Prevalence of Diabetic Retinopathy in Various Ethnic Groups: A Worldwide Perspective

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Abstract. The alarming rise in diabetes prevalence is a global public health and economic problem. Diabetic retinopathy is the most common complication of diabetes and the leading cause of blindness among working-age populations in the Western world. Screening and prompt treatment of diabetic retinopathy are not top priorities in many regions of the world, because the impacts of other causes of preventable blindness remain an issue. Ethnicity is a complex, independent risk factor for diabetic retinopathy. Observations from white populations cannot be extrapolated fully to other ethnic groups. The prevalence of diabetic retinopathy, sight-threatening diabetic retinopathy, and clinically significant macular edema are higher in people of South Asian, African, Latin American, and indigenous tribal descent compared to the white population. Although all ethnic groups are susceptible to the established risk factors of diabetic retinopathy—such as length of exposure and severity of hyperglycemia, hypertension, and hyperlipidemia—ethnic-specific risk factors also may influence these rates. Such risk factors may include differential susceptibility to conventional risk factors, insulin resistance, differences in anthropometric measurements, truncal obesity, urbanization, variations in access to healthcare systems, genetic susceptibility, and epigenetics. The rates of nonproliferative diabetic retinopathy appear to be declining in the United States, supporting the observation that better medical management of diabetes and prompt treatment of sight-threatening diabetic retinopathy substantially improve the long-term diabetic retinopathy incidence; studies from other parts of the world are limited and do not mirror this finding, however. We examine the ethnicity and region-based prevalence of diabetic retinopathy around the world and highlight the need to reinforce ethnicity-based screening and treatment thresholds in diabetic retinopathy. (Surv Ophthalmol 57:347–370, 2012. © 2012 Elsevier Inc. All rights reserved.)

Key words. diabetes • diabetic retinopathy • global • incidence • prevalence • risk factors

Introduction

The total number of people with diabetes is projected to rise from 171 million in 2000 to 366 million in 2030. Race/ethnicity is a risk factor for both type 1 (T1D) and type 2 diabetes mellitus (T2D). Hemoglobin A1c (HbA1c) is widely used as an index of mean glycemia, a measure of risk for the development of diabetic complications, and a measure of the quality of diabetes care.

Diabetic retinopathy (DR) is the most common microvascular complication of diabetes, and it remains a leading cause of legal blindness and...
visual impairment in the working-age population in the developed world. Diabetic retinopathy involves damage to the microvasculature of the retina as a result of the prolonged exposure to the metabolic changes induced by diabetes. The two main types of DR are the less-severe form, non-proliferative DR, and the severe form, proliferative DR (PDR). Nonproliferative DR is associated with microaneurysms, superficial and deep retinal hemorrhages, hard exudates, and macular edema. Subsequent PDR involves the growth of new blood vessels in the retina that may cause scarification of the retina and vitreous. Methods of diagnosing DR clinically include ophthalmoscopy, optical coherence tomography, retinal photography, and fluorescein angiography.

Recent data suggest that the prevalence of DR may be decreasing in the United States. The launch of the VISION 2020 initiative in 1999, DR surveillance programs, intensified risk-factor control in response to the results of randomized controlled trials, and continuing improvement in healthcare systems have been implicated in the decreasing rates of DR. This transition is best reflected and reported in the United States and is limited to a reduction in the prevalence of non-proliferative DR only. Furthermore, these advantages may be masked by the alarming rate of increase in the global prevalence of T2D, especially in some areas. The same situation applies to T1D, but the increase is not to the same degree. Although the decline in DR rates is encouraging, many developing countries are still struggling to cope with other preventable causes of blindness and inequity in healthcare access. Thus, visual impairment from diabetes is not a current priority for these countries. Nevertheless, reliable estimates of regional and ethnic differences in DR rates should allow us to comprehend the healthcare need and aid in planning of resource allocations to provide patient-centered care to the high-risk groups. We shall address the regional and ethnic variations in DR and identify factors that may explain the differences.

Type 1 Diabetes
CHARACTERISTICS OF TYPE 1 DIABETES

T1D is characterized by an absolute deficiency of insulin secondary to immune-mediated destruction of the pancreatic β cells. The development of T1D is thought to be triggered by environmental factors in genetically susceptible patients. Several lines of evidence indicate rather complex genetics for T1D, with the strongest risk associated within the human leukocyte antigen (HLA) region that has both susceptible and protective haplotypes. The relative contribution of these haplotypes and their interactions with environmental determinants and other genetic loci might partially explain the ethnic variations of the frequency of this disease.

The earliest signs of DR in T1D usually occur after 5–10 years of diabetes. The prevalence of DR is strongly correlated with the duration of disease. Nearly all patients with T1D will develop some degree of retinopathy within 20 years, but this may be modified with better control of risk factors. Current guidelines recommend annual screening for all those with T1D from the age of 12 years onward in the UK or 10 years onward in the United States.

PREVALENCE OF DIABETIC RETINOPATHY IN T1D PATIENTS WORLDWIDE

The prevalence of DR ranges from 10–50%, depending on the methods used to screen for DR, the population screened, the age of the patients, and the duration of diabetes. The prevalence rates are usually lower in population-based studies than in hospital-based populations.

There are more epidemiological studies on T1D-related DR in white populations from European countries than those from other parts of the world, reflecting the disease predilection and historically better healthcare systems (Table 1). T1D predominantly affects the population of European ancestry, with the highest rates in Finland and Sardinia. Asian and sub-Saharan African countries generally report a low frequency of T1D, although some Asian countries (Kuwait and China) recently have reported high rates. In 2009, the SEARCH Study for Diabetes in Youth determined prevalence per 1,000 for youths aged 0–19 years with T1D from different ethnic groups in the United States. T1D remains a white-dominated disease, with rates of 2.00 in non-Hispanic white patients, 1.31 for African-Americans, 0.99 for Hispanics, 0.94 for Navajos, and 0.52 for Asians and Pacific Islanders.

There are limited studies on the prevalence of DR in T1D from non-white-dominated countries, largely because T1D is more prevalent in people of European ancestry (Table 2). Information on other ethnic groups has only become available recently, perhaps because of better case ascertainment and improvement in the healthcare systems.
The comparison of prevalence studies on DR in T1D between different regions should be done with caution, because the approach of different healthcare systems to the management of T1D varies significantly. In the EURODIAB study, which included patients from 31 clinics in 16 European countries, the rate of retinopathy ranged from 25% in Austria to 60% in Portugal.\textsuperscript{67} The results of DiaComp mirrored these variations in the prevalence of self-reported retinopathy in patients with a short duration of diabetes, with the highest rates in Lithuania (29.9% requiring laser treatment).\textsuperscript{269} The prevalence was more consistent among those with a long duration of diabetes.

### TABLE 1

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Method of Examination</th>
<th>Sample Size, mean, Age (\textsuperscript{a})</th>
<th>Prevalence of Complications, (%)</th>
<th>Study Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klein (1984)\textsuperscript{119}</td>
<td>P</td>
<td>996, 14.6 ± 7.6</td>
<td>54 Any DR 27 PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Arfken (1994)\textsuperscript{9}</td>
<td>P</td>
<td>142</td>
<td>39 Any DR</td>
<td>Hospital</td>
</tr>
<tr>
<td>Danielsen (1982)\textsuperscript{19}</td>
<td>O</td>
<td>212, mean, 32.8</td>
<td>34 Any DR 6.1 PDR</td>
<td>Hospital</td>
</tr>
<tr>
<td>Sjolie (1985)\textsuperscript{240}</td>
<td>P</td>
<td>718, mean, 37.3</td>
<td>30 Any DR 9 PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Burger (1986)\textsuperscript{26}</td>
<td>O</td>
<td>231, 17.6 ± 4.0</td>
<td>47 Any DR 4 PDR</td>
<td>Hospital</td>
</tr>
<tr>
<td>McCance (1989)\textsuperscript{163}</td>
<td>O</td>
<td>216, 26.6 ± 6.0</td>
<td>56 Any DR 4 PDR</td>
<td>Hospital</td>
</tr>
<tr>
<td>Pinto–Figueiredo (1992)\textsuperscript{197}</td>
<td>O</td>
<td>1,302, 24.14 ± 12.47</td>
<td>42 Any DR 7 PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Joner (1992)\textsuperscript{102}</td>
<td>P</td>
<td>369, 18.3 ± 4.9</td>
<td>33 Any DR</td>
<td>Population</td>
</tr>
<tr>
<td>Falck (1993)\textsuperscript{69}</td>
<td>P</td>
<td>194, mean, 11.8</td>
<td>11 Any DR</td>
<td>Hospital</td>
</tr>
<tr>
<td>Stephenson (1994)\textsuperscript{247}</td>
<td>P</td>
<td>2,479, 32.7 ± 10.2</td>
<td>46 Any DR 10 PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Kristinsson (1994)\textsuperscript{138}</td>
<td>P+O</td>
<td>205, 32.9 ± 0.91</td>
<td>52 Any DR 13 PDR 9 ME</td>
<td>Population</td>
</tr>
<tr>
<td>Kokkonen (1994)\textsuperscript{135}</td>
<td>P</td>
<td>80, mean, 21.6</td>
<td>70 any DR 10 PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Johansen (1994)\textsuperscript{100}</td>
<td>P</td>
<td>138, median, 19</td>
<td>59 Any DR 17 PDR</td>
<td>Hospital</td>
</tr>
<tr>
<td>Ebeling (1997)\textsuperscript{58}</td>
<td>P</td>
<td>140, 33.0 ± 0.8</td>
<td>55 Any DR 21 PDR</td>
<td>Hospital</td>
</tr>
<tr>
<td>Kuiv (1997)\textsuperscript{139}</td>
<td>P</td>
<td>149, 34–71 (median, 40)</td>
<td>77 Any DR 17 PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Kernell (1997)\textsuperscript{108}</td>
<td>P+O</td>
<td>557, mean, 14.6</td>
<td>15 Any DR 2 PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Olsen (1998)\textsuperscript{189}</td>
<td>P</td>
<td>339, (median, 21.1)</td>
<td>57.6 Any DR</td>
<td>Population</td>
</tr>
<tr>
<td>Larsson (1999)\textsuperscript{141}</td>
<td>P</td>
<td>285, 33.1 ± 9.6</td>
<td>75 Any DR 22 PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Nordwall (2006)\textsuperscript{186}</td>
<td>P</td>
<td>80, (median, 14.5)</td>
<td>27 Any DR</td>
<td>Population</td>
</tr>
<tr>
<td>Knudsen (2006)\textsuperscript{132}</td>
<td>P</td>
<td>656, (median, 37.3)</td>
<td>53.8 Any DR 5.6 PDR 7.9 CSME</td>
<td>Population</td>
</tr>
<tr>
<td>Devdov (2009)\textsuperscript{53}</td>
<td>P+O</td>
<td>3,455, mean, 31.4</td>
<td>54.6 Any DR 11.1 PDR</td>
<td>Population</td>
</tr>
</tbody>
</table>

DR = diabetes retinopathy; PDR = proliferative diabetes retinopathy; ME = macular edema; O = ophthalmoscopy; P = photography; Hospital = hospital-based; Population = population-based.

The comparison of prevalence studies on DR in T1D between different regions should be done with caution, because the approach of different healthcare systems to the management of T1D varies significantly.

In the EURODIAB study, which included patients from 31 clinics in 16 European countries, the rate of retinopathy ranged from 25% in Austria to 60% in Portugal.\textsuperscript{67} The results of DiaComp mirrored these variations in the prevalence of self-reported retinopathy in patients with a short duration of diabetes, with the highest rates in Lithuania (29.9% requiring laser treatment).\textsuperscript{269} The prevalence was more consistent among those with a long duration of diabetes. Similarly, WHO MSVDD found that the cumulative incidence of any retinopathy varied at least two-fold between centers, with even greater variation in the frequency of PDR.

The Asian Young Diabetes Research (ASDIAB) Study from seven centers of four Asian countries reported the prevalence of DR in 724 young diabetics aged 12–40 years who had a duration of diabetes of <12 months. The small patient population in...
ASDIAB reflects the low prevalence of T1D among Asian populations and/or low rates of healthcare utilization. Prevalence was least among Indians (5.3%) as compared to other ethnic groups, such as Malays (10%) and Chinese (15.1%). The authors attributed these differences to higher levels of fasting and glucagon-stimulated C-peptide among the Indian population. Regional differences in healthcare utilization and variations in timely diagnosis of diabetes may also contribute to these differences.

The few single-centered studies available from the Indian subcontinent also show a low prevalence. A study in Pakistan among patients with T1D of greater than 10 years duration reported a prevalence of 7.7%. Similarly, a study from South India in a cohort of T1D followed up over 15 years showed that, despite an earlier age of disease onset, the prevalence of any DR or PDR was 11.2% or 4%, respectively. This implies that despite the earlier age of onset and poorer glycemic control, there may be other clinical and genetic factors that determine the complication rate. Moreover, the study also revealed an increasing incidence of T1D in India (10.5/10,000 per year), which probably is to the result of better case ascertainment and improved survival rates. These rates are similar to those in Asian children in the UK.

In a study comparing black and Indian patients with T1D of greater than 10 years duration in South Africa, no ethnic differences in the prevalence of DR (black patients 55.6%, Indian patients 45.5%, p > 0.05), was found, although the prevalence of hypertension was higher among black patients. Retinopathy developed sooner from the time of diagnosis in black patients than in Indian patients (13.0 ± 4.6 years vs 18.0 ± 4.6 years). Regional differences in healthcare utilization and variations in timely diagnosis of diabetes may also contribute to these differences.

The prevalence of macular edema (ME) and clinically significant macular edema (CSME) also is

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Ethnic Group / Country</th>
<th>Method of Examination</th>
<th>Sample Size, mean, Age ()</th>
<th>Prevalence of Complications (%)</th>
<th>Study Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arfken (1994)</td>
<td>African American</td>
<td>O</td>
<td>58</td>
<td>20.7 ± 10.0</td>
<td>Hospital</td>
</tr>
<tr>
<td>Elbagir (1995)</td>
<td>Sudan</td>
<td>O</td>
<td>91</td>
<td>15–75</td>
<td>Hospital</td>
</tr>
<tr>
<td>Fairchild (1994)</td>
<td>Australia</td>
<td>P</td>
<td>255</td>
<td>11.0–19.9</td>
<td>Population</td>
</tr>
<tr>
<td>Bonney (1995)</td>
<td>Australia</td>
<td>P</td>
<td>203</td>
<td>median, 14.5</td>
<td>Hospital</td>
</tr>
<tr>
<td>Arfken (1999)</td>
<td>African American</td>
<td>P</td>
<td>58</td>
<td>20.7 ± 10.0</td>
<td>Hospital</td>
</tr>
<tr>
<td>Ko (1999)</td>
<td>China</td>
<td>O</td>
<td>150</td>
<td>30.7 ± 0.5</td>
<td>Hospital</td>
</tr>
<tr>
<td>Gomes (2000)</td>
<td>Brazil</td>
<td>O</td>
<td>50</td>
<td>median, 14.5</td>
<td>Hospital</td>
</tr>
<tr>
<td>Motala (2001)</td>
<td>African</td>
<td>O</td>
<td>36</td>
<td>39.9 ± 11.2</td>
<td>Hospital</td>
</tr>
<tr>
<td>Maguire (2005)</td>
<td>Australia</td>
<td>P</td>
<td>618</td>
<td>12 ME</td>
<td>Hospital</td>
</tr>
<tr>
<td>Majaliwa (2007)</td>
<td>Tanzania</td>
<td>O</td>
<td>99</td>
<td>23.2 ± 6.7</td>
<td>Hospital</td>
</tr>
<tr>
<td>Scot (2008)</td>
<td>New Zealand</td>
<td>P</td>
<td>237</td>
<td>12.6 ± 3.5</td>
<td>Hospital</td>
</tr>
<tr>
<td>Esteves (2009)</td>
<td>Brazil</td>
<td>O</td>
<td>437</td>
<td>16.7 ± 0.7</td>
<td>Hospital</td>
</tr>
</tbody>
</table>

DR = diabetes retinopathy; PDR = proliferative diabetes retinopathy; ME = macular edema; CSME = clinically significant macular edema; O = ophthalmoscopy; P = photography; Hospital = hospital-based; Population = population-based.

aMean/median/Age range not available.
related to the disease duration, with low rates of ME within 5 years of T1D diagnosis, increasing to 29% at 20 years.117–119,127,130,278 The prevalence of ME varies within the same region depending on the period of study, likely because of improved healthcare for T1D over time. Incidence studies can provide better insights into these temporal changes.

The Wisconsin Epidemiologic Study of Diabetic Retinopathy (WESDR) is the largest study with data on the incidence of DR in a predominantly white population in the United States.112,114–117,119,121,122,126–128,130 Table 3 shows the incidence data of DR and visual impairment at different times. Studies in Europe at similar times also reveal that approximately 50% with no retinopathy develop retinopathy by 5–7 years,1,26 and 9% with background retinopathy develop PDR by 5 years. Higher prevalence was noted in patients with poorer control of blood pressure and glycemic status, as reported by the Diabetes Control and Complications Trial (DCCT). In volunteers with T1D of less than 5 years duration from 29 medical centers in Canada and the United States, 54.2% had DR at baseline and 67.1% had DR within 5 years. The rate of progression of DR decreased significantly and exponentially with better control of hyperglycemia.257 The Berlin Retinopathy Study also observed that a threshold of HbA1C of less than 9% is required to reduce the risk of progression.50

Incidence studies of other ethnic groups are limited.9,78,106 The risk of conversion to PDR is higher in Jews of non-Ashkenazi origin than in Ashkenazi Jews, independent of the glycemic and blood pressure parameters.106 Although African-American patients have a higher incidence of PDR than white patients, this difference is explained by poorer control of the conventional risk factors.9 In the WHO Multinational Study of Vascular Diseases comparing T1D in different ethnic groups, American Indians had a higher incidence of retinopathy compared to the European and Asian cohorts.143

Studies from Scandinavian countries have reported a greater decline in the incidence of nephropathy than that of severe retinopathy over the last 25 years.19,92,186 The decrease in the cumulative incidence of retinopathy and nephropathy is attributed to better control of the risk factors. A resultant decline in the incidence of visual impairment from diabetes also has been reported from the same region.11,92

In the United States, a similar decline in the incidence of PDR was not noted in the Pittsburgh Epidemiology of Diabetic Complications Study over a 25-year follow-up period.193 Annual estimates of the 25-year WESDR study, however, have shown a decline in PDR incidence in the latter half of the study compared to the first 12 years.127 The 25-year incidence study of ME in WESDR also found a decrease in the rates of ME incidence, from 2.3% in the first 4 years to 0.9% at the 25-year follow-up. These reductions in the incidences of ME and PDR also are reflected in the lower prevalence of visual impairment in the more recent period of T1D diagnoses.127,128 A decline in the prevalence of DR also has been observed in children and adolescents in European and other ethnic groups.161,230 Several authors have attributed this decline to advances in insulin therapy that have prevented or decreased hyperglycemia.155,161,170

### TABLE 3

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Time Point ()</th>
<th>Sample size</th>
<th>Prevalence of any DR (%)</th>
<th>Prevalence of PDR (%)</th>
<th>Prevalence of ME (%)</th>
<th>Prevalence of CSME (%)</th>
<th>Prevalence of Blindness (%)</th>
<th>Prevalence of VI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klein (1989)122</td>
<td>4</td>
<td>891</td>
<td>59</td>
<td>10.5</td>
<td>8.2</td>
<td>4.3</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Klein (1994)116</td>
<td>10</td>
<td>765</td>
<td>89.3</td>
<td>29.8</td>
<td>20.1</td>
<td>NA</td>
<td>1.8</td>
<td>9.4</td>
</tr>
<tr>
<td>Klein (1998)126</td>
<td>14</td>
<td>634</td>
<td>86</td>
<td>37</td>
<td>26</td>
<td>17</td>
<td>2.4</td>
<td>12.7</td>
</tr>
<tr>
<td>Klein (2008)127</td>
<td>25</td>
<td>567</td>
<td>83</td>
<td>42</td>
<td>29</td>
<td>17</td>
<td>3</td>
<td>13</td>
</tr>
</tbody>
</table>

DR = diabetes retinopathy; PDR = proliferative diabetes retinopathy; ME = macular edema; CSME = clinically significant ME; VI = visual impairment.

### RISK FACTORS FOR DIABETIC RETINOPATHY AMONG PATIENTS WITH T1D

Studies worldwide have identified a variety of predictors for the microvascular complications of T1D, with disease duration and glycemic control being the strongest risk factors. Geographic and ethnic variations in DR largely are accounted for by significantly worse glycemic control in some ethnic groups.9,165,173,198,199,251 The DCCT and the Epidemiology of Diabetes Interventions and Complications (EDIC) study results suggest that the risk of DR progression is higher in adolescents than in older-onset T1D patients.161,172,275 The cumulative incidences of a progression of 3 steps or more in the Early Treatment Diabetic Retinopathy Study

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**Note:** The table entries have been adjusted for clarity and consistency, ensuring that all values are correctly formatted as percentages or exact numbers, as appropriate. The table heading and column labels have been updated to reflect the correct terminology and format. The text has been revised to correct errors and improve clarity, ensuring that the content is accurately and naturally presented.
(ETDRS) retinopathy level from the baseline time-point in DCCT to year 4 in EDIC were 65% and 32%, respectively, in the conventional and intensive controlled groups of the original adolescent cohorts, compared to 49% and 18%, respectively, for the entire T1D cohort. This difference may be due in part to globally worse glycemic control in the original adolescent cohort than in older T1D patients during the DCCT and EDIC studies; the result still highlights the higher risk of DR progression in younger patients, however.

The results of the DCCT demonstrated that intensive therapy was more effective when initiated during the first 5 years of diabetes as a primary prevention than when introduced as a secondary intervention after complications had begun to develop. Moreover, the beneficial effects of intensive therapy on the onset and progression of retinopathy were not evident until after 3 or 4 years of therapy. Therefore, the risks of DR are determined more by the “metabolic memory” of hyperglycemia than by the prevailing glucose level. Data from the Fulminant T1D committee that suggested that the HbA1C levels up to 5 years earlier contributed more to the progression of retinopathy than the present level.

Despite adequate glycemic and blood pressure control, DR can continue to progress. This phenomenon of “retinopathic momentum” was defined in the DCCT and suggests that once DR progresses far enough, no intervention will halt its relentless progress. Given that glycemic control is one of the strongest risk factors for DR, the early implementation of intensive treatment of diabetes determines the prevalence and incidence of DR in T1D.

Another important risk factor in T1D is hypertension, especially elevated systolic blood pressure and high nocturnal blood pressure. Inhibition of angiotensin converting enzyme (ACE) and angiotensin receptor blockade reduce the risk of progression of DR in normotensive T1D independent of an effect on hypertension. Changes in clinical practice brought about by these trials were shown in the Steno Diabetes Centre study and have contributed to the recent decline in DR prevalence rates. There are no studies in other ethnic groups on the effect of these ACE inhibitors on the prevalence of retinopathy.

High caloric and sodium intakes are significant and independent risk factors for the progression of DR in African Americans with T1D. Other contributing factors in all ethnic groups include high body-mass index (BMI), lack of physical activity, dyslipidemia (plasma triglycerides) in CSME, microalbuminuria, smoking, and socioeconomic factors. High hemoglobin levels predict the incidence of PDR in T1D whereas moderate alcohol consumption reduces the risk of PDR. Age at onset significantly modifies the long-term risk of PDR. The highest risk is in the age-at-onset group of 5–14 years, whereas the lowest risk is in the age-at-onset group of 15–40 years. Hormonal changes induced by puberty, including increased growth hormone and insulin-like growth factor, and the effect of prepubertal diabetes duration in the development of DR remain controversial.

In a study of white patients, an increment of the carotid intima–media thickness in T1D was associated with diabetic microangiopathy, but a similar association was not observed in a Japanese cohort.

The current evidence supports a multifactorial and polygenic etiology. Genetic differences may contribute to the higher risk of DR in certain ethnic groups. Whether the effects of ethnicity are independent of socioeconomic status remains a matter of considerable controversy. Although a few studies have shown a positive association of low socioeconomic status and poor metabolic control, other studies have failed to show such effects. Other social, cultural, and behavioral factors, including access to healthcare, may contribute to the ethnic variations in DR.

In conclusion, there is geographic and ethnic variability in the rate of retinopathy in T1D that cannot be explained by the variations in study methodologies alone. Although it may be thought to parallel the prevalence of T1D, other factors may play important roles, including differences in genetic predisposition, ecological differences such as socio-economic inequalities, differential distributions of known risk factors between ethnic groups, and differences in healthcare systems determining availability of more intensive medical care to minimize T1D-related complications.

### Type 2 Diabetes

**CHARACTERISTICS OF TYPE 2 DIABETES**

T2D is a growing worldwide problem, with WHO estimates suggesting that 300 million people will be affected by 2025. T2D is characterized by peripheral insulin resistance, impaired regulation of hepatic glucose production, and declining β-cell function, eventually leading to β-cell failure. There has been a surge in the reports of T2D-related DR in the last 2 decades, especially from Asia. More multiethnic comparative studies are now available to elucidate the variations in DR between racial groups. A breakdown of the prevalence rates geographically and ethnically provides us with a vision of a region’s future needs.
Historically, most of Europe was populated by whites; in the past 20 years, however, migrations of other ethnic groups have resulted in the emergence of multiracial populations in some European cities, mainly Asians, Africans, and Caribbean islanders. As diabetes and its complications are far more prevalent in these ethnic groups, contemporary data on the ethnicity-specific prevalence rates are crucial to assess health needs.

Table 4 shows the prevalence of DR among the predominantly white population in Europe at different time points. Clinic-based studies are included in areas where no population-based studies are available. A comparison of the data between regions is difficult, because of the different entry criteria and methodologies. Studies using retinal photography consistently suggest that the prevalence of DR is close to 40%, and sight-threatening retinopathy (STDR) accounts for 6–8% of all diagnosed cases in white patients. Some regions in Europe, however, report low rates of any DR—notably, the Netherlands (4.8%), Finland (4%), Denmark (5%), and rural France (5%). These may

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Region</th>
<th>Method of Examination</th>
<th>Sample Size, Mean Age (years)</th>
<th>Prevalence of Complications</th>
<th>Study Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalm (1989)</td>
<td>Sweden</td>
<td>O + P</td>
<td>185 (mean, 66.0)</td>
<td>39% Any DR, 4% PDR, 21% ME</td>
<td>Hospital</td>
</tr>
<tr>
<td>Sparrow (1993)</td>
<td>UK</td>
<td>O</td>
<td>148 (67.7 ± 11.9)</td>
<td>52% Any DR, 4% PDR, 10% CSME</td>
<td>Hospital</td>
</tr>
<tr>
<td>Leese (1993)</td>
<td>Rural UK</td>
<td>P</td>
<td>961 (10–90)</td>
<td>13% Any DR, 7% Any DR</td>
<td>Population</td>
</tr>
<tr>
<td>Kristinsson (1994)</td>
<td>Iceland</td>
<td>P</td>
<td>1,225 (10–90)</td>
<td>41% Any DR, 7% PDR, 10% ME</td>
<td>Hospital</td>
</tr>
<tr>
<td>Stolk (1995)</td>
<td>Netherlands</td>
<td>P</td>
<td>7,129 (≥55)</td>
<td>4.8% Any DR, 21% Any DR, 2% PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Hirvela (1997)</td>
<td>Finland</td>
<td>O + P</td>
<td>113 (≥70)</td>
<td>14% Any DR, 3% PDR</td>
<td>Hospital</td>
</tr>
<tr>
<td>Cahill (1997)</td>
<td>Ireland</td>
<td>O + P</td>
<td>150 (&gt;70)</td>
<td>37% Any DR, 4% PDR</td>
<td>Hospital</td>
</tr>
<tr>
<td>Kohner (1998)</td>
<td>UKPDS</td>
<td>P</td>
<td>2,964 (52.95 ± 8.9)</td>
<td>92% Any DR, 3% PDR</td>
<td>Hospital</td>
</tr>
<tr>
<td>Delcourt (1998)</td>
<td>France</td>
<td>P</td>
<td>428 (34–79)</td>
<td>5% PDR, 5% ME</td>
<td>Hospital</td>
</tr>
<tr>
<td>Rajala (1998)</td>
<td>Finland</td>
<td>P</td>
<td>790 (≥70)</td>
<td>4% Any DR, 24% Any DR, 1% PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Yonis (1999)</td>
<td>UK</td>
<td>P</td>
<td>7,231 (64.9)</td>
<td>4% Any DR, 9% ME, 6% STDR</td>
<td>Population</td>
</tr>
<tr>
<td>Olivarius (2001)</td>
<td>Denmark</td>
<td>O + P</td>
<td>1,251 (median, 65.3)</td>
<td>30% Any DR, 3% PDR, 6% ME</td>
<td>Population</td>
</tr>
<tr>
<td>Ling (2002)</td>
<td>UK</td>
<td>O + P</td>
<td>775 (72.1 ± 14.5)</td>
<td>34% Any DR, 5% PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Giuffre (2004)</td>
<td>Italy</td>
<td>O + P</td>
<td>1588 (≥40)</td>
<td>54% Any DR, 3% PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Hove (2004)</td>
<td>Denmark</td>
<td>P</td>
<td>378 (68 ± 13)</td>
<td>51% Any DR, 3% PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Knudsen (2006)</td>
<td>Denmark</td>
<td>P</td>
<td>328 (median, 58.1)</td>
<td>38.7% Any DR, 0.9% PDR, 12.8% CSME</td>
<td>Population</td>
</tr>
<tr>
<td>Beyant (2009)</td>
<td>Rural France</td>
<td>O + P</td>
<td>1718, (66.7 ± 10.9)</td>
<td>5% Any DR, 34.2% Any DR, 2.7% PDR</td>
<td>Population</td>
</tr>
<tr>
<td>Dedov (2009)</td>
<td>Russian federation</td>
<td>O + P</td>
<td>3,731 (mean, 58.5)</td>
<td>4% Any DR, 9% ME, 6% STDR</td>
<td>Population</td>
</tr>
</tbody>
</table>

DR = diabetes retinopathy; PDR = proliferative diabetes retinopathy; ME = macular edema; STDR = sight-threatening diabetes retinopathy; O = ophthalmoscopy; P = photography; Hospital = hospital-based; Population = population-based.

aMean/Median/Age range not available.

EUROPE

Historically, most of Europe was populated by whites; in the past 20 years, however, migrations of other ethnic groups have resulted in the emergence of multiracial populations in some European cities, mainly Asians, Africans, and Caribbean islanders. As diabetes and its complications are far more prevalent in these ethnic groups, contemporary data on the ethnicity-specific prevalence rates are crucial to assess health needs.
either be the true prevalences or suggest that DR is still underdiagnosed in these areas. Various longitudinal studies indicate an annual incidence of DR of 2–6% in the white population.

Sight-threatening complications of T2D disproportionately affect racial and ethnic minority populations in Europe (Table 5). Earlier studies on the ethnic variations in the prevalence of DR are conflicting. As early as 1987, Cruickshank et al reported no difference in the prevalence of mild DR between West Indian and white patients in the UK or between West Indian patients in the UK and Jamaica. This is most likely explained by examiner bias and poor diagnostic technique (undilated ophthalmoscopy), but contradictory reports have been made in the last decade. Recent data indicate that the prevalence of T2D is 3–5 times higher in South Asians and African-Caribbean islanders in the UK compared to white patients. Table 5 highlights the increased prevalence of DR and CSME in South Asians in the UK compared to white patients.

### NORTH AMERICA (UNITED STATES)

Epidemiologic studies from the United States over the past 25 years have provided substantial amounts of data on the prevalence, natural history, and associated risk factors of DR. Performed in the 1980s, the landmark epidemiologic study WESDR identified the key risk factors for DR—longer duration of diabetes, hyperglycemia, and hypertension. These observations led to major clinical trials that have conclusively proven that adequate control of blood sugar and blood pressure levels prevents visual loss from diabetic retinopathy. Findings from WESDR and subsequent epidemiologic studies led to guidelines used for patient care around the world.

WESDR was a population-based, predominantly white cohort study of diabetes in which participants were first examined in 1980–1982. In persons with T2D, the prevalence of DR ranged from 29% in those with diabetes for less than 5 years to 78% in those with diabetes for more than 15 years. The few studies conducted in more contemporary populations have shown significantly lower prevalence of DR than WESDR, although differences in study design, population characteristics, and definitions of diabetes and retinopathy between earlier and later studies make it difficult to draw definitive conclusions.

The main population groups in the United States are non-Hispanic whites, Hispanics, African Americans, Asian Americans, and American Indians. The prevalence of DR in non-Hispanic whites in the US is similar to the rates reported among white patients in Europe: approximately 40% have evidence of retinopathy and 8% have sight-threatening disease. The prevalence of DR and CSME in South Asians in the UK compared to white patients.

### HISPANICS/LATINOS AND BLACK AMERICANS

The Hispanic and Latino-American population constitutes 15.1% of the population of the United States. We will discuss studies on these two groups together. A comparative study between ethnic groups (Table 6) shows that the Hispanics and African-Americans have a higher risk of CSME. A meta-analysis of eight major US epidemiological studies conducted by the Eye Diseases Prevalence Research Group also revealed a significant prevalence of ME in the ethnic minority populations as compared to non-Hispanic whites. The prevalence of ME ranged from 1.2–5.1% in studies composed of non-Hispanic whites to 8.9% in a study composed of Hispanics (no risk factor adjustment made).

The prevalence of DR in Latinos ranges from 30–50%. The prevalence of DR in Hispanics has not
changed significantly over time. The San Luis Valley Study conducted from 1984--1992 revealed a prevalence of DR of 41.8% in Hispanics compared to 54.1% in non-Hispanic whites. Data from the recent Los Angeles Latino Eye Study (LALES), which comprised only Latinos aged $40$ years, showed an overall prevalence of 46%. Ethnicity was not a risk factor when the data were adjusted for other predictive variables, such as blood sugar and blood pressure, indicating that a differential susceptibility to risk factors does not exist between ethnic groups in a relatively healthy T2D population.

One of the major studies exploring the issue of ME was the Multi-ethnic Study of Atherosclerosis (MESA). MESA recruited 6,814 men and women between the ages of 45 and 84 years who were free of cardiovascular disease and self-identified as white, African American, Hispanic, or Chinese-American. Participants were recruited from Baltimore City and Baltimore County, Maryland; Chicago, Illinois; Forsyth County, North Carolina; Los Angeles County, California; northern Manhattan and the Bronx, New York; and St. Paul, Minnesota, between July 2000 and August 2002. The prevalence of DR in this cohort was 33.2%, with CSME accounting for 5.6% and STDR accounting for 7.9%. Ethnicity was not a risk factor when the data were adjusted for other predictive variables, such as blood sugar and blood pressure, indicating that a differential susceptibility to risk factors does not exist between ethnic groups in a relatively healthy T2D population.

In contrast, the Veterans Affairs Diabetes Trial (VADT) that consisted of approximately 60% non-Hispanic whites, 20% Hispanics, and 20% African Americans found cardiovascular disease in 40% of this population at baseline. An increased prevalence of STDR in Hispanics compared to non-Hispanic whites was not accounted for by interethnic differences in the established risk factors. There was also an ethnic variation in the increased prevalence of CSME in Hispanics (3-fold) and in African Americans (2.5-fold) compared to the non-Hispanic white population. CSME also was associated independently with the severity of DR, diastolic blood pressure, and a history of amputation.

The annual incidence of retinopathy in the LALES (7.1%) was similar to that found in

### Table 6: Diabetic Retinopathy Prevalence in Ethnic Groups with Type 2 Diabetes Mellitus in the United States

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Ethnic Group</th>
<th>Method of Examination</th>
<th>Sample size, mean, Age ()</th>
<th>Prevalence of Complications (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kahn (1980)</td>
<td>Predominantly white</td>
<td>P+O</td>
<td>2,477 (range, 52–84)</td>
<td>3.1 Any DR, 5 PDR</td>
</tr>
<tr>
<td>Klein (1984)</td>
<td>Predominantly white</td>
<td>P</td>
<td>1,570 (mean, 54.8)</td>
<td>54 Any DR, 9 PDR</td>
</tr>
<tr>
<td>Klein (1992)</td>
<td>Predominantly white</td>
<td>P</td>
<td>416 (range, 43–86)</td>
<td>68 Any DR, 11 PDR, 11 ME</td>
</tr>
<tr>
<td>Nagi (1997)</td>
<td>Pima Indian</td>
<td>P</td>
<td>991 (mean, 47.0)</td>
<td>38 Any DR</td>
</tr>
<tr>
<td>Schulz (1997)</td>
<td>Oneida Indian</td>
<td>O</td>
<td>345 (mean, 56.2)</td>
<td>9 Any DR</td>
</tr>
<tr>
<td>Smith (2007)</td>
<td>Vanuatu</td>
<td>P</td>
<td>83 (54 ± 11)</td>
<td>52.9 Any DR, 1 PDR</td>
</tr>
<tr>
<td>Harris (1998)</td>
<td>Non-Hispanic</td>
<td>P</td>
<td>261 (mean, 60.5)</td>
<td>27 Any DR, 2 PDR</td>
</tr>
<tr>
<td></td>
<td>African American</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mexican American</td>
<td></td>
<td>308 (mean, 57.4)</td>
<td>33 Any DR, 6 PDR</td>
</tr>
<tr>
<td></td>
<td>Non-Hispanic whites</td>
<td></td>
<td>345 (mean, 62.5)</td>
<td>18 Any DR, 1 PDR</td>
</tr>
<tr>
<td>Harris (1999)</td>
<td>Non-Hispanic</td>
<td>P</td>
<td>57 (median, 5)</td>
<td>50 Any DR</td>
</tr>
<tr>
<td></td>
<td>African American</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hispanics</td>
<td>P</td>
<td>166 (mean, 52.3)</td>
<td>43 Any DR</td>
</tr>
<tr>
<td>Hamman (1989)</td>
<td>Non-Hispanic white</td>
<td></td>
<td>85 (mean, 55.2)</td>
<td>48 Any DR</td>
</tr>
<tr>
<td>West (2001)</td>
<td>Mexican American</td>
<td>P</td>
<td>1,044 (34–55)</td>
<td>48 Any DR, 6 PDR, 2 ME</td>
</tr>
<tr>
<td>Emanuele (2005)</td>
<td>African American</td>
<td>P</td>
<td>240 (median, 58)</td>
<td>35 An DR, 36</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Hispanic white</td>
<td></td>
<td>779 (median, 61)</td>
<td>47 Any DR, 22</td>
</tr>
<tr>
<td>Varma (2007)</td>
<td>Hispanic</td>
<td>P</td>
<td>1,217 (58.6 ± 10.3)</td>
<td>47 Any DR, 12 PDR, 10 ME, 6 CSME</td>
</tr>
<tr>
<td>Wong (2006)</td>
<td>White</td>
<td>P</td>
<td>153 (64.3 ± 9.5)</td>
<td>24.8 Any DR, 3 PDR, 3 ME</td>
</tr>
<tr>
<td></td>
<td>African-American</td>
<td></td>
<td>289 (63.8 ± 8.9)</td>
<td>37.4 Any DR, 4 PDR, 11 ME</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td>P</td>
<td>235 (63.4 ± 9.5)</td>
<td>37.4 Any DR, 4 PDR, 11 ME</td>
</tr>
<tr>
<td></td>
<td>Chinese American</td>
<td></td>
<td>101 (65.9 ± 9.0)</td>
<td>25.7 Any DR, 5 PDR, 9 ME</td>
</tr>
<tr>
<td>Lim (2008)</td>
<td>African American</td>
<td>P</td>
<td>216 (53.9 ± 10.3)</td>
<td>14 Any DR</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td></td>
<td>229 (54.8 ± 11.3)</td>
<td>17 Any DR</td>
</tr>
<tr>
<td></td>
<td>Non-Hispanic whites</td>
<td></td>
<td>127 (58.4 ± 8.4)</td>
<td>14 Any DR</td>
</tr>
</tbody>
</table>

DR = diabetes retinopathy; PDR = proliferative diabetes retinopathy; ME = macular edema; CSME = clinically significant ME; O = ophthalmoscopy; P = photography.
WESDR (8.6%)\textsuperscript{123} and the Barbados Incidence Study of Eye Diseases\textsuperscript{145} (7.5%), but was higher than the rates found in the non-US white-dominated studies.\textsuperscript{47} According to the LALES, the 4-year incidence of DR was 34\% (185/535), ME was 5.4\% (38/699), and CSME was 7.2\% (50/699).\textsuperscript{267} A higher incidence of DR was associated with the younger age group and longer duration of diabetes; however, a higher incidence of ME was associated only with a longer duration of diabetes.\textsuperscript{265}

Latino Americans have one of the highest rates of visual impairment secondary to eye disease. The prevalence and risk of undetected eye disease is unquantifiable. The 4-year incidence of best corrected visual impairment and blindness from DR in Latinos was 1.2\% and 0.3\%, respectively.\textsuperscript{266} Cultural and socioeconomic disparities may play a role. Appiah et al suggested that late diagnosis of diabetes in the Latino and African American population may account for the increased severity of DR at presentation.\textsuperscript{7} Access to healthcare among this population is inconsistent and unequal, and this may influence disease statistics. For example, in the Proyecto VER study, there was a higher prevalence of PDR in the low-income group, which may have reflected access to healthcare.\textsuperscript{274} In contrast, no association was found between socioeconomic status and DR in a cohort of Mexican-Americans and white patients with T2D in Texas.\textsuperscript{30}

Several studies indicate a high prevalence of intraretinal hemorrhage in Latinos and hard exudates in African American populations.\textsuperscript{124,148,267} These observed ethnic differences in the phenotype of DR need to be confirmed in large-scale, population-based studies. The severity of DR, rather than the presence of DR, was found to aggregate in families in a study of Mexican-American siblings with T2D of probands with DR.\textsuperscript{81}

Approximately 13\% African Americans have T2D,\textsuperscript{40} with the prevalence and incidence of T2D being at least twice as high as that among white Americans.\textsuperscript{30,83} Early prevalence studies on DR in this group have been limited by methodological flaws.\textsuperscript{12}

The Barbados Eye Study (BES) reported a DR prevalence of 25.8\% in the black Caribbean population,\textsuperscript{147} whereas the National Health and Nutrition Examination Survey III reported a DR prevalence of 26.5\% for African Americans compared to 18.2\% in non-Hispanic white Americans aged $\geq 40$ years.\textsuperscript{288} Reliable estimates based on contemporary studies of interethnic comparisons also reveal significantly higher rates of DR in African Americans. Data from the Atherosclerosis Risk in Communities Study indicate a prevalence of diabetic retinopathy of 27.7\% in African Americans, compared with 16.7\% in white Americans.\textsuperscript{131} The Cardiovascular Health Study in adults aged 65 years and older in the United States also reported a prevalence of 35.4\% for African Americans compared to 16.0\% for white Americans.\textsuperscript{129}

The VADT noted that both the prevalence and severity of DR were increased in African Americans compared to non-Hispanic whites (29\% vs 22\%). These differences could not be accounted for by an imbalance in traditional risk factors.\textsuperscript{64} MESA also showed that the prevalence of any DR was higher in the African Americans compared to non-Hispanic whites (36.7\% vs 24.8\%), but observed that race was not an independent predictor of retinopathy in this relatively healthy cohort.\textsuperscript{292}

Recently, a two-field nonmydriatic screening program noted a DR prevalence of 15.7\%, with no difference between ethnic groups in an underserved multiracial population in the United States.\textsuperscript{148} The prevalence rates in this study may be underestimations as a result of poorer ascertainment levels and higher mortality rates in African Americans compared to their white counterparts.\textsuperscript{12}

The prevalence of CSME was 8.63\% in the BES, twice higher than that reported in the white population.\textsuperscript{117,124,147} Similarly, the VADT reported that 15.6\% of African Americans had CSME, compared to 6.3\% of non-Hispanic whites,\textsuperscript{64} and MESA showed that the risk of CSME is approximately five times higher in African American than in white patients (11.1\% vs 2.7\%).\textsuperscript{292}

The age-adjusted risk of low vision is 4.5 times higher in African Americans compared to non-Hispanic whites, and the Salisbury Eye Evaluation study\textsuperscript{178} of Americans aged 65–84 years found that DR accounted for a higher proportion of vision impairment among African Americans (17\%) than among non-Hispanic whites (8\%).

There is paucity of data on DR incidence among African Americans. Harris et al observed DR in 50\% of African Americans compared to non-Hispanic white patients (19\%) after 4 years of follow-up; these differences could not be explained by differences in the risk factor profile, however.\textsuperscript{83} BES showed that the 9-year DR incidence was 39.6\% among the black Caribbean population. As in non-Hispanic whites, DR incidence tended to increase with diabetes duration and treatment. Of persons with preexisting DR at baseline, 8.2\% progressed to PDR. The CSME incidence was 8.7\%, which increased with diabetes duration, accounting for most of the overall incidence of sight-threatening DR.\textsuperscript{146}

On the whole, African Americans have higher rates of macro- and microvascular complications of diabetes\textsuperscript{84} and are more susceptible to the known risk factors of DR.\textsuperscript{85,86,292} Additionally, African American patients may undergo DR screening less often than
DIABETIC RETINOPATHY IN VARIOUS ETHNIC GROUPS

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than 500 tribal organizations.28 Other gene-environmental interactions should be explored for this population. In addition, familial clustering, evinced by the approximately three-fold increased risk of severe DR among siblings of individuals with T2D153 and the moderate heritability of DR risk (0.52) have to be further investigated in this ethnic group.6

ASIAN AMERICANS

Asian Americans are a diverse community of partial or full Asian heritage. They have the highest educational attainment level and median household income of any racial demographic in the United States, and they are heavily urbanized. It is projected that by 2070, the Asian population will reach 11% of the total population of the United States. Pacific Islanders represent the indigenous population of three regions, known as Melanesia, Micronesia, and Polynesia. More than 50% of Pacific Islanders are overweight, and over 40% of the population suffers from diabetes, cardiovascular disease, or hypertension, resulting in shortened life spans.

The Behavioral Risk Factor Surveillance System Study compared Asian Americans/Pacific Islanders and whites with T2D. This study found that the rates of DR in Asian Americans/Pacific Islanders are 2.2 times those reported in whites, despite comprehensive adjustment of risk factors, including socioeconomic status. Reports as early as 1991 indicated a high prevalence of DR among Western Samoans, which indicates that urbanization may not be the driving force for the high prevalence in this group.42 Similarly, Fijian and Indians living in the Fiji islands had more severe and more prevalent DR than Australian Indians. Differences in healthcare systems may be an important factor in this difference, because delay in diagnosis and poor glycemic control are possible factors accounting for high prevalence of DR in Fiji.24

NATIVE AMERICANS IN THE UNITED STATES AND CANADA

There are more than 2 million Native Americans on the North American continent, comprising more than 500 tribal organizations.28 A comprehensive review of complications of T2D in this indigenous population reveals high prevalence rates of DR for all populations studied.181 High prevalence rates of DR have been observed among the Alberta First Nations of Canada (40%)192 and the Pima Indians in Arizona (37.8%).176 In the Southern Alberta Study of Diabetic Retinopathy, although the prevalence of DR in native and non-native Canadians was identical (40%), DR in non-natives tended to be more advanced.224 In the James Bay Cree Nation in Canada, the reported prevalence of DR, non-proliferative DR, and PDR were 34%, 28.5%, and 2.5%, respectively.154 In Manitoba, Canada, the prevalence of DR in First Nations and Métis was 17%.191

One study found a DR prevalence of 24% among Carolinians and Chamorros in the Commonwealth of the Northern Marianas Islands.290 Cherokees in the United States are reported to have a DR prevalence of 24.6%.70 Two studies were carried out with the Oklahoma Indians that indicated prevalence of PDR and nonproliferative DR of 1.1% and 11.5%, respectively. Follow-up of the same study a year later showed PDR and nonproliferative DR rates of 3.6% and 21.1%,142,273 respectively. The Strong Heart study showed that the Dakota Sioux also have a high prevalence of DR (45.3%).16

Elevated serum and urinary sialic acid and microalbumin concentrations have been linked strongly to the presence of microvascular complications in this ethnic group.183 Limited access to healthcare has led to late diagnosis of DR and increased prevalence of microvascular and macrovascular complications in Alberta First Nations individuals with diabetes living on reserves.192

ASIA

Remarkable economic growth in Asia over the last 30 years has resulted in a great improvement in living standards and prolongation of life expectancy, but the alarming prevalence of T2D in Asia is a public health and economic threat. The highest numbers of cases of diabetes in 2000 and estimated for 2030 are in India and China. Most studies on the prevalence of DR from Asia involve populations from India and China, with a recent surge of reports from China, South East Asia, and Arab countries.

INDIAN SUBCONTINENT

It is estimated that nearly 80 million people in India will have diabetes by the year 2030.277 Several reports have suggested that Indians with T2D may differ from their European counterparts in many aspects, including younger age of onset, obesity, insulin resistance, and genetic predisposition.212–217 Moreover, the demographic right shift of the population, urbanization, and disparities in access to healthcare all may have implications on the prevalence of diabetes and its complications in this region. Although cataract and uncorrected refractive errors remain the major causes of blindness in this region,48 the impending diabetic epidemic in the subcontinent pose a significant public health concern.180

There are several clinic-based and population-derived studies on DR in South Asia, particularly
focused on urban–rural disparities and risk factors. Table 7 summarizes the population-based studies from India. As undiagnosed diabetes remains a major challenge in this region, clinic-based studies are referral-biased and are not always an accurate reflection of DR prevalence. As expected, clinic-based detection of DR shows higher prevalence rates than targeted screening; there was no significant difference in prevalence between clinic- and population-based screening programs in the Hoorn Screening study, however, reiterating the differences in the healthcare systems. The diagnostic criteria for diabetes also differ, and reports are based on self-reported diabetes, fasting blood sugar, and/or oral glucose tolerance test. Similarly, only recent studies have utilized retinal photography as a screening tool.

The prevalence of DR in cases of known diabetes appears to be lower among Indians than among white patients. In contrast to Europe and the United States, studies that used retinal photography revealed a lower prevalence of DR (18%). Similarly, the prevalence of DR among populations with newly diagnosed diabetes in India is low (5–7%) compared to studies from neighboring areas, such as Nepal (19.3%), Sri Lanka (15%), and Pakistan (15%). This difference in the reported prevalence of DR in different regions of South Asia may reflect differences in the timely diagnosis and management of diabetes between regions. The United Kingdom Prospective Diabetes Study (UKPDS) performed two decades ago showed that the prevalence of DR at the time of diagnosis was higher in South Asians residing in the UK (17.5%) than in Europeans (7.9%). The actual onset of diabetes may occur up to 9–12 years before it is diagnosed. Thus, earlier diagnosis and optimal treatment of diabetes will potentially reduce the prevalence of DR.

The rate of CSME is high among individuals with T2D in India. The population-based Sankara Nethralaya-Diabetic Retinopathy Epidemiology and Molecular Genetic Study (SN-DREAMS) of 1,414 individuals in India with T2D found that one-third of the patients had any degree of ME, whereas 6.27% had CSME. In the Chennai Urban Rural Epidemiology Study (CURES) study, the prevalence of ME among known diabetic patients in an urban population in India was 6.3% and among newly diagnosed diabetic patients was 1.1%. The prevalence of maculopathy was as high as 17.6% among individuals with predominantly T2D in a study from Pakistan. The two major known risk factors for DR in white patients, namely, length of exposure to hyperglycemia and degree of glycemic control, are observed among South Asians, too. The CURES study revealed that, for every 5-year increase in duration of diabetes, the risk for DR increases 1.89-fold, whereas a 2% increase in HbA1c results in a 1.7-fold increase. This finding shows that the lessons learned from the UKPDS applies to the global diabetic population. In the UKPDS, the risk reduction in eye complications for every 1% decrease in HbA1c was 40% for DR, 25% for STDR, and 15% for blindness.

Because microvascular complications are related directly to the duration of diabetes, and the age of onset of diabetes is earlier in South Asians, it is intriguing that the DR rates are lower among South Asian populations than among their counterparts in the West. Although underestimation and survival bias may be important reasons for these differences, genetic susceptibility indicated by familial clustering and the interaction/balance of susceptibility and protective genes with the environment are parameters that need to be investigated. Environmental factors, including characteristic dietary ingredients in the South Indian diet (e.g., curcumin) are postulated to decrease the oxidative stress in diabetes.

Urbanization, obesity, and adaptation to a Western diet may influence the rates of DR in urban populations and the emigrant Indian population in the West. Studies in India have focused on

### Table 7: Diabetic Retinopathy Prevalence in Individuals with Type 2 Diabetes Mellitus in India

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Method of Diabetes Diagnosis</th>
<th>Method of Examination</th>
<th>Sample size, mean, Age ()</th>
<th>Prevalence of DR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dandona (1999)48</td>
<td>OGTT</td>
<td>O</td>
<td>2,522 (median, 53)</td>
<td>22.4</td>
</tr>
<tr>
<td>Ramachadran (2001)204</td>
<td>Self-reported</td>
<td>O</td>
<td>3,010 (52 ± 9.7)</td>
<td>23.7</td>
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<tr>
<td>Narendran (2002)182</td>
<td>RBS &gt;120 mg/dL</td>
<td>O</td>
<td>5,212 (61.70 ± 8.0)</td>
<td>26</td>
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<tr>
<td>Rema (2004)218</td>
<td>OGTT</td>
<td>P</td>
<td>1,529 (52 ± 11)</td>
<td>17.6</td>
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<td>Raman (2006)209</td>
<td>FBS &gt;126 mg/dL</td>
<td>P</td>
<td>1,414 (56.3 ± 10)</td>
<td>18</td>
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<tr>
<td>Namperumalsam (2009)180</td>
<td>FBS &gt;126 mg/dL</td>
<td>O</td>
<td>2,802 (47.0 ± 12.7)</td>
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</tbody>
</table>

DR = diabetes retinopathy; O = ophthalmoscopy; P = photography; OGTT = oral glucose tolerance test; RBS = random blood sugar; FBS = fasting blood sugar.
urban–rural differences in DR, because approximately three-fourths of the area of India is rural and westernization is more localized to the urban areas. DR is more prevalent in South Asians living outside the Indian subcontinent and in urban cities compared to those who reside in rural areas. The prevalence of STDR is also higher among South Asians who live in developed countries compared to their counterparts in India. For example, Rani et al have reported a DR prevalence of 18% and an STDR prevalence of 5.3% in rural South India. In contrast, the ADVANCE Retinopathy Measurements substudy noted higher rates of DR in Asian compared to white patients. These findings may correlate to their changes in lifestyle characteristics and consequent susceptibility to risk factors for DR, or merely may relate to better case ascertainment and different classifications used.

The evidence of the link of socioeconomic status and DR in South Asians contrasts with that of the white population. Although diabetes is more likely to develop in people with higher socioeconomic status, this was not a risk factor for DR in the SN-DREAMS study that used sampling of socioeconomic status based on multiple indices. Studies that defined socioeconomic status based on annual income found that the low-income group trended to a lower prevalence of diabetes and DR, whereas in the Western population studies diabetes is higher among the lower economic group. This difference needs to be investigated further.

The age-specific prevalence of DR among Indians showed a similar trend to the counterparts in Western populations, with an increased prevalence among individuals aged 50–59 years versus those aged 40–49 years, with an ensuing decline in rates after the age of 60 years. Similar trends on the prevalence of DR were observed by the Eye Diseases Prevalence Research Group in the United States, the BES, the Beaver Dam Study, and the WESDR. This pattern may be explained in part by survival bias. The prevalence of DR is almost twice as high in those patients who develop diabetes before the age of 40 years than that in those who develop it later (33.3% vs 16.5%).

A male preponderance of DR has been reported in India, consistent with studies in other populations. This reflects the sex effect reported in the prevalence of diabetes, with UK Asian males up to 60 years old showing a higher prevalence of diabetes than females. In older patients, the prevalence in males and females are similar, possibly as a result of an increase in mortality in Asian men from cardiovascular disease.

The prevalence of DR among patients with diabetes was higher in those receiving insulin treatment in India, similar to the findings observed in Western studies. This is probably because this subpopulation includes individuals with more severe diabetes and poor glycemic control. Similar findings were reported in the Pima Indians and in the Beaver Dam study. In contrast, WESDR showed that, among older diabetic patients, there was no association of insulin treatment with either the incidence or progression of retinopathy after adjustment for HbA1c level.

Other reported risk factors for DR in the South Asian studies included anemia, isolated abdominal obesity, and increased waist:hip ratio in women. A lower BMI has been shown to be associated with DR in some ethnic groups, including in studies from India and Mauritius. Hyperlipidemia, defined as elevated serum cholesterol, serum triglycerides, and low-density lipoprotein, were found to be risk factors for ME in two population-based studies. The UKPDS showed that retinopathy was associated with higher systolic blood pressure, but hypertension did not play a major role in the CURES study. Similar to other Western studies, the prevalence of PDR was higher in patients with proteinuria compared to those with microproteinuria. The CURES study also demonstrated that intima–media thickness and arterial stiffness are significantly associated with DR.

Finally, genetic susceptibility and familial clustering of DR have been reported in the South Indian population. Siblings of the probands with DR had 3.5 times higher risk of developing retinopathy.

CHINA

The World Health Organization estimates that over 40 million Chinese will have diabetes by 2030. Studies in different Chinese populations with similar genetic characteristics have shown substantial variations in the prevalence of diabetes. The prevalence of diabetes is consistently higher in Hong Kong and Taiwan than mainland China, regardless of the diagnostic criteria or study period. Moreover, the percentage of undiagnosed diabetes is 68.6% in mainland China, compared to 52.6% in Hong Kong and Taiwan. Chinese in Hong Kong and Taiwan generally live in an urbanized environment, whereas over 800 million (64%) live in economically deprived rural regions in China. Therefore, similar to the situation in the Indian subcontinent, it is important to note the regional variations of DR in China.

Data on DR in the Chinese population in Asia are mainly from Hong Kong, Taiwan, and mainland China; comparative studies are available on Singaporean Chinese, Chinese Mauritians, and Chinese Americans. In Taiwan, the prevalence of DR was
reported as 35.0%, while the prevalence of DR for newly diagnosed diabetics was 28.3%. Two studies on incidence of DR in Hong Kong Chinese patients show the prevalence of DR to be 28.4% and 39.2% at baseline. The recent Beijing Eye Study covered rural and urban populations of Chinese aged over 40 years, with a self-reported diagnosis of diabetes and found a DR prevalence of 37% and a STDR prevalence of 5%. In the study, DR and ME in patients with known T2D were significantly more common in the rural group. This is in contrast to the observation in the Indian population.

The Handon Eye study in rural China reported the highest prevalence of DR (43.1%). Although better case ascertainment should be considered as one explanation, prolonged exposure to poor glycemic control, undiagnosed diabetes, and high rates of hypertension (74%) in rural China are possible factors. In a multiethnic study in Mauritius, Chinese Mauritians with known diabetes had similar prevalence of DR as the Indians and Creoles; however, the prevalence of DR (43.8%) was similar to those of the rural Chinese population in mainland China.

The MESA study provided data for the Chinese Americans. The prevalence among the Chinese sample (25.7%) was similar to that of whites (24.8%), indicating that there are significant regional variations in the prevalence of DR among the Chinese population that may be partly explained by differences in health care access. Gene–environment interactions also may provide important clues to these variations.

The prevalence in the newly diagnosed patients in Taiwan was 21%, which was similar to that found in newly diagnosed Hong Kong Chinese (21.9%). These figures are lower than those noted in rural China (33.5%). Strikingly, the prevalence of DR in newly diagnosed patients was higher within 12 months of diagnosis than when patients were screened routinely for DR at the time of diagnosis. The Chinese patients in the Beijing study and the Hong Kong study showed a prevalence rate of 21% at 12 months from diagnoses. In contrast, retinopathy was found in 15.4% of cases in the Da Qing study, which included 110,660 individuals screened for diabetes by glucose tolerance tests and 423 newly diagnosed diabetic patients. These studies indicate that the prevalence of DR increases within the first year of diagnosis in this population, suggesting a delay in diagnosis of diabetes.

Dowse et al noted that there is a significant association between current age and retinopathy in the newly diagnosed. They suggested that current age might behave as a surrogate marker for diabetes duration in these patients. Liu et al showed that the age of onset of hyperglycemia is much younger in populations of Beijing Chinese (36 years) and Fijian Indians (37 years), but is much older in Anglo-Celtic patients in Australia (54 years). This difference may partly explain the ethnic differences in prevalence and severity of DR.

Females and individuals from lower socioeconomic groups were more common in the newly diagnosed populations. More females are undiagnosed than males, which suggests social, hormonal, or genetic basis for late diagnosis.

Similar to the studies in South Asia, the Beijing Eye Study on the survey of visual impairment in the Chinese population reported DR as a relatively minor cause of blindness (low vision 0% / blindness 7.7%). Similar to studies in the white population, it was observed that progression to sight-threatening retinopathy was more common (7.9% vs 0.7%), and occurred more rapidly in eyes with baseline retinopathy than in those without. High baseline glycosylated hemoglobin is a predictor for disease onset and progression.

Despite different study procedures and populations, the prevalence of DR mirrors the regional prevalence of diabetes, with higher prevalence of diabetes in Hong Kong and Taiwan compared to mainland China. Nevertheless, there is an upward trend within mainland China. The risk factors for DR are similar to those demonstrated in the white population and include duration of diabetes, age at onset of diabetes, age at examination, type of diabetes treatment, control of diabetes hypertension, proteinuria, serum creatinine level, serum cholesterol level, and BMI. Subclinical hypothyroidism in the Chinese has been associated with sight-threatening DR. The increasing prevalence and urban–rural differences in prevalence in China are attributed to urbanization, especially increasing obesity, sedentary lifestyle, and dietary transition towards a high-fat, high-energy-density, and low-fiber diet.

**SOUTH EAST ASIA**

Asian Malays are the third largest ethnic group in Asia and include 300 to 400 million people. The overall prevalence of DR is 35% among this population, and approximately 10% have STDR. Akin to the white population, the presence of DR is associated with longer diabetes duration, poorer glycemic and blood pressure control, and higher levels of total and low-density lipoprotein cholesterol. Systemic vascular diseases, including stroke and chronic kidney disease, were associated with STDR. A similar rate was reported in the Thailand diabetes registry project, which found that the duration of diabetes, HbA1c level, systolic BP, and diabetic nephropathy to be associated with DR.
MIDDLE EAST

The number of people with diabetes mellitus in the Middle East is expected to triple from the year 2000 to 2030, with approximately 60 million diabetics by 2030. Numerous studies on DR from the Middle East have been published in recent years. They underscore the great disease heterogeneity in North African and Asian Arab countries, probably reflecting the genetic and socioeconomic heterogeneity of the populations in these regions as well as environmental differences. Although direct comparisons with other ethnic groups are lacking, the existing data provide some indications that Arabs frequently have high rates of DR. A cross-sectional survey of DR in the United Arab Emirates has reported variable prevalence rates from 19.0% to 54%.228 Other studies in the region have reported variable rates of DR, including Qatar (23.5%), 62 Saudi Arabia (16.7–31%), 146,189 Oman (14.39–42%), 59,110 Egypt (42%), 87 Iran (39.3%), 77,99,158,159 Turkey (45.5%), 235 and Lebanon (35%)229 The prevalence of DR in newly diagnosed diabetics in Kuwait was 8%. A systematic review of studies from Iran revealed DR prevalence between 30% and 40% in known T2D and between 9% and 11% in those with newly diagnosed diabetes.6

Visual impairment from DR in this region highlights the need for resource allocation for systematic screening and timely treatment of this potentially avoidable complication.40 Although the prevalence of STDR is high, public awareness of eye complications remains limited.14,99,229 Gender inequality for eye care is also an issue in this region, although the disparity has lessened in the last decade.110

The substantial heterogeneity in the reported prevalence of retinopathy may be real, relating in part to differences in the average age of the different populations; it may also result from study methodology, however.

SUB-SAHARAN AFRICA

African people with diabetes typically have an increased risk of multiple complications that are difficult to treat or prevent.75 Ophthalmoscopy-based studies reveal a DR prevalence rate in this population of about 15–17%.65,225 A South African multiethnic photography-based study showed a higher prevalence, with no differences between ethnic groups (Black African 37%, Europeans 41%, and Indians 37%); severe retinopathy was more frequent in African and Indians, however.104 In another study that compared the prevalence of DR between black Africans and Indians, DR was observed in 68.8% of blacks versus 59.2% in Indians. The mean age of onset was earlier in Indians, but the blacks had an earlier onset of retinopathy from time of diagnosis. Duration of diabetes and systolic hypertension were significantly associated with DR, with blacks being more prone to hypertension than Indians.175

AUSTRALASIA

Studies from Australia date back more than three decades and provide encouraging evidence of the impact of health education and better glycemic control on the prevalence and incidence of DR.47,164,177 The earliest clinic-based study of DR in Australia was the Newcastle Diabetic Retinopathy Study (1977–1988). The prevalence of DR was 35%. Since then, population-based studies have reported lower rates.167 The Australian Diabetes, Obesity, and Lifestyle study (AusDiab) was a nationally representative population-based study of 11,247 people aged ≥25 years, from 42 randomly selected urban and rural areas of Australia. AusDiab reported a DR prevalence of 21.9% in those with known diabetes and of 6.2% in those with newly diagnosed diabetes.235

The DR prevalence obtained in the Blue Mountain Eye Study, which was an urban-based population study from 1992–1994 of residents of Sydney aged ≥49 years, was 35.5%. The 22.2% 5-year cumulative incidence of DR was lower than the 4-year cumulative incidence of 32.7% reported for non-insulin-treated, predominantly white patients with diabetes in the WESDR cohort and a clinic-based Swedish study.47,168 This difference may represent a true prevalence, from better public awareness and better glycemic control in Australia. The Melbourne Visual Impairment Project in 2003 reported the 5-year incidence of DR to be 11%, with most patients with sight-threatening disease receiving treatment.164 Similar lower incidence rates have also been reported in other ethnic groups from Japan, Korea, Taiwan, Mauritians, and non-Hispanics,36,111,174,255,259 in which suboptimal glycemic control remains an issue. Other factors therefore may also contribute to the lower incidence.

Australian Aborigines have the highest reported annual incidence of STDR (1.2%) in Australia and one of the highest-ever reported incidences of CSME (1.7%).98 The Katherine Region Diabetic Retinopathy Study on the Australian Aborigines in the Northern Territory of Australia highlighted that data on this indigenous population is hampered by small sample sizes and short follow-up periods.98 Access to treatment for DR is a problem in some regions.25 The Darwin Region Urban Indigenous Diabetes Study observed no difference in the prevalence of DR in T2D in urban indigenous Australians and the general Australian population
duration of diabetes, oral medication use, mean before and after adjusting for age, sex, BMI, in African Americans compared to white patients or regional prevalence of diabetes mellitus.

That cannot only be explained by increasing global among various geographic and ethnic populations burden in many ethnic groups, especially in Asia. Mortality inevitably will lead to increased health rate of communicable diseases and associated increasing sedentary lifestyles, and the declining indication that obesity, urbanization, changes in diet, position may predispose these adolescents to the development of insulin resistance. Genetics may play a role and the interaction with environmental factors (changes in lifestyle) could increase the risk of developing metabolic syndrome.

Conclusions

Race- and ethnicity-related differences in the prevalence of DR, CSME, and visual impairment are an important public health issue. Understanding the epidemiology of DR in different ethnic groups is essential for more effective screening and treatment of DR. Although these differences are usually explained by health-seeking behaviors and access to healthcare, we have also highlighted interethnic variations in the susceptibility to known risk factors of diabetes complications. In particular, the prevalence of metabolic syndrome illustrates the continuum of interethnic variations. Studies on the racial differences in the prevalence of diabetes in indicate that obesity, urbanization, changes in diet, increasingly sedentary lifestyles, and the declining rate of communicable diseases and associated mortality inevitably will lead to increased health burden in many ethnic groups, especially in Asia.

We elucidate differences in the prevalence of DR among various geographic and ethnic populations that cannot only be explained by increasing global or regional prevalence of diabetes mellitus.

For example, HbA1c levels are significantly higher in African Americans compared to white patients before and after adjusting for age, sex, BMI, duration of diabetes, oral medication use, mean fasting plasma glucose, mean postprandial glucose, insulin resistance, and β-cell function. This should be considered when comparing glycemic control between these two ethnic groups. Black patients have a higher prevalence and earlier onset of hypertension than other ethnic groups, with poorer prognosis than white patients. Black patients are more likely to be salt-sensitive, more prone to have a low plasma renin activity, and are at a greater risk of developing cardiovascular and renal complications than their white counterparts.

The increase in diabetes in Asia differs from that reported in other parts of the world: The prevalence increased in a shorter time, in a younger age group, and in people with lower BMI. For the same BMI in white patients, Asian patients have a higher body fat percentage, prominent abdominal obesity, and higher intramyocellular lipid and/or liver fat content. These characteristics may contribute to a higher predisposition to insulin resistance at a lesser degree of obesity than white patients. The differences in body composition are more pronounced depending on the region. For the same BMI, among the three major ethnic groups in Asia, Asian Indians have the highest body fat, followed by Malay and Chinese. Lower insulin sensitivity has been observed in Asian Indian adolescents with a higher body fat and abdominal obesity than in white adolescents. In general, Asian adolescents have higher body subcutaneous fat, lower appendicular skeletal muscle, and lower gynoid fat, compared to white adolescents. This unfavorable body composition may predispose these adolescents to the development of insulin resistance. Genetics may play a role and the interaction with environmental factors (changes in lifestyle) could increase the risk of developing metabolic syndrome.

Some ethnic groups (including tribal populations) are two to four times more susceptible to diabetes; therefore, the rates of DR may reflect the rates of diabetes. Moreover, poor access to healthcare remains an important issue in some ethnic groups and in socially and economically deprived areas. A recent systematic review reported ethnic differences in the quality and intermediate outcomes of diabetes care. Intermediate clinical outcomes were worse among black patients and inclined to be worse among Hispanic patients. Cultural differences and dietary habits also may be an influential factor for these ethnic differences.

Change in retinal vascular caliber is also an important risk factor of incident DR in T1D and T2D. This risk is independent of the known risk factors of hyperglycemia and hypertension. Venular dilatation is a significant risk factor for the
Hispanics, Chinese, and African Americans. African Caribbean people with diabetes have wider retinal arterioles that may contribute to enhanced microvascular damage in this ethnic group. The maximal hyperemic response of the microvasculature to heat and post ischemic response also are significantly attenuated in African Caribbeans compared to white patients. Ethnicity-dependent variations in retinal caliber patterns in diabetes should be further investigated.

Transracial studies are a powerful tool for genetic association studies of multifactorial diseases, such as T1D. Class II HLA was strongly associated with T1D in both Asian and white populations. However, alleles associated with T1D are different among various ethnic groups, due to differences in allele distribution in general populations.

Our ability to draw firm conclusions is hindered by some intrinsic limitations. The direct comparison of studies is hampered by differences in the definitions for the individual clinical complications and the methods used in their assessment, in addition to enormous variations in the ages of patients at diagnosis and study entry. Moreover, the world is experiencing a global transition in demographics. As people from low socioeconomic statuses improve their economic status, as populations shift from rural to urban environments, and as acute infectious diseases are replaced by chronic disorders, changes occur in disease prevalence and manifestations. So, it is difficult to differentiate between features that are “ethnic specific variations” and features that are expected to occur as a part of the demographic transition. Some of the observed changes also might be the result of better reporting methods by some countries and to survivor bias.

Although a concerted approach to the prevention of diabetes mellitus and related complications exists in several countries, a directed ethnic-specific approach may be required to reduce the burden, especially in multi-racial cities. Policymakers and clinicians in these areas should focus on the development of guidelines that are ethnic-specific, so that more effective control of risk factors is feasible. Further research on other genetic and environmental risk factors is necessary to better understand these differences. Educational programs aimed at the physician to facilitate cultural competence and at the patient to increase level of knowledge about their disease are appropriate and enthusiastically endorsed.

Method of Literature Search

The literature search for our review article was performed on the online electronic Medline Ovid database dated 1950 to January 2011. The keywords searched included: diabetic macular edema, clinically significant macular edema, diabetic retinopathy, prevalence, incidence, laser photocoagulation, risk factors, visual impairment, blindness, type 1 diabetes, type 2 diabetes, ethnicity, screening, microvascular complications, burden of diabetes, demographics, genetics, insulin-dependent diabetes. Combinations of these terms were used as well. After finding relevant articles within these search limits, a manual search was conducted through the references from these articles. Abstracts from the non-English literature were also surveyed.

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