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IDF Diabetes Atlas: A review of studies utilising retinal photography on the global prevalence of diabetes related retinopathy between 2015 and 2018

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ABSTRACT

Aims: The purpose of this study is to assess the prevalence of diabetic retinopathy (DR) world-wide from articles published since 2015 where the assessment of the presence and severity of DR was based on retinal images.

Methods: A total of 4 databases were searched for the MESH terms diabetic retinopathy and prevalence. Of 112 publications 32 studies were included and individual data pooled for analysis. The presence of any DR or diabetic macular edema (DME) was recorded and severity as mild, moderate or severe non-proliferative DR (NPDR), proliferative DR (PDR) and DME and/or clinically significant macular edema (CSME). The level of severity of DR reported refer to persons with diabetes and not individual eyes.

Results: The global prevalence of DR and DME, for the period 2015 to 2019 were 27.0% for any DR comprising of 25.2%, NPDR, 1.4% PDR and 4.6% DME. The lowest prevalence was in Europe at 20.6% and South East Asia at 12.5% and highest in Africa at 33.8%, Middle East and North Africa 33.8%, and the Western Pacific region at 36.2%.

Conclusions: This study illustrated difficulties in deriving a meaningful global prevalence rate for DR and DME due to the lack of uniformity in defining the study populations, methodological differences, retinal image capture and grading criteria. Therefore, international consensus is required using a minimal data set for future studies.

Contents

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1. Introduction

The devastating consequences of diabetes mellitus is set to continue as a result of the predicted increase in prevalence from 463 million in 2019 to 700 million in 2045 due to population expansion, increased ageing, urbanisation, reduced physical activity and adverse dietary changes [1]. Whilst diabetic retinopathy/maculopathy (DR) remains amongst the commonest cause of preventable blindness in the working age population in most countries globally [2], it has been relegated to second place behind hereditary retinal diseases in the England and Wales, UK since 2014 [3] with the number of new registrations for blindness reduced by almost half in Wales between 2007 and 2015 [4].These encouraging trends are considered to be due, in major part, to the introduction of community based DR screening resulting in the earlier diagnosis and treatment of sight-threatening DR [3] commensurate with the objective of the World Health Organisation's Universal Eye Heath Global Initiative Action Plan 2014–2019 [5] and the IDF and partner organisation's Diabetic Eye Disease: A Global Advocacy Initiative 2017–2018.

1.1. *Aims*

The purpose of this study is to assess the prevalence of DR from articles published since 2015 where the assessments of the presence and severity of DR were based on retinal images. This follows on to an earlier meta-analysis by Yau et al, in 2012 [6] which reviewed 35 out of a potential 58 studies world-wide conducted between 1980 and 2008 in which fundal photographs were assessed for DR. Covering the same time period a second meta-analysis provided estimates of the number of persons blind or visually impaired specifically due to diabetic retinopathy [7]. Lee et al. 2015 [8] adopted a much broader search strategy to report on the epidemiology of DR, diabetic macular edema (DME) and related vision loss globally, whilst further highlighting regional and ethnic differences and the risk factors contributing to the progression or regression of DR and DME. Updating the prevalence of DR is an essential requirement to support the planning and allocation of resources needed in the future in an attempt to eliminate preventable vision loss and blindness associated with diabetes.

2. Methods

For this study a total of 4 databases were searched Pubmed, Embase, Web of Science and Medline for the MESH terms diabetic retinopathy and prevalence. The search was limited to those studies published after 2010 until the present day and to those published in the English Language and those performed in humans. The start date was chosen to ensure all studies published after the previous reviews were captured. These were hand sifted for relevant articles. A total of 180 articles were identified in the original search in January 2019 with alerts identifying an additional 7 publications after the original search but before the closure of the study. Titles and abstracts for all 187 publications were checked by 2 reviewers (DRO and SH). 75 abstracts were excluded as they did not mention prevalence of diabetic retinopathy. A total of 112 full text papers were requested and reviewed by the same 2 reviewers and any discrepancies were discussed and resolved with a third reviewer (SG). An additional 80 studies were excluded as they were either pre 2015, included in one of the 2 previous reviews or they did not utilise fundal photography to assess the level of diabetic retinopathy. Data was extracted from the remaining 32 included studies (Fig. 1).

The presence of any DR or DME was recorded and the severity of DR reported as mild (background DR), moderate or severe (pre-proliferative DR) (PPDR), proliferative DR (PDR) and DME according to the proposed international clinical diabetic retinopathy and diabetic macular edema disease severity scales [9]. DME was referred to as DME and/or clinically significant macular edema (CSME). The level of severity of DR reported refer to persons with diabetes and not individual eyes. The results are presented as the prevalence of any DR, non-proliferative DR (mild DR, moderate and severe PPDR), (NPDR), PDR and DME globally, per region and per study. The published studies either involved exclusively people with type 1 or type 2 diabetes or mixed populations where the numbers recruited of either was not always reported. No differentiation was made whether mydriasis or not was used prior to image capture, neither was there information about the number and width of the photographic fields captured in the majority of the publications.

This review was undertaken as part of the work for the 9th edition of the IDF Diabetes Atlas [1]. Therefore, the studies included are tabulated according to the IDF Regions ie Europe, Africa, Middle East and North Africa (MENA), North America and Canada (NAC), South America and Caribbean (SAC), South and East Asia (SEA) and Western Pacific (Tables 1–4). Included, where available, are the study period, type of study, location (community or hospital based), total number of population studied, age, gender, numbers according to type of diabetes, prevalence (%) of DR and DME/CSME. Identified risk factors were noted but not included in this analysis.

For the forest plots 2a–d all studies were included which reported prevalence of any DR, NPDR, PDR and DME. Studies which reported a combined prevalence for Type 1 and Type 2 diabetes these were included in the analysis along with those which included exclusively type 1 or type 2 populations. Separate symbols are included on the forest plots to denote

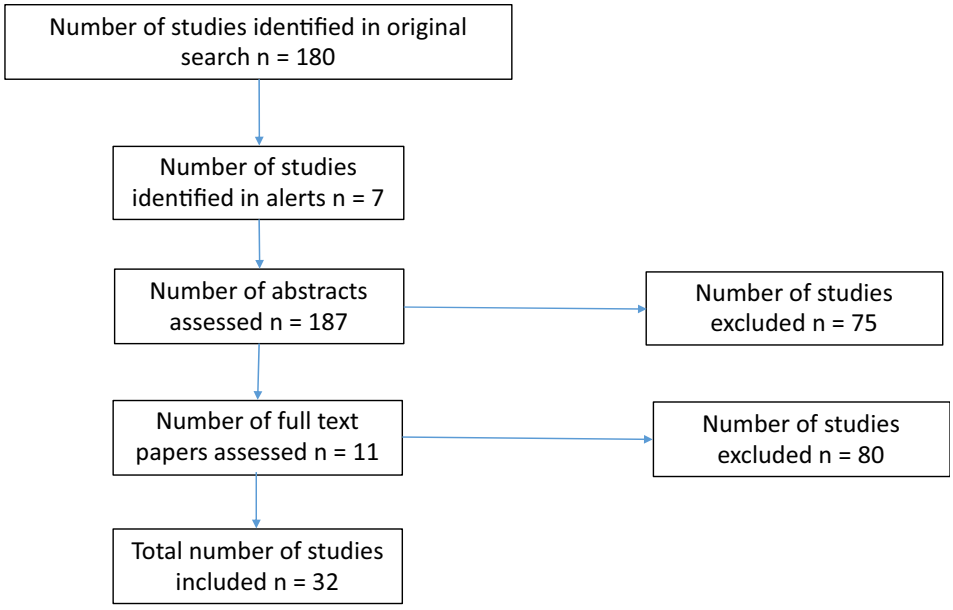

Fig. 1 – Prisma diagram for included study selection.

these differences. However, studies which did not report prevalence figures for NPDR, PDR and/or DME were removed from those forest plots rather than assuming this level of DR was not seen. The same principles were applied to the Type 1 and Type 2 forest plots included in the supplementary Figs. 1–4.

3. Results

There have been 32 studies published since 2015 describing the prevalence of diabetic retinopathy/maculopathy in the various IDF designated regions and individual countries world-wide. The 32 studies emanating from 21 separate countries met the inclusion criteria for this survey totalling 543,448 people with diabetes who underwent retinal photography as a basis for diagnosing the presence and severity of DR. The distribution of studies were: Europe 9, Africa 5, Middle East and North Africa 1, North America and Canada 3, South America and Caribbean 1, South East Asia 2 and the Western Pacific 11. The available data for the selected studies are represented in Tables 1–4 and Fig. 2a–d.

Of the total number of participants in the studies reviewed the type of diabetes was reported in only 53% of whom 97% were people with type 2 diabetes and the majority of studies, 28 out of 33 (85%) were community based/cohort cross-sectional surveys involving a wide range of observational periods up to 14 years during 1972–2017.

In Europe the majority of the studies, 7 out of 9 were population based with the remaining 2 studies derived from hospital populations (Table 1). Of the 9 studies, a third included a mixed population of individuals with either type 1 or type 2 diabetes [19,15,17], a third were restricted to people with type 2 diabetes [11–13] and a third involved only type 1 diabetes [14,15,17] with a slight preponderance of males in most studies (range 49.0–62.9%). In 6 studies [10–12,14,16,18] the period of observation commenced from 2005 onwards for periods ranging from 1 to 10 years duration, and with the others starting before 2000 at 1972 [13], 1983 [15] and 1999 [17] and lasting for 14, 27 and 10 years respectively.

When combining all people with type 1 and type 2 diabetes the overall prevalence of any DR, is 20.6% (range 12.3–71.5%), NPDR 19% (range 11.7–65%), PDR 1.7% (range 0.36–13%) and DME was 1.2% (range 0.18–15.3%). The overall prevalence of any DR in type 1 diabetes was 36.3% but in those with a mean age over 30 years was 56%, 61% and 72% compared to 19.5% in the study with a much lower mean age of 14 years [13]. In contrast, the overall prevalence of any DR was much lower in people with type 2 diabetes at 19.4% (range 12.3–33.8%). The prevalence of NPDR in people with type 1 diabetes was 46.0% (range 19.5– 47.0%) compared with 18.0% (range 11.7–32.2%) in those with type 2 diabetes. The prevalence of PDR in type 1 diabetes was 3.3% (range 0–13%) and in type 2 diabetes it was 0.6% (0.31–1.5%) with the prevalence of DME at 8.8% (range 0–14.8%) in type 1 diabetes and 1.3% (range 0.18–15.3%) in people with type 2 diabetes. In summary the prevalence of any DR was much higher in persons with type 1 diabetes, especially over the age of 30 years, with the difference due predominantly to the much higher prevalence of NPDR, PDR and DME.

Of the 5 studies from African countries one study was hospital based [22] including people with either type 1 or type 2 diabetes, and four community based, with one limited to persons with type 1 diabetes [19] and 3 involving both type 1 and type 2 [21–23] but with no reporting of numbers in one of these studies [22] (Table 2) and the remaining study [20] did not specify the type of diabetes. Overall the prevalence of any DR within this region was 33.8% (range 8.6–51.7%), NPDR 30%, PDR 4.0% (range 1.2–6.0%) and DME 21.5% (range 6.3–32%). The prevalence of any DR was highest in persons with type 1 diabetes at 61.5% (range 8.6–61.5%) compared with

Table 1 – Europe.

Country	Author Date (Ref)	Study period	Study type	Study location	Population					Diabetic retinopathy (%)						
					n			Mean Age (Range)	Sex M (%)	Any DR	Non-Sight threatening DR		Sight threatening DR			
					Total (screened)	T1DM	T2DM				Mild BDR	Mod PPDR	Severe PPDR	PDR	DME	CSME
REGION 1: EUROPE (EUR)																
UK	Thomas 2015 [10]	2005–2009	Cohort, X-section	Comm	89,584	5003	86,390	T1DM = 36.5 T2 = 65.3	All = 56 T1DM = 54.7 T2DM = 56.4	32.4 56.0 30.3	39.8 26.5	29.0 5.2 1.5		3.4 2.60 0.31	8.6 2.59	
Portugal	Mederios 2015 [11]	2009–2014	5-yr retrosp	Comm	52,739	No	52,739	69.1	50.4	16.3	10.4	2.8	1.3	1.8	1.4	
Spain	Rodrigues-Poncelas 2015 [12]	2008–2012	X-section	Comm	108,723	No	108,723	66.9	56.2	12.3	7.48	3.39	0.86	0.36	0.18	
Sweden	Olafsdothir 2016 [13]	1972–1996	Cohort	Comm	257	No	257	68.6	46.0	33.8	23.7	6.6	1.9	1.6		
UK	Dhillon 2016 [14]	2008–2010	Cohort	Hospital	149	149	No	14	52	19.5	20					
UK	Warwick 2017 [15]	1983–2010	Retrosp	Comm	464	464	No	43	53.4	71.5	61.6	3.4		6.5	10.8	
Italy	Vujosevic 2017 [16]	2005–2015	Cohort	Comm	9347	751	8596	60.6	62.9	27.5	12.5	11.3	2.9	0.9	5.7	0.7
Norway	Jansson 2018 [17]	1999–2009	X-section	Comm	237	237	No	34	51	61	26	16	5	13	8	
Turkey	Acan 2018 [18]	2011–2012	X-section	Hospital	413	Yes	Yes	NR	NR	All = 32 T1DM T2DM					15.3 14.8 15.3	

Key: X-section - cross sectional study; retrospec retrospective study; comm - community based study; Prim care - primary care based study; R - Rural; U - Urban; NR - Not Recorded; Cluster R Trial - Cluster randomised control trial; C - Chinese; M - Malay; I - Indian; NI - Non-Indigenous; IN - Indigenous; *median.

Table 2 – Region 2: Africa (AFR); Region 3 Middle East and North Africa (MENA).

Country	Author Date (Ref)	Study period	Study type	Study location	Population					Diabetic retinopathy (%)						
					n			Mean Age (Range)	Sex M (%)	Any DR	Non-sight-threatening DR		Sight-threatening DR			
					Total (screened)	T1	T2				Mild BDR	Mod PPDR	Severe PPDR	PDR	DME	CSME
REGION 2: AFRICA (AFR)																
Ethiopia	Alemu 2015 [19]	NR	X-section	Prim Care	511	Yes	No	34.6	62.1	8.6	2.2	4.9	0.4	1.2	6.3	
										R = 5.0	0.6	3.8	0	0.6	3.8	
										U = 16.1	5.4	7.1	1.2	2.4	11.3	
Tanzania	Cleland 2016 [20]	2010–2014	X-section	Comm	3187	NR	NR	60.8	39.7	27.9	19.1	6.0		2.9	16.1	
S Africa	Webb 2016 [21]	2010–2012	Cluster R Trial	Prim Care	497	18	334 + unspec	57.8 (20–90)	31.5	24.9	19.5			5.5	20.8	9.0
S Africa	Cairncross 2017 [22]	2014	Prospective	Hospital	185	Yes	Yes	57 (30–88)	27.5	20	10.2	3.6	2.5	3.1	12.7	
Zambia	Lewis 2018 [23]	2012	X-section	Comm	2153	208	921 + unspec	56	55	All 51.7	26	20		6	32	
										T1DM = 61.5	26	29		7	54	
										T2DM = 52.2	28	20		5	41	
REGION 3: MIDDLE EAST AND NORTH AFRICA (MENA)																
Iran	Dehghan 2015 [24]	NR	X-section	Comm	529	NR	NR	(40–80)	44	29.6	11.8	9.9	3.9	3.9		4.9

Key: X-section - cross sectional study; retrospec retrospective study; comm - community based study; Prim care - primary care based study; R - Rural; U - Urban; NR - Not Recorded; Cluster R Trial - Cluster randomised control trial; C - Chinese; M - Malay; I - Indian; NI - Non-Indigenous; IN - Indigenous; *median.

Table 3 – Region 4: North America and Caribbean (NAC); Region 5 South and Central America (SACA); Region 6 South East Asia (SEA).

Country	Author Date (Ref)	Study period	Study type	Study site	Population					Diabetic retinopathy (%)						
					n			Mean Age (Range)	Sex M (%)	Any DR	Non-sight threatening DR		Sight-threatening DR			
					Total (screened)	T1	T2				Mild BDR	Mod PPDR	Severe PPDR	PDR	DME	CSME
REGION 4: NORTH AMERICA AND CARIBBEAN (NAC)																
Canada	Kanjee 2016 [25]	2007–2013	Retrosp Review	Comm	4338	No	Yes	53	45.1	25.1	14.8	8.6	0.2	6.5		
Alaska	Bursell 2018 [26]	2011–2016	X-section	Comm	46,600	NR	NR	<50 = 40% >70 = 8.8%	44	20.2	9.4	8.1	0.1	2.3	2.3	
USA	Naik 2018 [27]	2013–2017	Retosp	Comm	5242	Yes	Yes	NR	NR	33.98	24.63	6.58	1.56	1.20	4.31	0.23
REGION 5: SOUTH AND CENTRAL AMERICA (SACA)																
Puerto Rica	Rodrigues 2016 [28]	2001–2009	X-section	Comm	411	44	367	56.1	29.5	37.7	22.6	7.8	20.4	5.1	10.9	
REGION 6: SOUTH EAST ASIA (SEA)																
Nepal	Mishra 2016 [29]	2014	X-section	Comm	648	NR	NR	56.1	52	9.9	9.1			0.5	5.5	
India	Sunita 2018 [30]	2011–2014	X-section	Comm	592	No	Yes	51	45.1	15.4	14.7			6.7		6.6

Key: X-section - cross sectional study; retrospec retrospective study; comm - community based study; Prim care - primary care based study; R - Rural; U - Urban; NR - Not Recorded; Cluster R Trial - Cluster randomised control trial; C - Chinese; M - Malay; I - Indian; NI - Non-Indigenous; IN - Indigenous; *median.

Table 4 – Region 7 Western Pacific.

Country	Author Date (Ref)	Study period	Study type	Study Location	Population					Diabetic retinopathy (%)						
					n			Mean Age (Range)	Sex M (%)	Any	Non-sight threatening DR		Sight-threatening DR			
					Total (screened)	T1	T2				Mild BDR	Mod PPDR	Severe PPDR	PDR	DME	CSME
REGION 7: WESTERN PACIFIC (WP)																
Singapore	Huang 2015 [31]	2004–2011	X-section	Comm	2376	NR	NR	(40–80)	NR	All 33.9 C = 17.8 M = 33.0 I = 49.1	28.7		6.6			4.6
Australia	Keel 2016 [32]	2009–2014	X-section	Hosp.	483	483	No	(4–20)	52	2.3	2.3					
Hong Kong	Lian 2016 [33]	2010–2014	X-section	Comm	164,755	Yes	Yes	64	47.3	39.0	35.7	3.0		0.3	8.6	
New Zealand	Chang 2017 [34]	2006–2015	Cohort	Comm	12,667	918	11,749	54.8	55	All 22.5 T1DM = 42.3 T2 = 21.0	20.2 36 19		2.3 6.3 2.0			
Indonesia	Sasongko 2017 [35]	NR	X-section	Comm	1138	No	1138	59* (52–65)	31.2	All = 43.1 R = 46.2 U = 36.6	9.45 9.21 9.96	10.5 10.5 10.5	11.1 11.2 10.7	12.1 15.2 5.47		17.1 19.3 12.0
China	Cui 2017 [36]	2010–11 2014–15	X-section	Comm	1749	No	1749	55.7 (18–79)	55.5	8.1						
REGION 7: WESTERN PACIFIC (WP) CONTINUED																
China	Liu 2017 [37]	2014–2015	X-section	Comm	13,473	96	13,304	62.5	45.7	All 34.08 T1DM = 31.5 T2DM = 30.5	15.8	0.71	0.89	11.51		
China	Zhang 2017 [38]	2014–2016	X-section	Hosp	15,078	Yes	Yes	63.2	NR	27.9	22.1	3.7	2.1	11.2		
Australia	Keel 2017[39]	NR	X-section	Comm	1004	NR	NR	NI 50–98 IN 40–92	NR	NI = 28.5 IN = 39.4	8.5 11.8	2.0 4.0	1.1 2.3	1.5 4.4	5.13 13.8	3.8 6.0
Australia	Brazonis 2018 [40]	2012–2016	X-section	Comm	237	No	237	48*	33	47	7.5	11.0	6.0	2.5	14.4	14.1
Singapore	Tan 2018 [41]	2004–2011	X-section	Comm	2877	51	2826	61.6	50.6	All 28.2 C=26.2 M=25.5 I=30.7	7.85 5.99 4.91 10.6	6.02 7.77 6.09 5.37	0.71 0.60 1.29 0.40	3.75 3.39 3.43 4.00	7.62 6.05 5.67 9.49	6.39 5.88 4.96 7.59

Key: X-section - cross sectional study; retrospec retrospective study; comm - community based study; Prim care - primary care based study; R - Rural; U - Urban; NR - Not Recorded; Cluster R Trial - Cluster randomised control trial; C - Chinese; M - Malay; I - Indian; NI - Non-Indigenous; IN - Indigenous; *median.

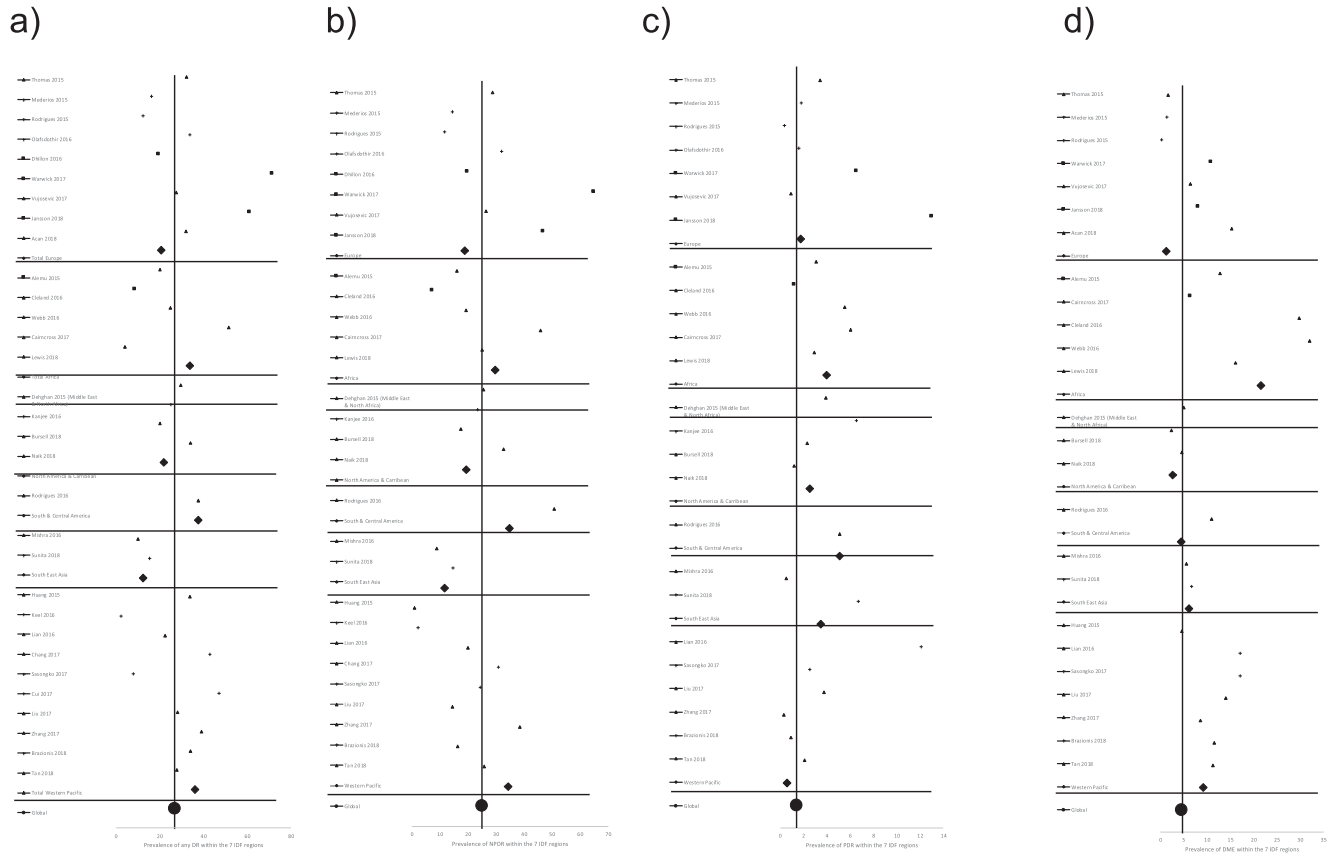

Fig. 2 – Forrest Plots for the prevalence of DR within the 7 IDF regions; (a) any DR, (b) NPDR, (c) PDR, and (d) DME. Key: Mixed diabetes population; Type 2 diabetes only +; Type 1 diabetes only.

52.2% in those with type 2 diabetes. In people with type 1 diabetes the prevalence of any DR was 23.9%, NPDR 21.27%, PDR 2.9% and DME 13.7% and in studies with type 2 diabetes the prevalence of any DR was 52.2%, NPDR 48.0%, PDR 5.0% and DME at 41.01%. The highest prevalence of PDR and DME in the region was seen in a study from Zambia at 7% and 54% respectively involving people with type 1 diabetes [23]. In one study from Ethiopia the prevalence of any DR, non-proliferative DR, PDR and DME was higher in the urban compared to the rural community [19].

There was only 1 cross-sectional community based study published from the Middle East and North Africa region which was from Iran [24] involving 529 people but without indicating the type of diabetes (Table 2). The overall prevalence of any DR was 29.6%, non-proliferative DR 25.6%, PDR 3.9% and DME/CSME at 4.9%.

In North America & Caribbean, Region 4, there were a total of 3 studies [25–27] involving 56,518 people with diabetes examined from 2007, 2011 and 2013 onwards, with periods extending over 4–6 years duration (Table 3). The overall prevalence of any DR, was 21.9%, NPDR 19.5%, PDR 2.5% and DME at 2.5%. In the one study from Canada [25] including only type 2 diabetes the prevalence of any DR, NPDR and PDR was 25.1%, 23.6% and 6.5% respectively. The 2 other studies from Alaska [26] and the USA [27] where the type of diabetes was either not recorded or the population was mixed the prevalence of any DR was 20.2% and 33.9%, NPDR 17.6% and 32.8%, PDR 2.3% and 1.2%, DME 2.3% and 4.3% respectively.

There was only one study reported from South and Central America, Region 5, which was conducted in Puerto Rico [28], involving a mixed population of people with diabetes, but predominantly type 2 diabetes (Table 3). In this study the prevalence of any DR was at 37.7%, NPDR 50.8%, PDR 5.1% and DME at 10.9%.

From South East Asia, region 6, there were 2 studies one each from Nepal [29] and India [30] (Table 3). Both were cross-sectional community based studies, but without specifying the type of diabetes although the mean age was similar with a preponderance of male persons in the Nepal study. The overall prevalence rates for any DR was 12.5% (range 9.9–15.4%), NPDR 11.8% (range 9.1–14.7%), PDR 3.5% (range 0.5–6.7%) and DME/CSME 6.0%.

During the review period the Western Pacific, Region 7, had the largest number of studies published numbering 11 emanating from 6 different countries: Australia (3), China (3), Singapore (2), Hong Kong (1), Indonesia (1) and New Zealand (1) (Table 4). The total population with diabetes who were screened for DR by having retinal images in the region was 214,833. There was only one study limited to a cohort of young people from Australia with type 1 diabetes [32] whereas there were 3 studies restricted to people with type 2 diabetes [35,36,40] with 5 studies involving a mixed population with

either type 1 or type 2 diabetes [33,34,37,38,41] with the 2 remaining 2 studies having not recorded the type of diabetes [31,39]. 9 of the studies were community based and 2 hospital based.

The overall prevalence of any DR in this regions was 36.2%, NPDR 34.4%, PDR 0.6% and DME at 9.1%. For the study involving children and young persons (aged 4 years to 20 years) with type 1 diabetes the prevalence of any DR was 2.3% all being mild NPDR or moderate PPDR [32]. Overall for those with type 1 diabetes the prevalence of any DR was 28.7% with NPDR at 0.7%. The overall prevalence in those with type 2 diabetes of any DR was 25.8%, NPDR 30%, PDR 10.4% and DME at 19.1%. A study only in people with type 2 diabetes from Australia [40] with a median age of 48 years with two-thirds female, revealed a prevalence of any DR of 47.0%, NPDR 18.5%, PDR 2.5% with DME 14.4% and CSME 14.1%. Another study from Australia [39] examined the differences between a non-indigenous and indigenous population without specifying the type of diabetes involved, although presumed to be mainly type 2 diabetes aged over 40 years, revealed a lower prevalence of any DR at 28.5% in the non-indigenous compared to 39.4% in the indigenous population. Similarly at each level of DR severity the prevalence was higher in the indigenous population: NPDR 18.1% vs 11.6%, PDR 4.4% vs 1.5%, DME 13.8% vs 5.1% and CSME 6.0% vs 3.8%, respectively.

The 3 studies from China included either persons with type 2 diabetes only [36] or a mixed population predominantly type 2 diabetes [37,38]. In the study with type 2 diabetes only [36], the prevalence of any DR was reported as 8.1% but with no indication of severity. In the 2 studies with a mixed population mainly of type 2 diabetes [37,38] there was a similar prevalence of any DR at 34.1% and 27.9%, comprising mainly of mild NPDR at 15.8% and 22.1%, a low prevalence of PDR at 0.89% and 2.1% but with a high prevalence of DME at 11.5% and 11.2%, respectively. In the one study [37] which included people with type 1 and type 2 diabetes the prevalence of any DR was only slightly higher in those with type 1 diabetes compared to those with type 2 diabetes at 31.5% vs 30.5% respectively.

In the 2 studies from Singapore [31,41] in addition to the overall prevalence of any DR and its severity, comparisons were made between the three main ethnic groups, Chinese, Malay and Indian populations comprising predominantly, if not exclusively of persons with type 2 diabetes. The overall prevalence of any DR was different between the two studies at 33.9% [31] and 28.9% [41] and although the highest prevalence was observed in the Indian population in both studies at 49.1% and 30.7% respectively with the Chinese lowest in the one study at 17.8% [31] but similar to the Malay population in the other [41] at 26.2% and 25.5% respectively.

In a mixed population in Hong Kong [33] with a mean age of 64 years the prevalence of any DR was 39% comprising of mainly mild NPDR with PDR at 0.3% but with higher proportion at 8.6% having evidence of DME.

In New Zealand [34] in a population comprising of people with either type 1 or type 2 diabetes the overall prevalence of any DR was 22.5% but was much higher in type1 diabetes at 42.3% vs 21.0% in type 2 diabetes, with an equivalent difference in the prevalence of mild to moderate NPDR. Overall sight-threatening DR was present in 2.3% of the population which was three times higher in those with type 1 diabetes at 6.0%.

Finally in Indonesia [35] in a population of people with type 2 diabetes only, the prevalence of any DR was 43.1% which was higher in the rural vs urban communities at 42.3% vs 36.6% due to the much greater prevalence of PDR and DME in the rural compared to the urban community at 15.2% versus 5.5% and 19.3% versus 12.0% respectively. Approximately 30% had NPDR in both rural and urban populations.

In summary, the global prevalence of DR and DME, for the period 2015 to 2019 as represented by these studies using retinal photography, and calculated as described in the methods section, were 27.0% for the presence of any DR comprising predominantly of NPDR contributing 25.2%, PDR 1.4% and DME 4.6%. The lowest prevalence of any DR was observed in Europe at 20.6% and SEA at 12.5% and highest in Africa at 33.8%, MENA 33.8%, and the Western Pacific region at 36.2%. The predominance of NPDR was seen in all the seven regions examined. In Europe and marginally in Western Pacific the prevalence rates for any DR were higher in persons with type 1 diabetes in contrast to Africa. No information was available on people with type 1 diabetes for comparison from the other four other regions (MENA, NAC, SAC, SEA). With respect to PDR the highest prevalence was seen in Africa and MENA at 4.0% and the lowest at 0.6% in the Western Pacific, being higher in type 1 diabetes in Europe and in type 2 diabetes in Africa and NAC. The overall presence of DME was highest at 21.5% in people with diabetes in African. Only Europe and Africa provided information on the prevalence of DME in persons with type 1 diabetes at 8.8% and 13.5% respectively. With regard to type 2 diabetes the prevalence of DME was much higher in Africa and Western Pacific at 41.0% and 19.1% respectively. Differences between rural and urban communities was evident in a study involving people with type 1 diabetes in Ethiopia with the prevalence of DR at all levels considerably higher in the urban areas of the country. Also in Australia the prevalence of DR was disproportionally higher in the indigenous versus non-indigenous population. Differences between ethnic groups was evident in Singapore with the prevalence of any DR highest in the Indian population, intermediate in Malays and lowest in the Chinese population.

In those studies that evaluated the risk factors for DR there was general consensus that duration of diabetes, glycaemic control and blood pressure were the dominant factors.

4. Discussion

In high income countries and in Eastern and Central Europe in 2015, cataract is the commonest cause of blindness, followed by age-related macular degeneration, glaucoma, uncorrected refractive error and diabetic retinopathy [42]. Diabetic retinopathy was also the fifth commonest cause of moderately severe visual impairment (MSVI) increasing slightly in its proportion between 1990 and 2015 [7,42]. Yau et al. [6] in 2012 estimated in a pooled individual participant meta-analysis (n = 22,896) during a 10 year period from 1980 to 2008 that 35.4% or persons with diabetes, including type 1

(77.3%) and type 2 diabetes (25.2%), had evidence of any DR. The overall prevalence of proliferative DR (PDR) was 7%, DME 7% and vision threatening DR (VTDR) 12%. The prevalence of each increased with increasing duration of diabetes, deterioration of glycaemic control and increasing blood pressure. The prevalence of any DR also varied widely between ethnic groups being higher in Caucasians at 46.7% compared to Asians at 20.8%. The estimated numbers of individuals world-wide with any DR, PDR, DME and VTDR were 93, 17, 21 and 28 million respectively. The more recent meta-analysis estimated that the global burden of visual impairment and blindness attributable to DR in 2015 to be 2.6 million people, a figure projected to rise to 3.2 million in 2020 [7]. Since, it was estimated that in 2017, 425 million adults will have diabetes of whom 149 million will have DR and 47 million VTDR which by 2045 will involve 700 million persons with diabetes, approximating 10% of the adult global population, of whom 245 million will have lesions of any DR and 77 million VTDR, predicting devastating socio-economic consequences [43]. Preservation of vision in this vulnerable population of people with diabetes, is nevertheless achievable in the vast majority provided diagnosis of DR is made at an early stage when treatment (medical and/or ophthalmological) is most effective.

Of great concern were the findings of the recent Barometer study, conducted in 41 countries to explore the provision of DR screening and treatment which discovered that although 94% of adults with diabetes saw a health care professional for their diabetes, only 79% had ever had an eye examination for DED, and 23% had not had an eye examination in the last year [44,45]. Diabetic eye disease (DED) without macular edema (DME) was reported by 19.5% of adults with diabetes and a further 7.6% reported that they had DME. Two-thirds of the ophthalmologists interviewed reported that most of their patients presented when visual problems had already occurred with 6% stating that their patients presented when it was already too late for effective treatment. Health care professionals listed amongst the most substantial barriers to eye health, patients' lack of knowledge and/or awareness about eye complications (43%), followed by lack of importance given to eye examinations by patients (33%).

The benefit of screening for DR utilising retinal photography has been demonstrated in several countries in Europe, Scandinavia and Iceland [46–51]. In the UK with the introduction of annual screening for DR it is no longer the commonest cause of blindness [3], with more recent findings suggesting that biennial screening is safe in low risk individuals with minimal or no retinopathy on two occasions one year apart [52]. However, a lower attendance rate has been observed in those aged between 17 and 34 years of age [53] with investigations now being undertaken to identify potential barriers and enables to improve attendance rates.

This study aimed at determining the prevalence and severity of DR, when employing retinal photography, and based on an analysis of individual level data, illustrates the considerable difficulties in deriving a meaningful/true global prevalence rate for DR and DME at this time. The analysis was limited due to the relatively small number of studies selected from across the world (32) and involved the pooling of data despite the lack of uniformity in defining the study populations including self-reported data on type of diabetes, methodological differences in the process of retinal image capture and grading which are essential elements in ensuring the quality of any reported findings. The majority of articles also did not specify whether mydriasis was used or not, nor the extent or location of the retinal fields being captured with the presence of DR presumed to be based on the worst affected eye. There were also variations in ethnicity and socioeconomic environments between the population groups reviewed in this analysis. Restricting the review to publications from 2015 onwards limits, but does eliminate, the impact of the different time periods involved in the different studies included in the review. Heterogeneity between studies makes comparisons difficult and the META-EYE study group in 2012 [6], who also relied on retinal photography to detect DR, acknowledged similar limitations. In comparing the two studies the estimated world-wide prevalence of any DR, PDR and DME appears to have fallen from 34.6% to 27.0%, 7.0% to 1.4% and 6.8% to 4.5% respectively, over the last 10 years from 2008 to 2018. Similarities between the studies included a much higher prevalence of DR in type 1 compared to type 2 populations with regional and ethnic differences observed in both studies. The highest prevalence of any DR in our study was seen in the IDF Regions of Africa and the Western Pacific at 33.8% and 36.2% respectively with the lowest prevalence in Europe at 20.5%. In contrast the highest age-standardised prevalence of any DR seen by Yau and colleagues [6] was in Caucasians at 45.8% with Asians (combined) at 19.9%. We also observed a clear difference in racial susceptibility to DR which was higher in the Indian versus Chinese populations in both Singapore and Hong Kong, and between indigenous versus non-indigenous populations in Australia as well as a higher prevalence in an urban versus rural community in Ethiopia. The overall rates of PDR and DME were also much higher in the earlier study at 7.0% and 6.8%, respectively [6] compared to our findings of 1.4% and 4.6%, respectively. In both studies, amongst the highest prevalence of PDR and DME was seen in the African populations studied.

Therefore, consensus is needed on the most appropriate methods of identifying and classifying DR to arrive at the true prevalence of DR on a world-wide, regional and national basis. This is essential for both clinical practice and research purposes in an attempt to evaluate the impact of advances in diabetes care under different geographical and socio-economic situations and in the many different ethnic groups exposed to a widely disparate spectrum of putative risk factors, world-wide. Therefore, in pursuance of lowering the prevalence of preventable loss of vision and blindness in the population with diabetes, progress needs the adoption of internationally agreed screening and diagnostic criteria. It is suggested that future studies should adopt a minimal data set for this purpose (supplementary Table 1). Political and financial considerations will undoubtedly persist as major challenges in the provision of various elements needed to achieve the aim of the international community to avoid the immeasurable personal and societal impact of blindness in the high risk population of people with diabetes [1].

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Declarations of interest

None.

Contributions

DRO and RLT prepared the manuscript. RLT created all forest plots and analysed the data. DRO, SH and SG read all abstracts and decided on those included or excluded as well as extracted all data and double checked to ensure correctness. All authors including SS discussed the study and decided on the search strategy and combination of data as well as reviewing the manuscript.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diabres.2019.107840.

REFERENCES

[1] Saeedi P, Petersohn I, Salpea P, Malanda B, Karuranga S, Unwin N, et al. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: results from the International Diabetes Federation Atlas, 9th edition. Diabetes Res and Clin Pract 2019;157:107843.

[2] Cheung N, Mitchell P, Wong TY. Diabetic retinopathy. Lancet 2010;376:124–36.

[3] Liew G, Michaelides M, Bunce C. A comparison of the causes of blindness certifications in England and Wales in working age adults (16–64 years), 1999–2000 with 2009–2010. BMJ Open 2014;4. https://doi.org/10.1136/bmjopen-2013-004015.

[4] Thomas RL, Luzio SD, North RV, Banerjee S, Zekite A, Bunce C, et al. Retrospective analysis of newly recorded certifications of visual impairment due to diabetic retinopathy in Wales during 2007–2015. BMJ Open 2017;7:e015024. https://doi.org/10.1136/bmjopen-2016-015024.

[5] World Health Organisation. Universal eye health: a global action plan 2014-2019. 2013. https://www.who.int/blindness/AP2014_19_English.pdf?ua=1. 29/08/2019.

[6] Yau JWY, Rogers SL, Kawasaki R, et al. The Meta-Analysis for Eye Disease (META-EYE) Study Group. Global prevalence and major risk factors of diabetic retinopathy. Diabetes Care 2012;35:556–64.

[7] Leasher JL, Bourne RRA, Flaxman SR, Jonas JB, Keeffe J, Naidoo K, et al. Global estimates on the number of people blind or visually impaired by diabetic retinopathy: a meta-analysis from 1990 to 2010. Diabetes Care 2016;39:1643. https://doi.org/10.2337/dc15-2171.

[8] Lee R, Wong TY, Sabanayagam C. Epidemiology of diabetic retinopathy, diabetic macular edema and related vision loss. Eye Vision 2015;2:17. https://doi.org/10.1186/s40662-015-0026-2.

[9] Wilkinson CP, Ferris 3rd FL, Klein RE, Lee PP, Agardh CD, Davis M, et al. Global diabetic retinopathy project group. Ophthalmology 2003;110:1677–82.

[10] Thomas RL, Dunstan FD, Luzio SD, Roy Chowdhury S, Hale SL, North RV, et al. Prevalence of diabetic retinopathy within the national screening programme of Wales, UK. BJO 2015;99:64–8.

[11] Dutra Medeiros M, Mesquita E, Papoila AL, Genro V, Raposo JF. First diabetic retinopathy prevalence study in Portugal: RETINODIAB study—evaluation of the screening programme for Lisbon and Tagus Valley region. Br J Ophthalmol 2015;99:1328. https://doi.org/10.1136/bjophthalmol-2015-306727.

[12] Rodriguez-Poncelas A, Miravet-Jimenez S, Casellas A, Barrot-De La Puente JF, Franch-Nadal J, Lopez-Simarro F, et al. Prevalence of diabetic retinopathy in individuals with type 2 diabetes who had recorded diabetic retinopathy from retinal photographs in Catalonia (Spain). Br J Ophthalmol 2015;99:1628–33. https://doi.org/10.1136/bjophthalmol-2015-306683.

[13] Olafsdottir E, Andersson DK, Dedorsson I, Svardsudd K, Jansson SP, Stefansson E. Early detection of type 2 diabetes mellitus and screening for retinopathy are associated with reduced prevalence and severity of retinopathy. Acta Ophthalmol 2016;94:232–9. https://doi.org/10.1111/aos.12954.

[14] Dhillon N, Karthikeyan A, Castle A, Dodson P, Högler W, Kirk J, et al. Natural history of retinopathy in children and young people with type 1 diabetes. Eye 2016;30:987. https://doi.org/10.1038/eye.2016.60.

[15] Warwick AN, Brooks AP, Osmond C, Krishnan R. Prevalence of referable, sight-threatening retinopathy in type 1 diabetes and its relationship to diabetes duration and systemic risk factors. Eye (London, England) 2017;31:333–41. https://doi.org/10.1038/eye.2016.294.

[16] Vujosevic S, Pucci P, Casciano M, Daniele A, Bini S, Berton M, et al. A decade-long telemedicine screening program for diabetic retinopathy in the north-east of Italy. J Diabetes Complications 2017;31:1348–53. https://doi.org/10.1016/j.jdiacomp.2017.04.010.

[17] Jansson RW, Hufthammer KO, Krohn J. Diabetic retinopathy in type 1 diabetes patients in Western Norway. Acta Ophthalmol 2018;96:465–74. https://doi.org/10.1111/aos.13654.

[18] Acan D, Calan M, Er D, Arkan T, Kocak N, Bayraktar F, et al. The prevalence and systemic risk factors of diabetic macular edema: a cross sectional study from Turkey. BMC Ophthalmol 2018;18:91. https://doi.org/10.1186/s12886-018-0753-y.

[19] Alemu S, Dessie A, Tsegaw A, Patterson CC, Parry EH, Phillips DI, et al. Retinopathy in type 1 diabetes mellitus: major differences between rual and urban dwellers in northwest Ethiopia. Diabetes Res and Clin Pract 2015;109. https://doi.org/10.1016/j.diabres.2015.04.010.

[20] Cleland CR, Burton MJ, Hall C, Hall A, Courtright P, Makupa WU, et al. Diabetic retinopathy in Tanzania: prevalence and risk factors at entry into a regional screening programme. Trop Med Int Health 2016;21:417–26. https://doi.org/10.1111/tmi.12652.

[21] Webb EM, Rheeder P, Roux P. Screening in primary care for diabetic retinopathy, maculopathy and Visual Loss in South Africa. Ophthalmologica 2016;235:141–9. https://doi.org/10.1159/000443972.
[22] Cairncross JP, Steinberg WJ, Labuschagne MJ. Prevalence of eye pathology in a group of diabetic patients at National District Hospital Outpatient Department in Bloemfontein, South Africa. Afr J Primary Health Care Family Med 2017;9:1–7.
[23] Lewis AD, Hogg RE, Chandran M, Musonda L, North L, Chakravarthy U, et al. Prevalence of diabetic retinopathy and visual impairment in patients with diabetes mellitus in Zambia through the implementation of a mobile diabetic retinopathy screening project in the Copperbelt province: a cross-sectional study. Eye 2018;32:1201–8. https://doi.org/10.1038/s41433-018-0055-x.
[24] Dehghan MH, Katibeh M, Ahmadieh H, Naurinia M. Prevalence and risk factors for diabetic retinopathy in the 40 to 80 year-old population in Yazd, Iran: the Yazd Eye Study. J Diabetes 2015;7:139–41. https://doi.org/10.1111/1753-0407.
[25] Kanjee R, Dookeran RI, Mathen MK, Stockl FA, Leicht R. Six-year prevalence and incidence of diabetic retinopathy and cost-effectiveness of tele-ophthalmology in Manitoba. Can J Ophthalmol 2016;51:467–70. https://doi.org/10.1016/j.jcjo.2016.05.002.
[26] Bursell S-E, Fonda SJ, Lewis DG, Horton MB. Prevalence of diabetic retinopathy and diabetic macular edema in a primary care-based teleophthalmology program for American Indians and Alaskan Natives. PLoS ONE 2018;13:e0198551. https://doi.org/10.1371/journal.pone.0198551.
[27] Naik S, Wykoff CC, Ou WC, Stevenson J, Gupta S, Shah AR. Identification of factors to increase efficacy of telemedicine screening for diabetic retinopathy in endocrinology practices using the Intelligent Retinal Imaging System (IRIS) platform. Diabetes Res Clin Pract 2018;140:265–70. https://doi.org/10.1016/j.diabres.2018.04.011.
[28] Rodriguez NM, Aguilar S. Prevalence of diabetic retinopathy in a clinic population from Puerto Rico. Optom Vis Sci 2016;93:750–3. https://doi.org/10.1097/opx.0000000000000854.
[29] Mishra SK, Pant BP, Subedi P. The prevalence of diabetic retinopathy among known diabetic population in Nepal. Kathmandu Univ Med J (KUMJ) 2016;14:134–9.
[30] Sunita M, Singh AK, Rogye A, Sonawane M, Gaonkar R, Srinivasan R, et al. Prevalence of diabetic retinopathy in urban slums: the Aditya Jyot diabetic retinopathy in urban mumbai slums study-Report 2. Ophthalmic Epidemiol 2017;24:303–10. https://doi.org/10.1080/09286586.2017.1290258.
[31] Huang OS, Tay WT, Ong PG, Sabanayagam C, Cheng C-Y, Tan GS, et al. Prevalence and determinants of undiagnosed diabetic retinopathy and vision-threatening retinopathy in a multiethnic Asian cohort: the Singapore Epidemiology of Eye Diseases (SEED) study. Br J Ophthalmol 2015;99:1614. https://doi.org/10.1136/bjophthalmol-2014-306492.
[32] Keel S, Itsiopoulos C, Koklanis K, Vukicevic M, Cameron F, Brazionis L. Prevalence and risk factors for diabetic retinopathy in a hospital-based population of Australian children and adolescents with type 1 diabetes. J Pediatr Endocrinol Metab 2016:1135.
[33] Lian JX, Gangwani RA, McGhee SM, Chan CKW, Lam CLK, Wong DSH. Systematic screening for diabetic retinopathy (DR) in Hong Kong: prevalence of DR and visual impairment among diabetic population. Br J Ophthalmol 2016;100:151. https://doi.org/10.1136/bjophthalmol-2015-307382.
[34] Chang LYL, Lee AC, Wilson S. Prevalence of diabetic retinopathy at first presentation to the retinal screening service in the greater Wellington region of New Zealand 2006–2015, and implications for models of retinal screening. New Zealand Med Assoc 2017;130:78–88.
[35] Sasongko MB, Widyaputri F, Agni AN, Wardhana FS, Kotha S, Gupta P, et al. Prevalence of diabetic retinopathy and blindness in Indonesian adults with Type 2 diabetes. Am J Ophthalmol 2017;181:79–87. https://doi.org/10.1016/j.ajo.2017.06.019.
[36] Cui J, Ren J-P, Chen D-N, Xin Z, Yuan M-X, Xu J, et al. Prevalence and associated factors of diabetic retinopathy in Beijing, China: a cross-sectional study. BMJ Open 2017;7:e015473. https://doi.org/10.1136/bmjopen-2016-015473.
[37] Liu Y, Song Y, Tao L, Qiu W, Lv H, Jiang X, et al. Prevalence of diabetic retinopathy among 13473 patients with diabetes mellitus in China: a cross-sectional epidemiological survey in six provinces. BMJ Open 2017;7:e013199. https://doi.org/10.1136/bmjopen-2016-013199.
[38] Zhang G, Chen H, Chen W, Zhang M. Prevalence and risk factors for diabetic retinopathy in China: a multi-hospital-based cross-sectional study. Br J Ophthalmol 2017;101:1591–5. https://doi.org/10.1136/bjophthalmol-2017-310316.
[39] Keel S, Xie J, Foreman J, van Wijngaarden P, Taylor HR, Dirani M. The prevalence of diabetic retinopathy in Australian adults with self-reported diabetes: the national eye health survey. Ophthalmology 2017;124:977–84. https://doi.org/10.1016/j.ophtha.2017.02.004.
[40] Brazionis L, Jenkins A, Keech A, Ryan C, Brown A, Boffa J, et al. Diabetic retinopathy in a remote Indigenous primary healthcare population: a Central Australian diabetic retinopathy screening study in the Telehealth Eye and Associated Medical Services Network project. Diabet Med 2018;35:630–9. https://doi.org/10.1111/dme.13596.
[41] Tan GS, Gan A, Sabanayagam C, Tham YC, Neelam K, Mitchell P, et al. Ethnic differences in the prevalence and risk factors of diabetic retinopathy: the Singapore epidemiology of eye diseases study. Ophthalmology 2018;125:529–36. https://doi.org/10.1016/j.ophtha.2017.10.026.
[42] Bourne RRA, Flaxman SR, Braithwaite T, Cicinelli MV, Das A, Jonas JB, et al. Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. Lancet Glob Health 2017;5:e888–97. https://doi.org/10.1016/s2214-109x(17)30293-0.
[43] International Diabetes Federation. IDF diabetes atlas. 2017. https://diabetesatlas.org/IDF_Diabetes_Atlas_8e_interactive_EN/. 30/08/2019.
[44] Cavan D, Makaroff L, da Rocha Fernandes J, Sylvanowicz M, Ackland P, Conlon J, et al. The Diabetic Retinopathy Barometer Study: global perspectives on access to and experiences of diabetic retinopathy screening and treatment. Diabetes Res Clin Pract 2017;129:16–24. https://doi.org/10.1016/j.diabres.2017.03.023.
[45] Cavan D, Makaroff LE, da Rocha Fernandes J, Karuranga S, Sylvanowicz M, Conlon J, et al. Global perspectives on the provision of diabetic retinopathy screening and treatment: Survey of health care professionals in 41 countries. Diabetes Res Clin Pract 2018;143:170–8. https://doi.org/10.1016/j.diabres.2018.07.004.
[46] Leese GP, Morris AD, Olson J. A national retinal screening programme for diabetes in Scotland. Diabetic Med 2003;20:962–4.
[47] Scanlon PH. The English national screening programme for sight-threatening diabetic retinopathy. J Med Screen 2008;15:1–4. https://doi.org/10.1258/jms.2008.008015.
[48] Thomas RL, Dunstan F, Luzio SD, Roy Chowdhury S, Hale SL, North RV, et al. Incidence of diabetic retinopathy in people with type 2 diabetes mellitus attending the diabetic retinopathy screening service for wales: retrospective analysis. BMJ 2012;344. https://doi.org/10.1136/bmj.e874 e874.

[49] Agardh E, Tababat-Khani P. Adopting 3-year screening intervals for sight-threatening retinal vascular lesions in type 2 diabetic subjects without retinopathy. Diabetes Care 2011;34:1318–9.
[50] Andersen N, Hjortdal JO, Schielke KC, Bek T, Grauslund J, Laugesen CS, et al. The Danish registry of diabetic retinopathy. Clin Epidemiol 2016;8:613–9. https://doi.org/10.2147/clep.S99507.
[51] Olafsdottir E, Stefansson E. Biennial eye screening in diabetic patients without retinopathy. 10 year experience. Brit J Ophthalmol 2007;91:1599–601.
[52] Leese GP, Boyle P, Feng Z, Emslie-Smith A, Ellis JD. Screening uptake in a well-established diabetic retinopathy screening program: the role of geographical access and deprivation. Diabetes Care 2008;31:2131–5.
[53] Scanlon PH, Stratton IM, Leese GP, Bachmann MO, Land M, Jones C, et al. Screening attendance, age group and diabetic retinopathy level at first screen. Diabet Med 2016;33:904–11. https://doi.org/10.1111/dme.12957.