ORIGINAL ARTICLE

Trends and Racial/Ethnic Disparities in Diabetic Retinopathy Among Adults with Diagnosed Diabetes in North Carolina, 2000–2015

Huabin Luo, Ronny A. Bell, Seema Garg, Doyle M. Cummings, Shivajirao P. Patil, Katherine Jones

BACKGROUND There is limited information available in North Carolina on the current burden of, and racial disparities in, diabetic retinopathy (DR), a major complication associated with diabetes mellitus (DM). This study aims to describe the overall trend of, and racial/ethnic disparities in, DR among adults with DM in North Carolina.

METHODS Data were from 13 waves (2000, 2002–2010, 2012, 2013, and 2015) of the Behavioral Risk Factor Surveillance System. The study sample included 16,976 adults aged ≥ 40 years with DM in North Carolina. DR was identified by self-report by the question, "Has a doctor ever told you that diabetes has affected your eyes or that you had retinopathy?" The overall prevalence of DR was assessed during the time period, and was compared between whites and blacks. All analyses were conducted using Stata 13.0.

RESULTS The prevalence of self-reported DR in North Carolina decreased from 27.2% in 2000 to 18.3% in 2015, a reduction of 33% (Trend *P* = .003). The age-adjusted DR prevalence in whites decreased from 21.7% to 17.6% (Trend *P* = .04), and in blacks from 39.4% to 20.2% (Trend *P* = .002). The declining rates in DR were not statistically different between whites and blacks (*P* = .06). Blacks were more likely to report DR (adjusted odds ratio = 1.20, 95% confidence interval, 1.03–1.40) during 2000–2015.

CONCLUSION The prevalence of self-reported DR in adults with DM declined significantly in North Carolina in the past 15 years. While racial differences in some years appeared to be decreasing, the black-white disparity in DR prevalence during the entire period persisted. Focused efforts on reducing the gap are needed.

Diabetic retinopathy (DR) is the most common microvascular complication of diabetes mellitus (DM) and is the leading cause of blindness in the United States [1]. The prevalence of DM has increased rapidly in the United States. In 2015, an estimated 30.3 million people or 9.4% of the US population had DM [2]. By the year 2050, it is expected that about 48.3 million adults will be affected by DM [3]. The burden of DR may increase as more people have DM. It is estimated that about 16.0 million adults aged ≥ 40 years are projected to have DR by 2050 [4]. DR prevalence and complications are higher among racial/ethnic minority populations, including African Americans, Hispanics, and American Indians [5].

North Carolina is one of the 15 southern states identified as being in the "diabetes belt" by the Centers for Disease Control and Prevention [6]. North Carolina has the 13th highest prevalence of DM in the United States. An estimated 750,000 (1 in 10) adults in North Carolina have been diagnosed with DM [7]. By 2025, the number of people with DM in North Carolina is projected to increase to almost 1.9 million, with an annual cost to the state of $17.9 billion (including both medical and non-medical costs) [8]. Racial and ethnic disparities in DM prevalence are also significant in North Carolina. In 2013, 11.0% of non-Hispanic white adults had DM compared to 15.4% of non-Hispanic black adults [9].

The early stages of DR are often asymptomatic. Thus, early detection and treatment is imperative to preventing vision loss. Population-based studies on DR trends in the United States [10-12] are very limited. Little data exists on DR status in North Carolina [13]. The target of Healthy People 2020 is to reduce DR to 30.8 per 1,000 in the population aged 18 years and older with DM [14]. The purpose of this study is to describe the trends of DR in adults with DM and to assess racial/ethnic disparities in DR in the past 15 years in North Carolina. An update on the current status of DR will provide useful information for both eye care professionals and other medical providers in their practice and inform public health officials in the design or modification of interventions and policies regarding DR and DM.

Methods

Data

For this study, data from the Behavioral Risk Factor Surveillance System (BRFSS) was analyzed. The BRFSS is an annual state-based, random-digit–dialed telephone survey of the non-institutionalized, US civilian population aged 18 years and older. The BRFSS questionnaire consists of 3 sections: a core survey, optional modules, and state-added questions [15]. BRFSS has been proven to provide valid national and state estimates of health and risk factors [16]. In the BRFSS Core Questionnaire, respondents

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were asked whether they had ever been told by a doctor that they had DM. An optional diabetes module was administered to respondents with self-reported diabetes. North Carolina administered the diabetes module in 13 waves of BRFSS: 2000, 2002–2010, 2012, 2013, and 2015. The analytical sample for this study included 16,976 adults with self-reported diabetes, aged 40 years or older, from North Carolina. To compare the trend of DR prevalence (see Figure 1), we included 474,685 adults from other states who participated in the same 13 waves of BRFSS diabetes module (the number of US states and territories participating in the BRFSS diabetes module varied during the period, ranging from 48 in 2000 to 28 in 2004, and 31 in 2015).

Measures

Diabetes status. Respondents were asked, "Have you ever been told by a doctor that you have diabetes?" If the response answered "yes" and the respondent was female, then she was asked, "Was this only when you were pregnant?" Since 2004, another option was added to the response set: "No, prediabetes or borderline diabetes." As in prior research [17], we combined those respondents who reported that they did not have diabetes with those who indicated that they had only been told that they had diabetes during a pregnancy (gestational diabetes), and who indicated that they have prediabetes or borderline diabetes. Collectively, these were considered as not having diabetes and were therefore not included in the analytic sample. Although BRFSS does not differentiate between diabetes types, national prevalence data for type 1 and type 2 indicate that the vast majority of adults with diabetes have type 2 diabetes [2].

DR was ascertained by asking the respondents with self-reported diabetes, "Has a doctor ever told you that diabetes has affected your eyes or that you had retinopathy?" The options were "Yes," "No," and "Don't know/not sure." For the purposes of this study, the variable was coded as a binary outcome (Yes/No). Thus, those who answered "Don't know/not sure" were not included in the study sample.

Covariates. The following demographic and socioeconomic status (SES) variables were included as covariates: age, sex, race/ethnicity (non-Hispanic white [whites], non-Hispanic black [blacks], and other [combining Hispanics and other racial groups due to small sample sizes]), marital status (married/living with partner versus others), duration of diabetes (years), educational attainment (less than high school, high school graduate, some college education, and above), annual household income (less than $25,000, $25,000–$49,999, and greater than or equal to $50,000), and health insurance status (Yes/No).

Analysis

We first calculated the overall rate of DR in adults with DM in each BRFSS survey from 2000 to 2015, and rates of DR by race/ethnicity. Next, the temporal linear trends of DR were assessed by REGRESS procedure with year as the independent variable. Rate of change (ie, slope of trend lines) in DR prevalence was profiled by race/ethnicity [18]. Third, we ran 3 logistic regression models. In Model I, we assessed the time effect. In Model II, we added demographics and SES variables and time by race/ethnicity interaction to assess changes in racial/ethnic disparities over time. We also tested time by SES interactions (time by income, time by education, and time by health insurance coverage). Interaction terms were removed from the final model if not significant. Model 3 was the final model. Sampling weights were applied to account for the complex survey design and nonresponse [15]. All analyses were conducted using Stata Version 13.0 (College Station, TX).

Results

Characteristics of the sample across all survey years are presented in Table 1. Self-reported DR was more common in

FIGURE 1.
Trend of Prevalence of Self-Reported Diabetic Retinopathy in North Carolina and Other US States, 2000–2015 BRFSS

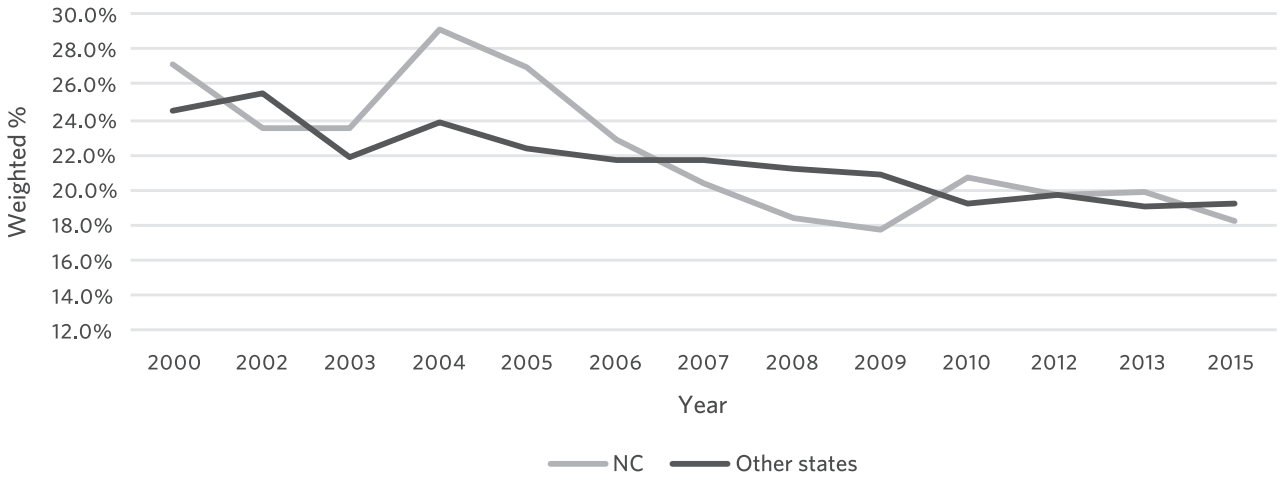


TABLE 1.
Characteristics of the Aggregate Sample by Diabetic Retinopathy Status, 2000–2015 NC BRFSS

Variables	Retinopathy (n=3,587) % (95% CI)	No Retinopathy (n=13,113) % (95% CI)	*P*
Age groups			0.011
40-44	6.8 (5.6 to 8.3)	6.6 (5.9 to 7.4)	
45-64	53.7 (51.3 to 56.1)	49.6 (48.3 to 50.8)	
≥ 65	39.5 (37.2 to 41.8)	43.9 (42.6 to 45.1)	
Gender			< 0.001
Male	52.2 (49.8 to 54.5)	46.1 (44.9 to 47.4)	
Female	47.8 (45.5 to 50.2)	53.9 (52.6 to 55.1)	
Married/partnered			0.0406
No	44.1 (41.8 to 46.4)	41.4 (40.2 to 42.6)	
Yes	55.9 (53.6 to 58.2)	58.6 (57.4 to 59.8)	
Duration of diabetes (years) (Mean)	15.6 (15.0 to 16.2)	9.7 (9.5 to 9.9)	< 0.001
Race/Ethnicity			< 0.001
White non-Hispanic	59.4 (57.1 to 61.7)	66.6 (65.4 to 67.8)	
Black non-Hispanic	31.8 (29.7 to 34.1)	26.3 (25.2 to 27.5)	
Other	8.8 (7.5 to 10.2)	7.1 (6.5 to 7.8)	
Education level			< 0.001
Less than high school	31.4 (29.2 to 33.7)	22.9 (21.8 to 24.0)	
High school grad	32.6 (30.5 to 34.8)	31.4 (30.3 to 32.6)	
Some college or above	36.0 (33.8 to 38.2)	45.7 (44.4 to 46.9)	
Annual household Income			< 0.001
< $25,000	57.5 (55.0 to 60.0)	44.0 (42.6 to 45.3)	
$25,000–$49,999	25.2 (23.1 to 27.5)	28.7 (27.4 to 29.9)	
≥ $50,000	17.3 (15.5 to 19.2)	27.4 (26.2 to 28.6)	
Health insurance			< 0.001
No	14.3 (12.6 to 16.1)	11.1 (10.2 to 12.0)	
Yes	85.7 (83.9 to 87.4)	88.9 (88.0 to 89.8)	

Note. CI = confidence interval; NC BRFSS = North Carolina Behavioral Risk Factor Surveillance System.

the following groups compared to their counterparts: individuals aged 45–64 years, males, adults who were not married or living with their partner, adults with a longer duration of diabetes, blacks, adults with less than a high school education, adults with an annual household income below $25,000, and adults with no health insurance.

Trend of Self-reported DR in North Carolina and Other US States

The trend of crude DR for North Carolina and the other US states is displayed in Figure 1. Overall, there was a significant downward trend of DR from 27.2% in 2000 to 18.3% in 2015 in adults with DM in North Carolina, a reduction of 33% (slope = -0.60, Trend *P* = .003). A significant decreasing trend of DR was also observed in other states, from 24.2% to 19.2%, a reduction of 21% (slope = -0.42, Trend *P* < .001). During the period 2000–2015, the overall prevalence of DR in North Carolina was 21.6% (95% confidence interval [CI], 20.7%–22.6%), almost the same as in other states: 21.6% (95% CI, 21.3%–21.9%).

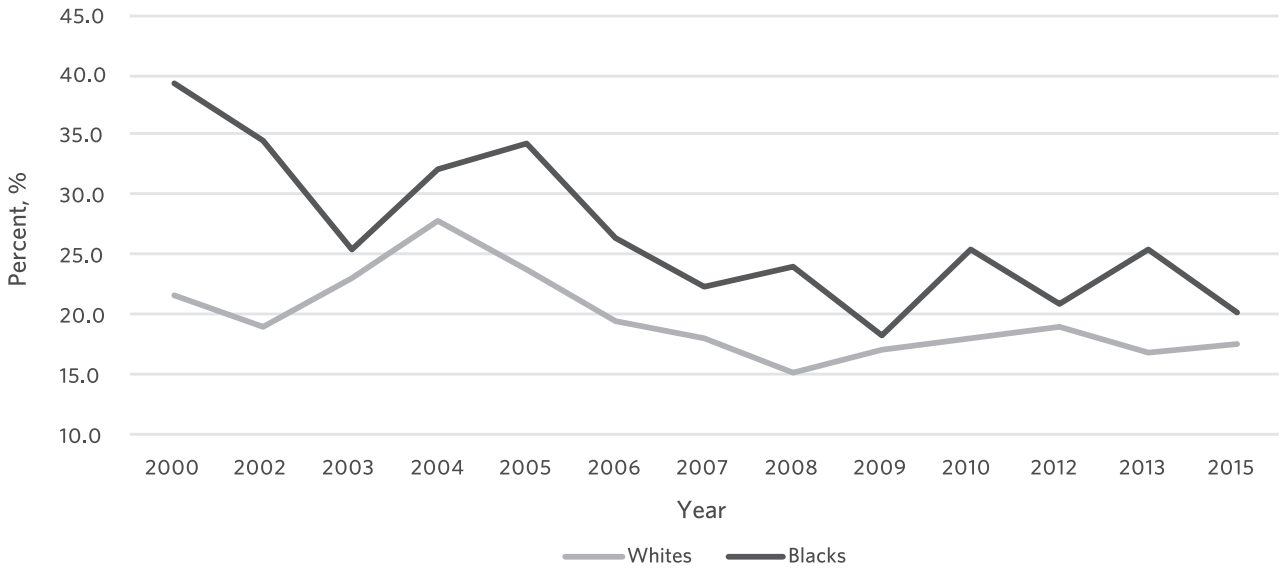
Since a new survey methodology was implemented in BRFSS in 2011 (ie, adding cellular telephone surveys and applying new methods of weighting) [19], we conducted additional analyses to assess whether the rate of change (ie, slopes) for DR was significantly different between the pre-2011 (ie, 2000–2010) and post-2011 (ie, 2012–2015) survey periods. A comparison of the slopes for these 2 survey periods did not detect significant differences (*P* = .27). Thus, we decided to combine the data for these 2 periods in analyses.

The age-adjusted trends of DR for whites and blacks are displayed in Figure 2. For brevity, the trend for "other race" was not displayed in Figure 2 because the group may be composed of many different/mixed races, and it is difficult to make meaningful interpretation of the results. A downward trend of DR was shown for both blacks (slope = -1.10, Trend *P* = .002) and whites (slope = -0.44, Trend *P* = .04). The DR prevalence was higher in blacks than in whites, with the difference fluctuating from 17.7% in 2000 to 2.6% in 2015. Finally, overall, the 2 trend lines seem to be closer over time, although a comparison of the slopes (ie, rate of change) of trend lines for whites and blacks did not show significant differences (*P* = .06), which was confirmed by the insignificant results of time by race/ethnicity interaction product terms in the logistic regression model introduced below.

Multiple Logistic Regression Model Results

Model I results showed that the time effect was significant (adjusted odds ratio [AOR], 0.96; 95% CI, 0.94–0.97). Model II results showed that 3 of the 4 interaction terms

FIGURE 2.
Trend of Prevalence of Self-Reported Diabetic Retinopathy in North Carolina and Other US States, 2000–2015 BRFSS



(ie, time by income, time by education, and time by health insurance coverage) were not statistically significant; the time by non-Hispanic, black was significant (P = .040). However, the time by non-Hispanic, black became insignificant (P = .084) in Model III when the other 3 interaction terms were excluded. Thus, these interaction terms were not included in Model III.

Model III results showed the time effect was significant (AOR, 0.97; 95% CI, 0.95–0.99), indicating a 3% annual decline in DR during the study period. Blacks were more likely to report DR (AOR, 1.20; 95% CI, 1.03–1.40). Adults with higher income (P < .001) and education levels (P = .032) were less likely to report DR. Females were less likely to report DR (AOR, 0.69; 95% CI, 0.61–0.79). Those with a longer duration of diabetes were more likely to report DR (AOR, 1.06; 95% CI, 1.05–1.06) (see Table 2).

Discussion

This study provides an update on the trends in self-reported DR rates in adults with self-reported DM and assesses the racial/ethnic disparities in North Carolina in the past decade. The BRFSS data showed that self-reported DR in North Carolina declined significantly from 2000 to 2015, similar to the prevalence trend in other states in the United States. Yet, the white-black disparity persisted over time, with blacks having a higher prevalence of DR than whites at all time points.

To our knowledge, this study is the first to assess these trends in self-reported DR rates at the national or state level. The crude prevalence of self-reported DR in North Carolina and other states was declining at an annual rate of 6% and 4%, respectively. As shown by national data, the significant declining of DR in the past decades may result from better blood glucose, blood pressure, and lipid control, as well as improved detection and treatment of eye problems [20]. In addition, various initiatives in the state, such as Eat Smart, Move More NC (www.eatsmartmovemorenc.com), Quitline NC (www.quitlinenc.com), Community Care of North Carolina network (www.communitycarenc.org), and most importantly the intense focus on health care quality since the passage of the Patient Protection and Affordable Care Act in 2010 [21], may have contributed to the progress.

Our analysis found an average self-reported DR prevalence of 21.6% in North Carolina (average prevalence in other states 21.5%), ranging from 27.2% in 2000 to 18.3% in 2015. These estimates of DR prevalence from the BRFSS data are lower than estimates reported in prior studies using other datasets. For example, using clinical examination data from the 2005–2008 National Health and Nutrition Examination Survey (NHANES), a CDC study found that the prevalence of DR was 28.5% among US adults age 40 or older with DM [22]. The clinical data from the Multi-Ethnic Study of Atherosclerosis showed a prevalence of 33.2% [23]. Additionally, a meta-analysis of 8 population-based studies reported an overall estimate of DR prevalence of 40% and a prevalence of vision-threatening diabetic retinopathy of 8% [24]. Thus, the results of our study may suggest underreporting of DR in North Carolina. Patients may not know they have DR, especially at the early stage. Prior research has found that 73% of adults with DR were unaware of their condition [25]. Our study findings underscore the need to ensure regular eye examinations to detect early signs of DR so timely treatment can be provided. With timely laser treatment and intravitreal anti-vascular endothelial growth factor (VEGF) therapy, severe vision loss from DR can be reduced by 90% [26].

Our study results showed persistent white-black disparities in DR prevalence, a finding that is similar to prior research [22]. A Maryland study of adults aged 40–69 with type 2 diabetes found a 50% prevalence of DR among blacks compared with 19% among whites [27]. The Los Angeles Latino Eye Study found that 46.9% of Latinos had DR [28]. Overall, our study results of the SES variables (eg, income and education) were consistent with prior studies [22]. Health insurance coverage was not a significant protective factor for DR (AOR, 0.84; *P* = .104), which may suggest limited access to eye care providers (eg, ophthalmologists) in some communities. Research has found that residence in a county with a low density of eye care professionals reduced the likelihood of receiving annual dilated eye examinations among insured adults with diabetes [29]. As of January 2017, 42 counties in North Carolina do not have any ophthalmologists, and another 20 counties have only one (unpublished data, NC Medical Board Physician Roster, January 2017).

Our study did not find any significant time by race/ethnicity interactions, indicating that the white-black gap in DR has persisted in the past decade. Nevertheless, 2 other patterns need to be noted: first, the DR trend lines for whites and blacks seem to come closer (see Figure 2), indicating the narrowing of white-black disparities; second, the DR trend lines, especially for blacks, fluctuated considerably. It is not clear why the prevalence of DR in blacks has been fluctuating since 2007. Prior research has shown that non-Hispanic blacks and Mexican Americans were more likely to have poorer glycemic control and were less likely to be screened and treated for DR [30]. A closer assessment of the fluctuation pattern in blacks is needed in North Carolina.

North Carolina has been proactive and innovative in improving access to eye care and quality. For example, Project I See, a collaboration between Community Care of North Carolina and Wake Forest School of Medicine, represents an innovative initiative to increase access to eye examination in primary care settings [31]. The University of North Carolina's (UNC's) management of DM patients is a current example of a health care system utilizing electronic medical records, automatic reminders, and interdisciplinary collaboration. In UNC's system, all patients with DM are automatically reminded to schedule an annual eye exami-

TABLE 2.
Factors Associated with Having Diabetic Retinopathy, NC BRFSS 2000–2015

	Model I				Model II				Model III			
Variables	**AOR**	**95% CI**		***P***	**AOR**	**95% CI**		***P***	**AOR**	**95% CI**		***P***
Time (year)	0.96	0.94	0.97	< 0.001	1.01	0.95	1.08	0.728	0.97	0.95	0.99	0.002
Age group (vs. 40-44)												
45-64	0.96	0.74	1.24	0.757	1.02	0.77	1.35	0.894	1.02	0.77	1.35	0.881
≥ 65	0.65	0.50	0.84	< 0.001	0.63	0.47	0.85	< 0.001	0.63	0.47	0.84	0.002
Female	0.74	0.65	0.83	< 0.001	0.70	0.61	0.80	< 0.001	0.69	0.61	0.79	< 0.001
Race/ethnicity (vs. Whites)												
Non-Hispanic Blacks	1.36	1.18	1.56	< 0.001	1.81	1.19	2.75	0.005	1.20	1.03	1.40	0.021
Other	1.38	1.11	1.72	< 0.001	1.75	0.87	3.52	0.117	1.11	0.86	1.44	0.412
Married	0.82	0.73	0.93	< 0.001	1.02	0.89	1.18	0.743	1.02	0.89	1.18	0.736
Duration of diabetes	1.05	1.05	1.06	< 0.001	1.06	1.05	1.06	< 0.001	1.06	1.05	1.06	< 0.001
Annual household income (< $25,000)												
$25,000–$49,999					0.77	0.51	1.15	0.201	0.69	0.59	0.82	< 0.001
≥ $50,000					0.75	0.44	1.28	0.298	0.51	0.42	0.62	< 0.001
Education level (vs. < high school)												
High school grad					0.74	0.47	1.16	0.188	0.90	0.75	1.08	0.259
Some college or above					0.79	0.49	1.27	0.336	0.82	0.68	0.98	0.032
Health insurance					1.07	0.61	1.90	0.808	0.84	0.67	1.04	0.104
Race/ethnicity by time												
Black × time					0.96	0.92	1.00	0.040				
Other × time					0.95	0.88	1.02	0.181				
Income × time												
($25,000–$49,999) × time					0.99	0.95	1.03	0.617				
(≥ $50,000) × time					0.96	0.91	1.01	0.111				
Education × time												
High school × time					1.02	0.98	1.07	0.346				
Some college/above × time					1.00	0.96	1.05	0.867				
Health insurance × time					0.97	0.92	1.03	0.366				

Note. AOR = adjusted odds ratio; CI = confidence interval; NC BRFSS = North Carolina Behavioral Risk Factor Surveillance System.

nation through the electronic medical record system [32]. Telemedicine screening at the point of care of the primary care physician has great potential in DM management and prevention of vision-threatening DR [33]. The North Carolina Diabetic Retinopathy Telemedicine Network (NCDRTN) is an innovative screening program developed to address the growing burden of DR in rural and underserved areas in the state. From 2014 to 2015, a total of 1,787 patients with diabetes in 5 Area Health Education Center primary care clinics received retinal screening photographs with remote expert interpretation to determine the presence and severity of DR [34].

Studies have shown that almost all individuals with type 1 diabetes and more than 60% of those with type 2 diabetes may develop DR during the first 2 decades of the disease [35]. Risk of vision loss due to DR can be reduced by effective control of blood glucose and blood pressure and by early detection and timely treatment [36]. The efficacy and cost-effectiveness of early detection and treatment of DR is well established [37]. Yet, in a separate analysis of NC BRFSS data from 2000–2015, we found approximately 20% to 30% of adults with DM did not have a dilated eye exam in the past year [38]. Continuing patient education and promoting annual eye examination are necessary. Patients' knowledge of the detrimental effects of DR and referral by health care providers are important factors in the uptake of DR screening services [39].

Limitations

Several limitations inherent in the BRFSS data should be noted. First, both data on DM and DR were self-reported and thus subject to recall bias and underreporting. Second, it is possible that some subjects may have reported other eye diseases that were associated with DM but not retinopathy. Third, institutionalized adults (eg, those in nursing homes) were not included in the analysis. Thus, our results may be underestimated. Fourth, due to small sample sizes, we could not estimate the prevalence in other minority groups. Future survey needs to increase the sample size for other racial groups. Lastly, we did not control for other variables like glycemic status, which is not available in BRFSS.

Conclusion

The self-reported DR in adults with DM declined significantly in North Carolina in the past 15 years. While racial differences in some years appeared to be decreasing, the black-white disparity in DR prevalence across the entire period persisted. Tight glycemic control and routine eye screening may diminish the impact of this devastating condition. It is crucial that patients and health care providers all understand the impact of DR and make use of available interventions to reduce its impact. Additional efforts to improve diabetes-related vision care for the racial and ethnic minority patients are needed in North Carolina. NCMJ

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