Approximately 26.4% (95% CI, 21.4%-32.2%) of non-Hispanic white individuals, 38.8% (95% CI, 31.9%-46.1%) of non-Hispanic black individuals, and 34.0% (95% CI, 26.7%-42.1%) of Mexican American individuals with diabetes had diabetic retinopathy (P=.008). Prevalence of vision-threatening diabetic retinopathy was not statistically different between individuals aged 40 to 64 years and those aged 65 years and older (4.1%; 95% CI, 2.8%-5.8%; vs 5.1%; 95% CI, 3.5%-7.3%; P=.41). There was no significant difference in the prevalence of vision-threatening diabetic retinopathy between men and women (4.2%; 95% CI, 2.8%-6.1%; vs 4.7%; 95% CI, 3.2%-6.9%; P = .67). Approximately 3.2% (95% CI, 2.0%-5.1%) of non-Hispanic white individuals, 9.3% (95% CI, 5.9%-14.4%) of non-Hispanic black individuals, and 7.3% (95% CI, 3.9%-13.3%) of Mexican American individuals with diabetes had vision-threatening diabetic retinopathy (P=.006).

Extrapolating survey findings to the entire US adult population in the same period (without regard for diabetes status), the prevalence of diabetic retinopathy was significantly higher among individuals who were aged 65 years or older than those younger than 65 years of age (6.1%; 95% CI, 5.1%-7.3%; vs 3.1%; 95% CI, 2.4%-3.9%; P < .001). Approximately 4.3% (95% CI, 3.5%-

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5.3%) of adult men in the United States had diabetic retinopathy compared with 3.3% (95% CI, 2.7%-4.1%) of adult women (P = .046). Non-Hispanic black individuals and Mexican American individuals had a higher prevalence of diabetic retinopathy than non-Hispanic white individuals (9.6%; 95% CI, 7.7%-11.9%; 6.7%; 95% CI, 5.4%-8.4%; vs 2.9%; 95% CI, 2.2%-3.9%; both P < .001).

Prevalence of vision-threatening diabetic retinopathy was higher among people aged 65 years or older than those aged 40 to 64 years (1.0%; 95% CI, 0.7%-1.5%; vs 0.4%; 95% CI, 0.3%; P = .009). There was no significant difference in the prevalence of vision-threatening diabetic retinopathy between men and women observed (0.6%; 95% CI, 0.4%-0.9%; vs 0.6%; 95% CI, 0.4%-0.9%; P = .81). Approximately 0.4% (95% CI, 0.2%-0.6%) of non-Hispanic white individuals, 2.3% (95% CI, 1.5%-3.6%) of non-Hispanic black individuals, and 1.4% (95% CI, 0.8%-2.7%) of Mexican American individuals had vision-threatening diabetic retinopathy (P < .001).

Among individuals with diabetes, those with diabetic retinopathy were more likely to be men (33.7%; 95% CI, 47.4%-59.9%; vs 27.1%; 95% CI, 22.4%-31.8%; OR, 2.07; 95% CI, 1.39-3.10), higher systolic blood pressure (134.2 mm Hg; 95% CI, 131.6-136.9; vs 130.1 mm Hg; 95% CI, 127.9-132.4; P = .04), and higher hemoglobin A1c level (7.9%; 95% CI, 7.6%-8.1%; vs 7.0%; 95% CI, 6.8%-7.1%; P < .001) than those without diabetic retinopathy. Diabetic individuals with diabetic retinopathy were more likely to use insulin than those with diabetes but no diabetic retinopathy (44.6%; 95% CI, 38.5%-50.9%; vs 10.2%; 95% CI, 8.1%-12.7%; P < .001).

### Table 1. Estimated Prevalence of Diabetic Retinopathy and Vision-Threatening Diabetic Retinopathy in Individuals With Diabetes Aged 40 Years and Older and in the Adult US Population, by Age, Sex, and Race/Ethnicity: NHANES 2005-2008

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>No. a</th>
<th>No. b</th>
<th>Weighted Size, in Thousands c</th>
<th>Diabetes Population</th>
<th>US Population</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>% (95%CI)</td>
<td>% (95%CI)</td>
</tr>
<tr>
<td>Total</td>
<td>1006</td>
<td>324</td>
<td>4202</td>
<td>28.5 (24.9-32.5)</td>
<td>3.8 (3.2-4.5)</td>
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<tr>
<td>Age, y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40-64</td>
<td>575</td>
<td>189</td>
<td>2588</td>
<td>28.0 (23.0-33.6)</td>
<td>3.1 (2.4-3.9)</td>
</tr>
<tr>
<td>≥65</td>
<td>431</td>
<td>135</td>
<td>1613</td>
<td>29.5 (25.4-33.9)</td>
<td>6.1 (5.1-7.3)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>504</td>
<td>173</td>
<td>2257</td>
<td>31.6 (26.8-36.8)</td>
<td>4.3 (3.5-5.3)</td>
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<tr>
<td>Female</td>
<td>502</td>
<td>151</td>
<td>1944</td>
<td>25.7 (21.7-30.1)</td>
<td>3.3 (2.7-4.1)</td>
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<td>Race/ethnicity</td>
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<tr>
<td>Non-Hispanic white</td>
<td>396</td>
<td>107</td>
<td>2507</td>
<td>26.4 (21.4-32.2)</td>
<td>2.9 (2.2-3.9)</td>
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<tr>
<td>Non-Hispanic black</td>
<td>306</td>
<td>119</td>
<td>1006</td>
<td>38.8 (31.9-46.1)</td>
<td>9.6 (7.7-11.9)</td>
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<tr>
<td>Mexican American</td>
<td>197</td>
<td>70</td>
<td>401</td>
<td>34.0 (26.7-42.1)</td>
<td>6.7 (5.4-8.4)</td>
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<tr>
<td>Other</td>
<td>107</td>
<td>28</td>
<td>286</td>
<td>19.7 (12.5-29.7)</td>
<td>3.3 (2.3-4.7)</td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40-64</td>
<td>575</td>
<td>36</td>
<td>376</td>
<td>4.1 (2.8-5.8)</td>
<td>0.4 (0.3-0.7)</td>
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<tr>
<td>≥65</td>
<td>431</td>
<td>26</td>
<td>278</td>
<td>5.1 (3.5-7.3)</td>
<td>1.0 (0.7-1.5)</td>
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<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>504</td>
<td>24</td>
<td>298</td>
<td>4.2 (2.8-6.1)</td>
<td>0.6 (0.4-0.9)</td>
</tr>
<tr>
<td>Female</td>
<td>502</td>
<td>38</td>
<td>356</td>
<td>4.7 (2.6-6.9)</td>
<td>0.6 (0.4-0.9)</td>
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<tr>
<td>Race/ethnicity</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic white</td>
<td>306</td>
<td>13</td>
<td>304</td>
<td>3.2 (2.0-5.1)</td>
<td>0.4 (0.2-0.8)</td>
</tr>
<tr>
<td>Non-Hispanic black</td>
<td>306</td>
<td>28</td>
<td>241</td>
<td>9.3 (5.9-14.4)</td>
<td>2.3 (1.5-3.6)</td>
</tr>
<tr>
<td>Mexican American</td>
<td>197</td>
<td>16</td>
<td>85</td>
<td>7.3 (3.9-13.3)</td>
<td>1.4 (0.8-2.7)</td>
</tr>
<tr>
<td>Other</td>
<td>107</td>
<td>5</td>
<td>22</td>
<td>1.6 (0.6-3.8) a</td>
<td>0.3 (0.1-0.6)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; NHANES, National Health and Nutrition Examination Survey.

aNumber of participants with diabetes in NHANES 2005-2006.

bNumber of participants with diabetes who had diabetic retinopathy or vision-threatening diabetic retinopathy in NHANES 2005-2008.

Weighted total number of US adult population who had diabetic retinopathy or vision-threatening diabetic retinopathy.

aEstimate is considered unreliable because relative standard error is greater than 30%.
creasing physical activity, the burden of diabetes in the population, due in part to undiagnosed diabetes. If undiagnosed diabetes would be 32.8% (95% CI, 28.6-37.2) and 5.2% (95% CI, 4.0-6.7), respectively.

It is also possible that the lower prevalence reported in this study reflects a true reduction in the prevalence of diabetic retinopathy. Rates of other diabetic complications have declined during recent decades. For example, Geiss et al\(^4\) found that hospitalization rate for lower extremity amputations among individuals with diabetes began decreasing in 1997. Another recent study found that age-adjusted diabetes-related end-stage renal disease decreased between 1996 and 2006.\(^3\)

### Table 2. Comparison of Characteristics of Individuals With Diabetes Aged 40 Years and Older, by Diabetic Retinopathy Status: NHANES 2005-2008

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>With Diabetic Retinopathy</th>
<th>Without Diabetic Retinopathy</th>
<th>(P) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at examination, y</td>
<td>61.6 (60.2-62.9)</td>
<td>60.0 (58.9-61.0)</td>
<td>.04</td>
</tr>
<tr>
<td>Duration of diabetes, y</td>
<td>15.0 (13.4-16.5)</td>
<td>7.3 (6.5-8.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>134.2 (131.6-136.9)</td>
<td>130.1 (127.9-132.4)</td>
<td>.04</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg</td>
<td>67.5 (66.0-69.0)</td>
<td>71.6 (70.2-73.0)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hemoglobin A1c, %</td>
<td>7.9 (7.6-8.1)</td>
<td>7.0 (6.8-7.1)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

**Abbreviations:** BMI, body mass index; CI, confidence interval; CVD, cardiovascular diseases; NHANES, National Health and Nutrition Examination Surveys.

\(^a\)BMI was calculated as weight in kilograms divided by height in meters squared.

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survival resulting in higher prevalence of diabetic retinopathy. Moreover, a recent longitudinal cohort study suggested that low vision and blindness could be substantially reduced among individuals with diagnosed diabetes who received guideline-recommended levels of care.36

We found that the age-standardized prevalences of diabetic retinopathy and vision-threatening diabetic retinopathy were statistically significantly different between NHANES III and NHANES 2005-2008. These differences between surveys may be real or may be attributed to improved methods used to photograph the fundus in the more recent NHANES 2005-2008 compared with NHANES III. Two digital 45° color images of both eyes were taken in the NHANES 2005-2008 while in NHANES III only one 45° color film image from 1 eye was taken. Although some studies have shown grading of digital images to have similar sensitivity for detecting diabetic retinopathy as grading of film images, it is possible that the current method led to increased detection of both diabetic retinopathy and vision-threatening diabetic retinopathy because of more retina being assessed in 2 images compared with 1 and higher-quality digital images compared with earlier film images used in NHANES III, thus limiting our ability to directly compare results from NHANES III and current NHANES 2005-2008 study (R.K., unpublished data, 2009).

A previous analysis of NHANES III data by Harris et al32 suggests that the prevalence of diabetic retinopathy was 46% higher in non-Hispanic black individuals and 84% higher in Mexican American individuals than in non-Hispanic white individuals. Although not statistically significant at a .05 level, we also found that among individuals with diabetes, non-Hispanic black individuals (47% higher) and Mexican American individuals (29% higher) had a higher crude prevalence of diabetic retinopathy than their non-Hispanic white counterparts. Moreover, the prevalence of vision-threatening diabetic retinopathy in individuals with diabetes was 190% higher in non-Hispanic black individuals and 130% higher in Mexican American individuals than in non-Hispanic white individuals. This may be due to individuals of non-Hispanic black and Mexican American heritage being more likely to have poorer glycemic control and being less likely to be screened and treated for diabetic retinopathy.37 Data from National Health Interview Survey also suggest that non-Hispanic black individuals and Hispanics are less likely to use eye care services.38 These findings lend further insight to inform national efforts to reduce disparities in care among racial/ethnic and socioeconomic groups and preserve sight for all adults in the United States.

Consistent with previous research, we found that higher levels of hemoglobin A1c, longer duration of diabetes, insulin use, and higher systolic blood pressure were independently associated with diabetic retinopathy in the NHANES data.29,36-41 This is

| Table 3. Multiple Logistic Regressions for Risk Factors of Diabetic Retinopathy and Vision-Threatening Diabetic Retinopathy in Individuals With Diabetes Aged 40 Years and Older: NHANES 2005-2008 |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Characteristics | Diabetic Retinopathy | Vision-Threatening Diabetic Retinopathy | |
|                 | PM (95%CI) | OR (95%CI) | PM (95%CI) | OR (95%CI) | |
| Age per y       | NA | 0.99 (0.95-1.02) | NA | 1.00 (0.95-1.05) | |
| Sex             | Male | 38.1 (32.6-43.6) | 2.07 (1.39-3.10) | 6.1 (3.4-8.8) | 1.79 (0.67-4.80) |
|                 | Female | 27.1 (22.4-31.8) | 1 [Reference] | 3.8 (1.9-5.7) | 1 [Reference] | |
| Race/ethnicity  | Non-Hispanic white | 31.2 (25.4-37.0) | 1 [Reference] | 3.3 (1.6-5.0) | 1 [Reference] | |
|                 | Non-Hispanic black | 38.9 (30.4-47.4) | 1.62 (0.81-3.26) | 9.8 (5.7-13.8) | 3.77 (1.47-9.69) | |
|                 | Mexican American | 31.7 (19.6-43.9) | 1.03 (0.39-2.76) | 9.5 (2.0-17.0) | 3.63 (1.05-12.56) | |
|                 | Other | 29.3 (19.9-38.6) | 0.88 (0.42-1.82) | 2.9 (0-6.5) | 0.86 (0.19-3.82) | |
| Education       | <High school | 33.8 (26.9-40.7) | 1 [Reference] | 6.3 (3.2-9.3) | 1 [Reference] | |
|                 | ≥High school | 31.8 (26.8-36.7) | 0.87 (0.51-1.50) | 4.0 (2.1-5.9) | 0.59 (0.22-1.54) | |
| Health insurance | Yes | 31.8 (27.2-36.4) | 0.74 (0.34-1.59) | 5.1 (3.6-6.6) | 2.27 (0.54-9.52) | |
|                 | No | 36.5 (25.4-47.6) | 1 [Reference] | 2.5 (0-5.5) | 1 [Reference] | |
| Hemoglobin A1c, percentage point | NA | 1.45 (1.20-1.75) | NA | 1.21 (0.97-1.50) | |
| Duration of diabetes per y | NA | 1.06 (1.03-1.10) | NA | 1.03 (1.01-1.05) | |
| Insulin use     | Yes | 47.4 (39.1-55.5) | 3.23 (1.99-5.26) | 7.5 (4.8-10.1) | 2.63 (1.34-5.15) | |
|                 | No | 26.7 (21.9-31.5) | 1 [Reference] | 3.3 (1.9-4.7) | 1 [Reference] | |
| Systolic blood pressure per mm Hg | NA | 1.03 (1.02-1.03) | NA | 1.03 (1.01-1.06) | |
| Diastolic blood pressure per mm Hg | NA | 0.96 (0.93-0.98) | NA | 0.96 (0.94-0.98) | |
| BMI^a           | Normal <25 | 30.9 (21.2-40.6) | 1 [Reference] | 4.0 (0-8.0) | 1 [Reference] | |
|                 | Overweight 25-<30 | 37.0 (29.4-44.6) | 1.49 (0.71-3.13) | 4.8 (2.2-7.4) | 1.25 (0.29-5.41) | |
|                 | Obese ≥30 | 30.3 (25.4-35.3) | 0.96 (0.47-1.96) | 5.0 (2.7-7.2) | 1.31 (0.34-5.05) | |
| Smoking status  | Yes | 36.8 (25.4-48.3) | 1.40 (0.67-2.92) | 3.3 (1.1-5.5) | 0.61 (0.25-1.47) | |
|                 | No | 31.6 (27.3-35.9) | 1 [Reference] | 5.0 (3.5-6.5) | 1 [Reference] | |
| History of CVD  | Yes | 33.5 (27.0-40.0) | 1.10 (0.72-1.71) | 6.4 (2.7-10.1) | 1.69 (0.58-4.92) | |
|                 | No | 32.0 (27.4-36.5) | 1 [Reference] | 4.2 (2.3-6.3) | 1 [Reference] | |

Abbreviations: BMI, body mass index; CI, confidence interval; CVD, cardiovascular disease; NA, not applicable; NHANES, National Health and Nutrition Examination Surveys; OR, odds ratio; PM, predictive margin.

^aBMI was calculated as weight in kilograms divided by height in meters squared.
consistent with findings from randomized controlled clinical trials that showed that modifying identified risk factors such as glycemic control and blood pressure control could reduce the burden of diabetic retinopathy and also prevent vision loss caused by it.7,8 Prevention efforts may also need to target individuals with longer duration of diabetes and those using insulin. The new availability of care for vulnerable sections of the population should have demonstrable effect on risk of blindness in diabetes. Furthermore, primary prevention of diabetes, including identifying and protecting individuals at risk (ie, by reduced body weight and increased physical activity), may also help delay the onset of type 2 diabetes and reduce complications of diabetic retinopathy. We also found an inverse relationship between diastolic blood pressure and the presence of diabetic retinopathy. The underlying reason remains unexplained and requires further exploration. It could be due to selective participation bias. However, previous studies from Singapore42 and Africa43 also suggested a possible association between pulse pressure (difference between systolic and diastolic blood pressure) and diabetic retinopathy.

The strengths of this study include its population-based national sample, its inclusion of individuals with undiagnosed diabetes, and improved detection of retinopathy due to use of digital fundus images of both eyes. This improved methodology results in estimates that are less biased than those obtained from NHANES III. However, individuals without diabetes may have retinopathy because of higher glucose level or hypertension, which is not assessed in the current study. Also, due to the infrequency of proliferative diabetic retinopathy (n = 23) and clinically significant macular edema (n = 37), we were unable to provide meaningful estimates by age, sex, and race/ethnicity.

Our study is subject to several limitations. First, individuals who were institutionalized (eg, nursing home residents) were not included in the NHANES, which may have led to an underestimate of diabetic retinopathy prevalence. Second, we could not distinguish between type 1 and type 2 diabetes and the specific risk of diabetic retinopathy complications. Third, there were substantial numbers of eligible individuals with diabetes who did not have photographs that could be graded, which may negatively bias estimates of diabetic retinopathy prevalence. Survey participants who had no light perception or severe visual impairment in both eyes, or a severe infection in 1 or both eyes were excluded—this might negatively bias the prevalence estimates. Small sample sizes might have prevented us from detecting differences, if they existed, between and among subgroups. Due to limitations inherent with the NHANES sampling frame, we were unable to estimate the prevalence of diabetic retinopathy and vision-threatening diabetic retinopathy among racial/ethnic groups other than non-Hispanic white individuals, non-Hispanic black individuals, and Mexican American individuals.

CONCLUSIONS

Our data demonstrate that a high prevalence of diabetic retinopathy and vision-threatening diabetic retinopathy in the United States exists, especially among racial/ethnic minorities. Male sex, higher hemoglobin A1c level, longer duration of diabetes, insulin use, and higher systolic blood pressure were independently associated with the presence of diabetic retinopathy. These estimates provide policy makers updated information for use in planning eye care services and rehabilitation. With the aging of the population and the increasing proportion of the population with diverse racial/ethnic heritage, the number of cases of diabetic retinopathy and vision-threatening diabetic retinopathy will likely increase. Furthermore, the need for eye care and for culturally appropriate interventions that can reduce disparity and improve access to eye care among diverse populations is also likely to increase.


