Disease burden of diabetes, diabetic retinopathy and their future projections in the UK

Haider, Sajjad; Thayakaran, Rasiah; Subramanian, Anuradha; Toulis, Konstantinos A; Moore, David; Price, Malcolm James; Nirantharakumar, Krishnarajah

DOI:
10.1136/bmjopen-2021-050058

BMJ Open

Disease burden of diabetes, diabetic retinopathy and their future projections in the UK: cross-sectional analyses of a primary care database

Sajjad Haider, Rasiah Thayakaran, Anuradha Subramanian, Konstantinos A Toulis, David Moore, Malcolm James Price, Krishnarajah Nirantharakumar

To cite: Haider S, Thayakaran R, Subramanian A, *et al*. Disease burden of diabetes, diabetic retinopathy and their future projections in the UK: cross-sectional analyses of a primary care database. *BMJ Open* 2021;**11**:e050058. doi:10.1136/bmjopen-2021-050058

► Prepublication history and additional online supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2021-050058).

DM, MJP and KN are joint senior authors.

Received 09 February 2021
Accepted 18 June 2021

Institute Of Applied Health Research, University of Birmingham, Birmingham, UK

Correspondence to
Dr Krishnarajah Nirantharakumar; k.nirantharan@bham.ac.uk

ABSTRACT

Objectives To estimate the current disease burden, trends and future projections for diabetes mellitus (DM) and diabetic retinopathy (DR) in the IQVIA Medical Research Data (IMRD).

Participants/design/setting We performed a cross-sectional study of patients aged 12 and above to determine the prevalence of DM and DR from the IMRD database (primary care database) in January 2017, involving a total population of 1 80 824 patients with DM. We also carried out a series of cross-sectional studies to investigate prevalence trends, and then applied a double exponential smoothing model to forecast the future burden of DM and DR in the UK.

Results The crude DM prevalence in 2017 was 5.2%. The DR, sight-threatening retinopathy (STR) and diabetic maculopathy prevalence figures in 2017 were 33.78%, 12.28% and 7.86%, respectively, in our IMRD cross-sectional study. There were upward trends in the prevalence of DM, DR and STR, most marked and accelerating in STR in type 1 DM but slowing in type 2 DM, and in the overall prevalence of DR.

Conclusion Our results suggest differential rising trends in the prevalence of DM and DR. Preventive strategies, as well as treatment services planning, can be based on these projected prevalence estimates. Improvements that are necessary for the optimisation of care pathways, and preparations to meet demand and capacity challenges, can also be based on this information. The limitations of the study can be overcome by a future collaborative study linking DR screening and hospital eye services data.

Strengths and limitations of this study

- ► This is an up-to-date study to give diabetes mellitus (DM) and diabetic retinopathy (DR) prevalence trends from 1998 to 2018.
- ► This study forecasts the future DR disease burden up to 2030 to enable preparation for impending challenges.
- ► Current prevalence of age 12 and over, diagnosed DM, DR, sight threatening retinopathy, diabetic macular oedema disease and treatment burden in UK.
- ► This study has not, however, been adjusted for the risk factors for the incidence/prevalence of DM or DR.
- ► A possible impact of coding errors and subjectivity in documentation cannot be precluded.

INTRODUCTION

DR is the fourth most common cause of blindness and visual impairment in high-income countries.[1] Services are overburdened and optimisation requires accurate estimates of disease and the expected treatment burden.[2] A recent systematic review of studies estimating the incidence of DR[3] highlighted the paucity of contemporary evidence from developed countries on the disease burden and recommended that estimates should be based on populations with diabetes mellitus (DM) rather than the general population so as not to dilute the estimates. A recent attempt to forecast the UK-wide disease burden of DR was hindered by the need for reliable data.[4]

Previous studies have been conducted on the prevalence of DR,[5–9] with the most recent UK-wide study being performed in 2014 based on Clinical Practice Research Datalink (CPRD). Two of these studies also explored trends in DR incidence and prevalence.[6 9] A significant amount of heterogeneity in the populations studied, the classification of DR, the definition of its presence and severity was present in these studies. Studies of the forecasts of the future disease burden of DR would be useful both for preparing healthcare delivery systems for the future, and in preventing blindness in patients with DM. There is a Europe-wide forecast study with UK component based on pre 2009 data dealing with DR only.[10] The disease burden estimate of DR will not be complete without a similar estimate for the diabetes burden. A UK-wide

up-to-date study dealing with DM, DR and sight threatening retinopathy (STR) is needed.

A previous study on future projections of DM in the UK was found to underestimate prevalence.[11] Moreover, evidence suggests that the rate of increase is not constant or uniform across DM subtypes (namely type 2 DM (T2DM) and T1DM, especially in children.[12] The incidence rate of T1DM (pooled estimate of European centres, UK included) in children is expected to continue to rise at a rate of 3.4% per annum.[13] Gonzalez *et al*[14] reported an increasing prevalence of DM for the 10 years up to 2005. Public Health England (PHE) figures are available for 2019, based on the Quality Outcome Framework, except in Scotland where they are based on Scottish Diabetes Survey.[15] However, these figures are limited to those over 17 years old. We aimed to estimate recent trends in the disease burden of DM, and to use this as a base on which to estimate the current disease burden for DR and STR in the UK. We then wanted to design, train, and validate a forecasting model to support future projections of these disease burdens. Since DR screening is offered after age 12 only, the population of interest to us was age 12 or over only.

METHODS

Study design and data source

Several studies have already been performed on IQVIA Medical Research Data (IMRD) (previously The Health Improvement Network) and their findings have been extrapolated to UK and European population.[16–21] This database has documented generalisability to the UK population.[22]

To study the trend, and to forecast the future burden of diagnosed DM, DR and STR, we used the IMRD database to conduct a series of yearly cross-sectional analyses on the first of each year from 1998 to 2018. In addition, a detailed cross-sectional study was carried out on the 1 January 2017 to estimate the prevalence of T1DM and T2DM in the whole UK population, and of DR in patients with T1DM and T2DM.

IMRD is a large UK general practice electronic database containing anonymised patient records from 787 general practices, with over 15 million patient records, of which around 3.7 million are active at a given time point (6.2% of the UK population). IMRD provides information on demographics, lifestyle, diagnoses and prescriptions, and is quality checked.[23] Based on the demographic distribution observed in IMRD, it is considered generalisable to the UK population.[22] IMRD has previously been used and validated to estimate prevalence trends of DM and DR, and to identify risk factors for DR.[14 24–27]

Study population

To ensure that only high-quality data were included, and that all important covariates were documented, general practices were eligible only if they showed acceptable mortality rates 1 year before the cross-sectional study date,[23] and had been using the electronic medical record system for at least a year. Patients from eligible general practices must have been registered with their practice for at least 1 year and must be aged 12 years or above to be included in the study to match the Diabetic Eye Screening Programme criteria (DESP). For estimation of the prevalence of T1DM and T2DM, the whole registered population was included as the denominator population (per 1000). For estimation of STR and DR prevalence, patients with DM served as the denominator (per 100). Estimates are stratified by type of diabetes.

Case definition of diagnoses of DM and DR

Clinical diagnosis and symptoms in the IMRD database are recorded using the Read code classification system.[28] Read codes were selected using a rigorous seven step process and selected search terms (online supplemental appendix 1,2). Read codes are given in online supplemental appendix 3. Patients with a Read code record of DM before the study entry date were identified. Patients with a record of DM were categorised as type 1 if they had at least one prescription record for insulin and no record for any oral glucose-lowering medication other than metformin in the database. The remaining patients with diabetes were categorised as type 2. Prevalence estimates calculated were verified against PHE estimates of DM.[29]

The most severe DR Read code recorded before patient's study entry was used to classify their DR or STR status. Stages of DR among those patients identified with DM were classified using the Royal College of Ophthalmology modified classification.[30] However, patients with a retinopathy record were stratified into mutually exclusive categories of (1) Pre-STR including no retinopathy and background retinopathy, (2) STR and (3) Retinopathy unspecified as either pre-STR (background retinopathy) or STR. Pre-STR was further categorised into mutually exclusive categories: (1) R0 or (2) R1. STR was further categorised into mutually exclusive categories of (1) STR based on diagnostic codes and (2) STR that needed treatment or resulted in vision loss. Within STR we categorised preproliferative DR (R2) and proliferative DR (R3) as mutually exclusive groups. STR was further stratified into overlapping categories based on the presence of STR (R2/3) and maculopathy (M1). Treatment and vision loss codes included: (1) laser therapy, (2) vitreous injection and other vitreous procedures, (3) low vision or blindness.

Time trend analysis and forecasting models

A double exponential smoothing model was chosen to cover the level and trend, as this was yearly cross-sectional data with no seasonal/cyclical variation expected or observed[31] not unlike Adams *et al* published model.[32] The IMRD serial cross-sectional data for the prevalence of DM and DR (STR and any retinopathy) were split into two portions—1998–2013 (training data) and 2014–2018 (test data). The model was fitted to the training data and then prediction was carried out from 2014 to 2018. This was

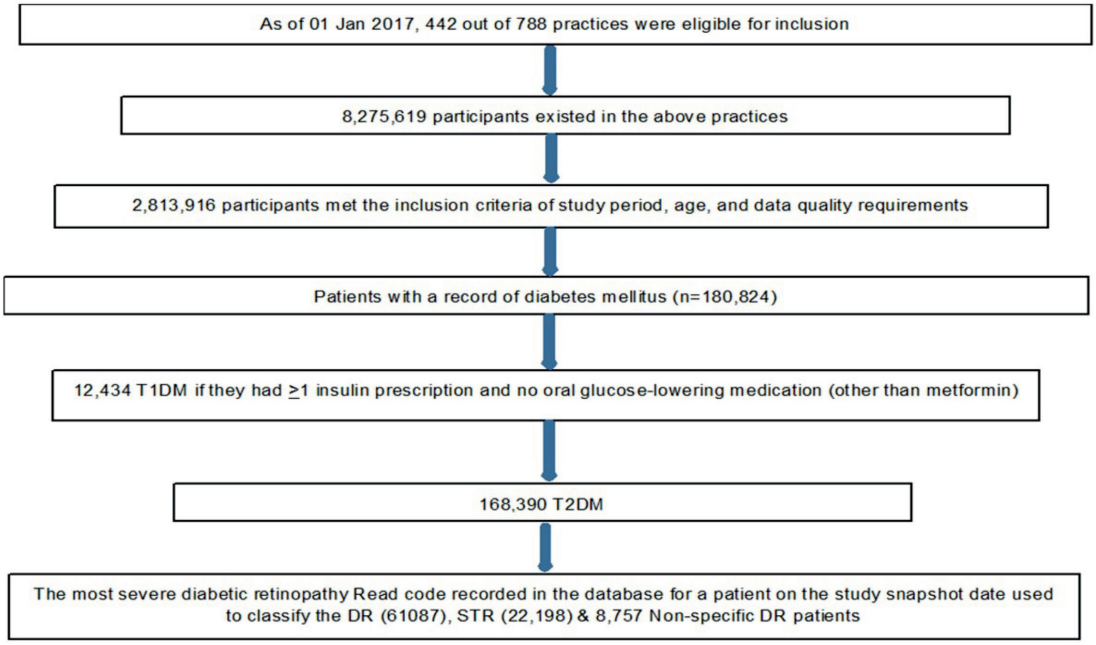

Figure 1 Patients flow and case selection algorithm. DR, diabetic retinopathy; STR, sight threatening retinopathy; T1DM, type 1 diabetes mellitus.

then compared with the test data for validation. Thereafter, the yearly prevalence of DR and STR were projected up to 2030 using the same model with 95% prediction intervals (PI). This was done using the statistical software R (2019).[33] Prevalence rates were then converted into patient numbers, using projected population figures from the Office of National Statistics.[34]

IMRD data analysis for annual prevalence of DM and DR

Prevalence trends between the two decades before and after 2008 were compared for trend analysis. Patients identified as T1DM or T2DM on or before 1 January in each year analysed were identified as the numerators for calculating the prevalence of T1DM and T2DM. The prevalence was estimated by dividing the numerator population by the eligible registered population aged above 12 years (denominator) on 1 January for the corresponding year. Among these patients, those diagnosed with any retinopathy and those with STR were numerators for calculating the prevalence of DR and STR respectively. Prevalence estimates are provided for patients with T1DM and T2DM separately with 95% CIs. A description of patients aged 12 or above with a diagnosis of DM is also given for the year 2017. Baseline characteristics such as age, and age at diagnosis of diabetes were summarised as the mean (SD), and as frequency (percentage) for sex, Townsend deprivation quintile and ethnicity. These characteristics were also reported as stratified by type of DM. A detailed description of the proportion of DM patients (T1DM and T2DM aged 12 or above) with DR in the year 2017 categorised by DR severity is also presented. Estimates from IMRD were compared with estimates obtained from data from UK studies[5–7 9 35] for verification and comparison.

RESULTS

Figure 1 gives the Patients flow and case selection algorithm. As of 1 January 2017, 2 813 916 people were eligible to be included in the primary cross-sectional analysis. The demography characteristics of the sample are given in table 1. The mean age of patients with T1DM and T2DM as of 1 January 2017 was 42.5 (17.2) and 66.3 (13.0), respectively. The mean age at diagnosis of T1DM and T2DM were 21.4 (14.3) and 57.0 (13.1), respectively. Nearly 80% and 55% of patients, respectively, had their Townsend deprivation and ethnicity recorded in the IMRD database.

Prevalence trends

The results in figures 2 and 3 show an almost a global upward trend in the prevalence of both types of diabetes (T1DM and T2DM) and in DR (all types of DR/STR). The highest rise was seen in STR in those with T1DM (3.7 times increase in two decades). The second highest rise was in all types of DR in the T2DM population (2.8 times). Splitting this data by the decades (1998–2007 vs 2009–2018), the end of the first decade showed a higher increase in every category (diabetes as well as DR) as compared with the second decade, except in T1DM where it was higher in second decade (online supplemental appendix 4). T2DM increased more than T1DM between 1998 and 2018, but while the increase in T2DM prevalence slowed recently, the increase in T1DM prevalence accelerated significantly in the recent decade.

Forecasting model

The forecasted annual UK prevalence values of T1DM, T2DM, DR and STR, with their 95% PI, are given in the online supplemental appendix 5. These suggest that the

Table 1 Demography of patients with DM in IMRD data on 1 January 2017

	DM (N)	%/(SD)	T1DM (N)	%/(SD)	T2DM (N)	%/(SD)
Total	180 824	100.00%	12 434	6.88%	168 390	93.12%
Gender:						
Male	101 628	56.20%	7192	57.84%	94 436	56.08%
Female	79 196	43.80%	5242	42.16%	73 954	43.92%
Age	180 824	64.7 (SD 14.7)	12 434	42.5 (SD 17.2)	168 390	66.3 (SD 13.0)
Age at diagnosis	180 788	54.6 (SD 16.0)	12 422	21.4 (SD 14.3)	168 366	57.0 (SD 13.1)
Townsend:						
1	27 616	15.27%	2037	16.38%	25 579	15.19%
2	30 011	16.60%	2206	17.74%	27 805	16.51%
3	32 434	17.94%	2222	17.87%	30 212	17.94%
4	31 332	17.33%	1978	15.91%	29 354	17.43%
5	24 606	13.61%	1568	12.61%	23 038	13.68%
Missing	34 825	19.26%	2423	19.49%	32 402	19.24%
Ethnicity:						
Caucasian	88 420	48.90%	6584	52.95%	81 836	48.60%
Black afro Caribbean	2738	1.51%	98	0.79%	2640	1.57%
Chinese/Middle eastern/ others	567	0.31%	45	0.36%	522	0.31%
South Asians	6361	3.52%	124	1.00%	6237	3.70%
Mixed race	1243	0.69%	32	0.26%	1211	0.72%
Missing	81 495	45.07%	5551	44.64%	75 944	45.10%

DM, diabetes mellitus; IMRD, IQVIA Medical Research Data; N, Number; SD, Standard Deviation; T1DM, type 1 DM; T2DM, type 2 DM.

prevalence will increase by 24% (5% to 43%), 7% (–28% to 41%), 9% (–50% to 65%) and 17% (–21% to 54%), respectively by 2030. Corresponding estimates of the absolute numbers of people in the UK forecast to have these conditions are shown in table 2. These correspond to 0.36 (3–0.4), 4 (2.6–5.3), 1.6 (7–2.5) and 0.64 (0.42–0.86) million people, respectively, having each condition, respectively. We verified our UK forecast for 2019 and found the total figure (3800,920) to be close to the Quality Outcome Framework provided estimate of diagnosed DM of 3 809 119.

2017 cross-sectional analysis

In the 2017 data analysis, 180 824 patients had a code for diabetes prior to this date of which 12 434 (6.9%) were identified as T1DM and 168 390 (93.1%) were identified as T2DM. Patients with DM were more likely to be men (56.2% vs 43.8%). The prevalence of DR in different stages of progression is given in table 3. Prevalence of any DR and STR among patients with DM aged 12 and above was 33.8% and 12.3%, respectively. When stratified by diabetes type, a higher proportion of patients with T1DM had a more severe form of retinopathy than

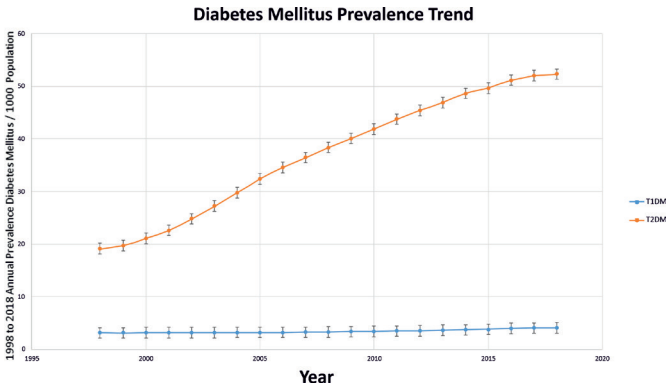

Figure 2 Prevalence trends of DM from year 1998 to2018. DM, diabetes mellitus; T1DM, type 1 diabetes mellitus; T2DM, Type 2 diabetes mellitus.

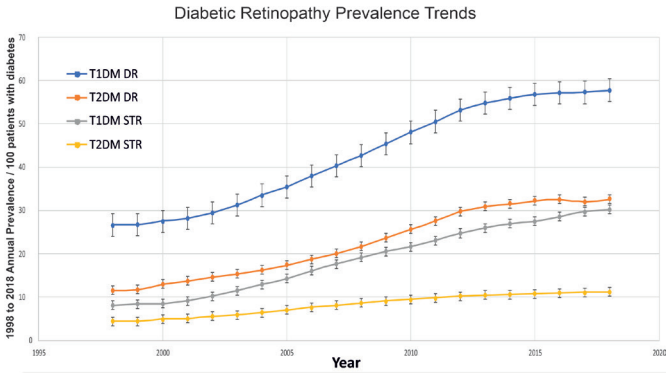

Figure 3 Annual prevalence (95% CI) of DR and STR from year 1998 to 2018. DR, Diabetic Retinopathy; T1DM, type 1 diabetes mellitus number; T2DM, type 2 diabetes mellitus; STR, sight threatening retinopathy.

Table 2 Future projections of diabetes and DR disease burden

Year	Projected population	T1DM*	T2DM*	Total DM*	DR†	STR†
2019	66 800 000	280 560	3 520 360	3 800 920	1 311 317	482 717
2020	67 200 000	288 960	3 568 320	3 857 280	1 342 333	497 589
2021	67 500 000	297 000	3 604 500	3 901 500	1 369 427	511 097
2022	67 800 000	305 100	3 647 640	3 952 740	1 399 270	525 714
2023	68 100 000	306 450	3 684 210	3 990 660	1 420 675	538 739
2024	68 400 000	314 640	3 720 960	4 035 600	1 448 780	552 877
2025	68 700 000	322 890	3 764 760	4 087 650	1 479 729	568 183
2026	68 900 000	330 720	3 796 390	4 127 110	1 506 395	581 923
2027	69 200 000	339 080	3 833 680	4 172 760	1 535 576	596 705
2028	69 400 000	347 000	3 872 520	4 219 520	1 561 222	611 830
2029	69 600 000	354 960	3 904 560	4 259 520	1 588 801	626 149
2030	69 800 000	362 960	3 936 720	4 299 680	1 616 680	640 652

*The DR and STR forecast is actual IMRD based figures projected for the UK population.[34] Formula used is Affected Population=Projected Prevalence × Projected Population.
†In calculating projections for diabetic retinopathy, we have applied the retinopathy rates of those aged 12 and above for the whole diabetes population rather than for those above 12 years old (age at which retinopathy screening commences and was one of our inclusion criteria). This approximately gives the projected total population, as breakdown for over 12 years is not available but the number of patients with DM below 12 years is negligibly small.
DR, diabetic retinopathy; IMRD, IQVIA Medical Research Data; STR, sight threatening retinopathy.

patients with T2DM (prevalence of STR was 29.7% vs 11%), while prevalence of pre-STR (R0/R1 & M0) was higher among patients with T2DM (31.8% in T1DM vs 37.8% in T2DM). Each subcategory among STR population (R2/R3/M1 and their combinations), was present in higher proportion of patients with T1DM as compared with T2DM (R2: 3.7% vs 1.2%; R3: 12.1% vs 1.9%; and M1: 19.6% vs 7.0%, respectively). A higher proportion of patients with T1DM compared with T2DM also received treatment procedures (laser: 7.1% vs 1.3%; vitreous injection and procedures: 5.1% vs 1.1%). There was also a higher proportion of documented cases of visual impairment or vision loss among T1DM (3.1% vs 2.8%).

Table 3 Diabetic Retinopathy in patients with DM in IMRD data on 1 January 2017

	DM		T1DM		T2DM	
Diabetes (N)	**180 824**	**%**	**12 434**	**%**	**168 390**	**%**
No retinopathy coding available	82 119	45.41	3846	30.93	78 273	46.48
Retinopathy Coding available	98 705	54.59	8588	69.07	90 117	53.52
Pre-STR	67 750	37.47	3951	31.78	63 699	37.83
No DR (R0M0)	37 618	20.80	1472	11.84	36 146	21.47
R1	30 132	16.66	2479	19.94	27 553	16.36
STR	22 198	12.28	3693	29.70	18 505	10.99
STR without Rx or vision loss	13 165	7.28	2271	18.26	10 894	6.47
R2	2487	1.38	454	3.65	2033	1.21
R3	4729	2.62	1505	12.10	3224	1.91
M1	14 206	7.86	2440	19.62	11 766	6.99
STR with Rx and vision loss	9033	5.00	1422	11.44	7611	4.52
Laser	3092	1.71	885	7.12	2207	1.31
Vitreous injections/procedures	2536	1.40	637	5.12	1899	1.13
Vision loss/blindness	5050	2.79	384	3.09	4666	2.77
None specific for STR or Pre-STR	8757	4.84	844	6.79	7913	4.70
Any retinopathy	61 087	33.78	7016	56.43	53 971	32.05

Pre-STR is combination of no diabetic retinopathy and background retinopathy, R2 is preproliferative diabetic retinopathy, R3 is proliferative diabetic retinopathy, M1 is diabetic maculopathy, STR is a combination of R2, R3 and M1, non-specific retinopathy is where it cannot be categorised into R1 or STR. Where colour codes are assigned, the same colour indicates that they are mutually exclusive. Where colour codes are not assigned, they overlap within that category. For example, patients with M1 can have either R2 or R3, likewise patients who received laser treatment could have received vitreous injection. WHO standards[50] were used for vision loss. Here, all categories were combined into a single category.
DR, diabetic retinopathy; IMRD, IQVIA Medical Research Data ; M0, no maculopathy; R0, no retinopathy; R1, background retinopathy; STR, sight-threatening retinopathy.

DISCUSSION

Principal findings

We explored the disease burden associated with DM and DR in the UK from the past, present and future perspectives. Our study followed a tripartite structure, comprising of (1) a series of epidemiological studies throughout a 20-year span to document disease-specific trends, (2) training a forecasting model to predict the future disease burden to guide clinical practice and service development and (3) a detailed descriptive cross-sectional analysis in 2017 using a study population of 180 824 people with diabetes to explore contemporary prevalence estimates of different forms of DR.

Between 1998 and 2018, the prevalence of DR and STR increased. The prevalence of all DR in T2DM nearly tripled and STR almost quadrupled among patients with T1DM aged 12 and above. There was a parallel increase in the overall prevalence of DM. While the growth in the numbers of T1DM patients was less than that for patients with T2DM, stratifying the calculations by two decades showed a marked rise in the rate of increase in T1DM prevalence in the latter half of the whole period between 1998 and 2018. This was in sharp contrast to the trends in T2DM, STR and DR prevalence, which showed a higher rise in the decade between 1998 and 2007 but slowed down in the later decade between 2009 and 2018.

Our forecasting model showed that, in less than ten years, over 1.5 million people with diabetes will have some DR, almost two-thirds of a million of whom will have STR. With T1DM expected to rise faster and higher, it is also likely to correspond to a comparatively higher rise in STR, forcing a further increase in demand on services.

A key parameter when calculating the current and future prevalence of DR is the accuracy of estimates of the trend of the underlying condition, that is, the presence of DM. T1DM showed a smaller increase in the period starting from 1998, but this has accelerated since 2009. This is the most concerning recent trend considering that these are younger patients (mean age of diagnosis of 21.4 vs 57), having to live with the condition and its complications for more life years, and suffering from the more severe form of DR, with the consequent disability, treatment burden and treatment costs. There is a recent report of a 3.4% annual increase in the incidence rate of T1DM in children.[13] Although there is an association between T1DM and obesity,[36] it is believed that the cause may be multifactorial, including hygiene, viral factors and vitamin D deficiency among others.[37]

The diagnosed DM prevalence based on the 2017 IMRD cross-sectional survey is 5.2%. The detailed descriptive analysis in 2017 showed that, out of 180 824 people with diabetes, 33.8% had any DR as a complication, 12.3% had STR and importantly, 2.8% had blindness or vision loss. STR was 52% of total DR in T1DM and 34% of total DR in T2DM. In 2017, nearly one-third of all patients with T1DM were affected by a sight threatening form of DR. This analysis also confirmed the notion that, from the healthcare perspective, neither DM type is 'benign' with regards to DR risk, since DR severity is graver in T1DM, and absolute numbers of affected individuals are higher in T2DM.

Diabetic complications are mainly macrovascular damage (coronary artery disease, peripheral arterial disease and stroke) or microvascular damage to blood vessels in organs like kidney, foot and nerves.[38] Tackling the first reduces mortality rate and might mean these patients living longer and consequently a higher prevalence of DR among higher risk patients. With greater efficacy and a rapid reduction of glycosylated haemoglobin (HBA1C), the new agents might induce progression of DR (early worsening).[39] So, with increased prevalence there may be a disproportionate rise in more high-risk DR cases. There are conflicting reports on direct effect of newer medical treatments like Incretin based therapies on DR[39 40] but the follow-up is limited at the moment.

Strengths and weaknesses of this study

This study reports up to date prevalence figures of DM, DR and STR, as well as trends from 1998 to 2018, in a clinically relevant form, which clinicians and managers leading hospital eye services can use in the management of services for diabetes and DR. Our work is based on a cross-sectional analysis of primary care data and is therefore closer to routine practice. Our findings have also been verified against PHE, DESP and other previously published figures.[5–7 14 35 41 42] This is also the first observational IMRD based study to forecast the DM, DR and STR disease burden in the UK all together. While incorporating current evidence on the trend of underlying condition (DM), this study portrays a comprehensive analysis of the recent DR disease burden.

The findings of this study should be interpreted within the context of its limitations. In particular, the inability to incorporate evidence regarding the potential impact of glycaemia control and concomitant medications on the incidence of DR should be promptly acknowledged. Suboptimal glycaemic control is a well-established risk factor for microvascular complications (such as DR), whereas fenofibrate, an agent used in in some patients with diabetes may have a positive effect on the course of DR.

Additional limitations are possible coding errors, challenges of addressing missing data, changes in the diagnostic criteria of DM and the potential risk of an overestimation of vision failure. The findings of this study should be interpreted within that context. First, the possible impact of coding errors, as well as subjectivity in documentation across a retrospective nationwide database involving several practices in different areas, cannot be precluded. This potential risk was minimised through a strict Read code selection process. The prevalence of severe DR was higher for those of South Asian and mixed ethnicity,[9] therefore, could have implications for local variations in its prevalence, and estimates could differ depending on the local ethnic mix. The potential impact of several concomitant medications on the course of DR was not captured in this

study design. For the sake of future projections, estimates from individuals over 12 years old were applied to the whole population to calculate the final values, assuming that the number of DM patients under 12 is extremely low. Finally, we acknowledge that these projections are subject to the assumption that factors affecting the incidence, course and progression of the disease will remain stable over the next few years.

We wanted to verify our figures against data from DESP which screens everyone from age 12[43] and Mathur *et al* work.[9] Both these research studies used a cut-off of over 12 years for their estimates. We wanted our findings to be generalisable to the whole UK populations with diabetes including those under care of DESP and Hospital Eye Services. We also wanted it to be generalisable internationally where majority of world population with diabetes is within one pool, without access to screening services. Limitations of this age cut-off are that 2017 figures are not easily verifiable against PHE figures 2017 being over 17 years of age. So, verification against that estimate is a bit problematic and thus adds uncertainty to our UK forecast estimates.

Strengths and weaknesses in relation to other studies, discussing particularly any differences in results

Gonzalez *et al*[14] reported an increasing prevalence of diabetes between the years 1996 and 2005 (10 years) based on THIN data analysis of patients aged 10–79 years old. They reported an overall increase of 54%. Our estimate between 1998 and 2005 (our data did not match the years) was 60%. In a CPRD based study, Zghebi *et al*[42] found an overall increase of 64% in the patient population between 2004 and 2014, but this was limited to patients over 16 years old with T2DM. Our corresponding figures are 63%. Thus, our estimates fall midway between these two studies. Bagust *et al* presented a future forecast for UK, but is limited to T2DM and is an underestimation.[11] It projected T2DM figures for 2036 to be 1.1 million.

The PHE estimate for prevalence of diabetes in UK in 2017 arrived at by Quality and Outcome Framework figures was 3.7 million (5.6%) in those aged 17 years and over[41] and included diagnosed patients with diabetes. Our estimate of diagnosed patients with diabetes in 2017 of 3.4 million (crude prevalence of 5.2%) in over 12 years old population contrasts with the 2017 PHE figures. Similarly), PHE predicted the diabetes burden for 2025 to be 4.9 million for people aged over 16 years.[44] It is not possible to make a direct comparison with our forecast of just under 4.3 million for 2025 because of our estimate being for people over 12 years of age but could mean the present study to be an underestimation. Alternatively, PHE figures could be an overestimation for 2017, because of the inbuilt assumptions in that model. Our estimate for 2019 matches the quality and outcome estimate of 3.8 million. International Diabetes Federation[45] estimated total diabetes prevalent cases (20–79 years old) to be 2.7 million in 2017, which is an underestimation when compared with PHE and our study.

A recent DR prevalence study focused on lower risk patients with diabetes under screening services.[9] The DR period prevalence in the Mathur's study (2004 to 2014) was found to be 48.4% for patients with T1DM and 28.3% for patients with T2DM, contrasting with point prevalence (2017) of 56.4% and 32.0% for patients with T1DM and T2DM, respectively, in our study. They also did not split the pathology into maculopathy and preproliferative categories and did not include treatment and vision failure.[1010] is the only study so far, that has projected DR till 2050. They estimated that 8.6 million people with diabetes (DR in 25% of the European population with T2DM and 50% with T1DM) will have diabetic eye disease inn 2050. The British studies included within this systematic review were based on diabetic screening services from pre-2009[46] and pre-2003 data.[7] Case definitions and patient pathways have since changed. Consequently, their figures are a significant underestimation as compared with ours (710 510 vs 1 612 395 in 2030)

Other prevalence studies from the UK[5–7 35] are compared with estimates from our study in detail for completeness in online supplemental appendix 6,7. Majority of these UK studies are quite old, come from the screening programme setting, and do not deal with all of the categories of DR due to changed case definitions. Keenan *et al*[47] is a study based on work between 2007 and 2009 on hospital patients. They based their estimates of prevalence in eyes rather than patients, therefore, due to this heterogeneity, cannot be directly compared with our figures.

Meaning of the study: possible mechanisms and implications for clinicians or policymakers

Consecutive analyses over the course of over two decades provides information regarding the trend and severity of diabetic disease, and by a detailed analysis of different forms and severity groups, it captures the implications for the public health system. With the use of relevant outcomes, coupled with a prerequisite validation, the study provides a forecasting model which will be of use for clinicians and managers leading the professional services in planning the capacity to meet the increasing demand, and will guide public health strategy. Local demand can be calculated with the help of national figures provided by taking local factors into account.[48]

Out of the 33.8% of total DR in all patients with diabetes, 12.3% was made up of the STR. Those STR patients that actually needed treatment or experienced vision failure constituted a total of 5%. These figures reflect a high false-positive rate of referrals (50%–70% as reported earlier[2 49] and needs to be considered in the future relationship between DESP and overburdened hospital eye services. Our estimated prevalence figures, in a clinically relevant form, will help the clinicians and managers leading hospital eye services to optimise capacity planning for the increased demand.

Unanswered questions and future research

PHE used a prevalence model to predict the disease burden of diabetes in 2016.[48] The predictive factors they used were age, ethnicity, gender and deprivation index. To accommodate local variation in populations and practices, final calculations can be made using these predictive factors. The above-mentioned limitations of the study can be overcome by a future collaborative study linking DR screening and hospital eye services data, with figures based on patient numbers and not eyes, to prevent heterogeneity among studies. Forecasting capacity needs is an area that should be repeated periodically with the help of the forecasting model presented.

CONCLUSION

In our study, the estimates suggested a trend of differential rise in prevalence rates in T1DM and T2DM. Overall, there is a continuing rise in the numbers of patients with DM and DR needing care. Preventive strategies and service planning can be based on these projected prevalence estimates to meet demand over the next ten years. Future forecasting will need repeating periodically to capture any external factors causing a change in the present trend.

Contributors SH and KN designed the main study. AS performed data extraction. SH made the main contribution to the interpretation of data and wrote up the draft. RT designed and carried out the future projection model. AS, MJP, DM, KAT and KN made a contribution verbally or by critical revision of the draft. All authors approved the final version of the manuscript.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Ethics approval The IMRD database has blanket approval by the NHS South East Multi-centre Research Ethics Committee (MREC) in 2003 (51). The study protocols were submitted to both the Scientific Review Committee and the Science, Technology, Engineering and Mathematics Ethical Review Committee at the University of Birmingham for review and approval, which were granted. Consent was not required.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as online supplemental information. Data were part of a digital database and are not available to be shared. Analysis details are in the publication/appendices.

ORCID iD
Sajjad Haider http://orcid.org/0000-0001-8111-8577

REFERENCES

1 Bourne RRA, Jonas JB, Bron AM, *et al*. Prevalence and causes of vision loss in high-income countries and in eastern and central Europe in 2015: magnitude, temporal trends and projections. *Br J Ophthalmol* 2018;102:575–85.
2 The Royal College of Ophthalmologists. The way forward age-related macular degeneration and diabetic retinopathy, 2016. Available: https://www.rcophth.ac.uk/wp-content/uploads/2015/10/RCOphth-The-Way-Forward-AMD-300117.pdf [Accessed 20 July 2019].
3 Sabanayagam C, Banu R, Chee ML, *et al*. Incidence and progression of diabetic retinopathy: a systematic review. *Lancet Diabetes Endocrinol* 2019;7:140–9.
4 Buchan JC, Norman P, Shickle D, *et al*. Failing to plan and planning to fail. can we predict the future growth of demand on UK eye care services? *Eye* 2019;33:1029–31.
5 Thomas RL, Dunstan FD, Luzio SD, *et al*. Prevalence of diabetic retinopathy within a national diabetic retinopathy screening service. *Br J Ophthalmol* 2015;99:64–8.
6 Misra A, Bachmann MO, Greenwood RH, *et al*. Trends in yield and effects of screening intervals during 17 years of a large UK community-based diabetic retinopathy screening programme. *Diabetic Medicine* 2009;26:1040–7.
7 Younis N, Broadbent DM, Harding SP, *et al*. Incidence of sight-threatening retinopathy in type 1 diabetes in a systematic screening programme. *Diabetic Medicine* 2003;20:758–65.
8 Looker HC, Nyangoma SO, Cromie D, *et al*. Diabetic retinopathy at diagnosis of type 2 diabetes in Scotland. *Diabetologia* 2012;55:2335–42.
9 Mathur R, Bhaskaran K, Edwards E, *et al*. Population trends in the 10-year incidence and prevalence of diabetic retinopathy in the UK: a cohort study in the clinical practice research Datalink 2004–2014. *BMJ Open* 2017;7:e014444.
10 Li JQ, Welchowski T, Schmid M, *et al*. Prevalence, incidence and future projection of diabetic eye disease in Europe: a systematic review and meta-analysis. *Eur J Epidemiol* 2020;35:11-23.
11 Bagust A, Hopkinson PK, Maslove L, *et al*. The projected health care burden of type 2 diabetes in the UK from 2000 to 2060. *Diabetic Medicine* 2002;19:1–5.
12 Candler TP, Mahmoud O, Lynn RM, *et al*. Continuing rise of type 2 diabetes incidence in children and young people in the UK. *Diabetic Medicine* 2018;35:737–44.
13 Patterson CC, Harjutsalo V, Rosenbauer J, *et al*. Trends and cyclical variation in the incidence of childhood type 1 diabetes in 26 European centres in the 25 year period 1989–2013: a multicentre prospective registration study. *Diabetologia* 2019;62:408–17.
14 González ELM, Johansson S, Wallander M-A, *et al*. Trends in the prevalence and incidence of diabetes in the UK: 1996-2005. *J Epidemiol Community Health* 2009;63:332–6.
15 Public Health England. Diabetes prevalence 2019, 2019. Available: https://www.diabetes.org.uk/professionals/position-statements-reports/statistics/diabetes-prevalence-2019 [Accessed 12 May 2020].
16 Petherick ES, Pickett KE, Cullum NA. Can different primary care databases produce comparable estimates of burden of disease: results of a study exploring venous leg ulceration. *Fam Pract* 2015;32:cmv013–80.
17 Pham TM, Carpenter JR, Morris TP, *et al*. Ethnic differences in the prevalence of type 2 diabetes diagnoses in the UK: cross-sectional analysis of the health improvement network primary care database. *Clin Epidemiol* 2019;11:1081–8.
18 Guest JF, Ayoub N, McIlwraith T, *et al*. Health economic burden that wounds impose on the National health service in the UK. *BMJ Open* 2015;5:e009283-e.
19 Tulloch JSP, Christley RM, Radford AD, *et al*. A descriptive epidemiological study of the incidence of newly diagnosed Lyme disease cases in a UK primary care cohort, 1998–2016. *BMC Infect Dis* 2020;20:285.
20 Adderley NJ, Subramanian A, Nirantharakumar K, *et al*. Association between idiopathic intracranial hypertension and risk of cardiovascular diseases in women in the United Kingdom. *JAMA Neurol* 2019;76:1088–98.
21 Chandan JS, Gokhale KM, Bradbury-Jones C, *et al*. Exploration of trends in the incidence and prevalence of childhood maltreatment and domestic abuse recording in UK primary care: a retrospective cohort study using 'the health improvement network' database. *BMJ Open* 2020;10:e036949-e.
22 Blak BT, Thompson M, Dattani H, *et al*. Generalisability of the health improvement network (thin) database: demographics, chronic disease prevalence and mortality rates. *Inform Prim Care* 2011;19:251–5.

23 Maguire A, Blak BT, Thompson M. The importance of defining periods of complete mortality reporting for research using automated data from primary care. *Pharmacoepidemiol Drug Saf* 2009;18:76–83.
24 Martín-Merino E, Fortuny J, Rivero E, *et al*. Validation of diabetic retinopathy and maculopathy diagnoses recorded in a U.K. primary care database. *Diabetes Care* 2012;35:762–7.
25 Martín-Merino E, Fortuny J, Rivero-Ferrer E, *et al*. Incidence of retinal complications in a cohort of newly diagnosed diabetic patients. *PLoS One* 2014;9:e100283.
26 Martín-Merino E, Fortuny J, Rivero-Ferrer E, *et al*. Risk factors for diabetic retinopathy in people with type 2 diabetes: a case–control study in a UK primary care setting. *Prim Care Diabetes* 2016;10:300–8.
27 McEwan P, Bennett H, Ward T, *et al*. Refitting of the UKPDS 68 Risk Equations to Contemporary Routine Clinical Practice Data in the UK. *Pharmacoeconomics* 2015;33:149–61.
28 Davé S, Petersen I. Creating medical and drug code Lists to identify cases in primary care databases. *Pharmacoepidemiol Drug Saf* 2009;18:704–7.
29 Public Health England. Diabetes prevalence model, 2016. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/612306/Diabetesprevalencemodelbriefing.pdf [Accessed 12 July 2019].
30 Haider S, Sadiq SN, Moore D, *et al*. Prognostic prediction models for diabetic retinopathy progression: a systematic review. *Eye* 2019;33:702–13.
31 Hyndman RJ, Athanasopoulos G. Forecasting: principles and practice. Available: https://otexts.com/fpp2/tspatterns.html
32 Adams RJ, Tucker G, Hugo G, *et al*. Projected future trends of hospital service use for selected obesity-related conditions. *Obes Res Clin Pract* 2008;2:133–41.
33 R Core Team. *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing, 2019. http://www.R-project.org/
34 Office For national Statistics. National population projections: 2018-based, [Figure 1: UK population projected to rise to 69.4 million by mid 2028 and to 72.4 million by mid 2043], 2019. Available: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/nationalpopulationprojections/2018based [Accessed 24 Nov 2020].
35 Minassian DC, Owens DR, Reidy A. Prevalence of diabetic macular oedema and related health and social care resource use in England. *Br J Ophthalmol* 2012;96:345–9.
36 Łuczyński W, Szypowska A, Głowińska-Olszewska B, *et al*. Overweight, obesity and features of metabolic syndrome in children with diabetes treated with insulin pump therapy. *Eur J Pediatr* 2011;170:891–8.
37 Egro FM. Why is type 1 diabetes increasing? *J Mol Endocrinol* 2013;51:R1–13.
38 Fowler MJ. Microvascular and macrovascular complications of diabetes. *Clinical Diabetes* 2008;26:77–82.
39 DeFronzo RA. Combination therapy with GLP-1 receptor agonist and SGLT2 inhibitor. *Diabetes Obes Metab* 2017;19:1353–62.
40 Wang T, Hong J-L, Gower EW, *et al*. Incretin-Based therapies and diabetic retinopathy: real-world evidence in older U.S. adults. *Diabetes Care* 2018;41:1998–2009.
41 Diabetes UK. Diabetes prevalence 2017, quality and outcomes framework, 2018. Available: https://www.diabetes.org.uk/professionals/position-statements-reports/statistics/diabetes-prevalence-2017 [Accessed 12 July 2019].
42 Zghebi SS, Steinke DT, Carr MJ, *et al*. Examining trends in type 2 diabetes incidence, prevalence and mortality in the UK between 2004 and 2014. *Diabetes Obes Metab* 2017;19:1537–45.
43 Scanlon PH. The English national screening programme for diabetic retinopathy 2003–2016. *Acta Diabetol* 2017;54:515–25.
44 England PH. Research and analysis - Diabetic eye screening: 2016 to 2017 data; 2018. https://www.gov.uk/government/publications/diabetic-eye-screening-2016-to-2017-data
45 Cho NH, Shaw JE, Karuranga S, *et al*. IDF diabetes atlas: global estimates of diabetes prevalence for 2017 and projections for 2045. *Diabetes Res Clin Pract* 2018;138:271–81.
46 Thomas RL, Dunstan F, Luzio SD, *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:e874.
47 Keenan TDL, Johnston RL, Donachie PHJ, *et al*. United Kingdom national ophthalmology database study: diabetic retinopathy; report 1: prevalence of centre-involving diabetic macular oedema and other grades of maculopathy and retinopathy in hospital eye services. *Eye* 2013;27:1397–404.
48 Public Health England. Diabetes Prevalnce Estimates for CCG's by GP registered populations, 2016. Available: https://www.gov.uk/government/publications/diabetes-prevalence-estimates-for-local-populations [Accessed 12 May 2020].
49 Jyothi S, Elahi B, Srivastava A, *et al*. Compliance with the Quality Standards of national diabetic retinopathy screening Committee. *Prim Care Diabetes* 2009;3:67–72.
50 World Health Organization. Blindness and vision impairment - key facts, 2019. Available: https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment [Accessed 06 Aug 2020].

Appendix 1: 7 Step Process of Read codes selection methods

Read codes cover clinical features, diagnosis, procedures, some drugs and investigations (1). Ones used in IMRD consist of 7 characters. They have a hierarchy with more specific ones down the order. This was done in collaboration with Jhot Chandan, a fellow doctoral researcher and my supervisor Krishnarajah Nirantharakumar (Institute of Applied Health Research)

1. The Read code database (MsAcess, MsExcel) is divided into two main columns: A Medcode column with unique 8 character codes for each condition and a description column. Both were used.
2. We developed a list of key search terms for the read codes of interest. These were searched for in the description column. Appendix below provides a list of key search words.
3. Results from the key word search were used to identify the main stem codes where the Read codes of interest belong to.
4. The Next step involved searching the MedCode column for the main stem codes to pick out codes that were otherwise missed on searching the description column.
5. We then also conducted an online search of published articles that have published similar Read Codes (2, 3).
6. Once collected, they were split into possible, probable and definite. There was deliberation between clinicians in the THINking group to achieve these three lists.
7. They were then hand over to a group of data scientists within the THINking group who split them into various files following epidemiological principles and saved them in CSV files database.

References:

1. Health I. THIN Data Guide for Researchers. 2017(Version 3):108.
2. Mathur R, Bhaskaran K, Edwards E, Lee H, Chaturvedi N, Smeeth L, et al. Population trends in the 10-year incidence and prevalence of diabetic retinopathy in the UK: a cohort study in the Clinical Practice Research Datalink 2004-2014. BMJ open. 2017;7(2):e014444.
3. McEwan P, Bennett H, Ward T, Bergenheim K. Refitting of the UKPDS 68 risk equations to contemporary routine clinical practice data in the UK. Pharmacoeconomics. 2015;33(2):149-61.

Appendix 2: Search Terms for diabetic Retinopathy

Keywords for identifying diabetic retinopathy in the Read Codes Dictionary
O/E or *PHOTOGRAPHY* or *RETINAL* or *SCR* **and** *HAEMORRHAGES* or *EXUDATE* or *MICROANEURYSMS* or *INTRARETINAL MICROVASCULAR ANAOMALY* or *ABNORMALITY*
RETINA or *FUNDUS* or *MACULAR* or *VITREOUS* **and** *LASER" or *PHOTOCOAGULATION* or *INTRA-VITREAL INJECTIONS* or *INJECTIONS* or *RANIBIZUMAB* or *BIVACIZUMAB* or *AFLIBERCEPT* or *TRIAMCINOLON* or *ILEUVIEN* or *DEXAMETHOSON*
RETINOPATHY or *FUNDOSCOPY* or *SEEN or *RETINAL SCR* or *RETINOSCOPY* or *SLIT LAMP* or *DIABETIC EYE* or *EXAMINATION OF RETINA* or *RETINA and OTHER PARTS OF EYE OPERATIONS* or *VITRECTOMY* or *MACULOPATHY* or *BACKGROUND* or *PRE PROLIFERATIVE* or *PROLIFERATIVE*
*BLIND" or *PARTIAL SIGHTED" or **SIGHT IMPAIRMENT" or *VISUAL IMPAIRMENT" or *VISUAL FAILURE"

Appendix 3: Read Codes

Code	Description	Status
	No Retinoipathy (ROMO)	
2BBD.00	O/E - Right retina normal	Probable
2BBJ.00	O/E - no right diabetic retinopathy	Definite
2BB1.00	O/E - retina normal	Probable
2BBI.00	O/E - no retinopathy	Definite
3128000	Fundoscopy normal	Probable
3128200	Dilated fundoscopy normal	Probable
2BBM.00	O/E - diabetic maculopathy absent both eyes	Possible
	Background Retinopathy (R1)	
2BBP.00	O/E - right eye background diabetic retinopathy	Definite
2BBQ.00	O/E - left eye background diabetic retinopathy	Definite
F420000	Background diabetic retinopathy	Definite
F421.00	Other background retinopathy	Definite
F421000	Unspecified background retinopathy	Definite
F421z00	Other background retinopathy NOS	Definite
2BB4.00	O/E - retinal microaneurysms	Definite
2BBa.00	O/E- non-referable retinopathy	Probable
	Pre proliferative Diabetic Retinopathy (R2)	
F420200	Pre proliferative diabetic retinopathy	Definite
2BBR.00	O/E - right eye pre proliferative diabetic retinopathy	Definite
2BBS.00	O/E - left eye pre proliferative diabetic retinopathy	Definite
F420800	High risk non proliferative diabetic retinopathy	Definite
	Proliefartive Diabetic Retinoipathy (R3)	
2BBk.00	O/E - right eye stable treated prolif diabetic retinopathy	Definite
2BBl.00	O/E - left eye stable treated prolif diabetic retinopathy	Definite
F420100	Proliferative diabetic retinopathy	Definite
F420700	High risk proliferative diabetic retinopathy	Definite
F422z00	Proliferative retinopathy NOS	Definite
F422.00	Other proliferative retinopathy	Definite
FyuF700	[X]Other proliferative retinopathy	Definite
2BBT.00	O/E - right eye proliferative diabetic retinopathy	Definite
2BBV.00	O/E - left eye proliferative diabetic retinopathy	Definite
7272500	Panretinal laser photocoagulation to lesion of retina NEC	Definite
7272800	Panretinal laser photocoagulation to lesion of retina	Definite
2BB7.00	O/E - retinal vascular prolif.	Probable
2BB8.00	O/E - vitreous haemorrhages	Probable
7276	Pan retinal photocoagulation for diabetes	Definite
F420500	Advanced diabetic retinal disease	Possible
F422y00	Other specified other proliferative retinopathy	Definite

F4K2800	Vitreous haemorrhage	Probable
FyuH400	[X]Vitreous haemorrhage in diseases classified elsewhere	Probable
2BB8.00	O/E - vitreous haemorrhages	Probable
	Diabetic Maculopathy (M1)	
2BBL.00	O/E - Diabetic maculopathy present both eyes	Definite
2BBm.00	O/E - right eye clinically significant macular oedema	Definite
2BBn.00	O/E - left eye clinically significant macular oedema	Definite
2BBW.00	O/E - right eye diabetic maculopathy	Definite
2BBX.00	O/E - left eye diabetic maculopathy	Definite
F425900	Maculopathy	Definite
F42y900	Macular oedema	Definite
C10EP00	Type 1 diabetes mellitus with exudative maculopathy	Definite
C10EP11	Type I diabetes mellitus with exudative maculopathy	Definite
C10FQ00	Type 2 diabetes mellitus with exudative maculopathy	Definite
C10FQ11	Type II diabetes mellitus with exudative maculopathy	Definite
F420300	Advanced diabetic maculopathy	Definite
7272900	Focal laser photocoagulation of retina	Probable
F420400	Diabetic maculopathy	Definite
	Referrable Retinopathy (R2, R3, M1)	
2BBY.00	O/E - referable retinopathy	Definite
2BBo.00	O/E - sight threatening diabetic retinopathy	Definite
	Advanced diabetic retinal disease	
F420500	Advanced diabetic retinal disease	Definite

Code	Description	Status
	Laser Procedures	
7276	Pan retinal photocoagulation for diabetes	Definite
7272012	Photocoagulation of the retina NEC	Definite
7272013	Laser therapy lesion of retina	Definite
7272300	Laser destruction of lesion of retina	Definite
7272500	Pan retinal laser photocoagulation to lesion of retina NEC	Definite
7272600	Laser photocoagulation to lesion of retina NEC	Definite
7272800	Pan retinal laser photocoagulation to lesion of retina	Definite
7272900	Focal laser photocoagulation of retina	Definite
2BBk.00	O/E - right eye stable treated proliferative diabetic retinopathy	Definite
2BBl.00	O/E - left eye stable treated proliferative diabetic retinopathy	Definite
2BBO.00	O/E - Laser photocoagulation scars	Definite
5B4..11	Retinal laser therapy	Definite
Z6F..11	Laser therapy	Definite

5B42.00	Laser therapy - retinal lesion	Definite
	Vitreous/ Peribulbar procedures / haemorrhage	
7270D00	Injection of Ranibizumab into vitreous body	Definite
7270z00	Operation on vitreous body NOS	Definite
7270300	Injection into vitreous body NEC	Definite
7274800	Injection of therapeutic substance around the eye	Possible
727C200	Injection therapeutic substance posterior segment of eye NEC	Definite
7270D00	Injection of Ranibizumab into vitreous body	Definite
7L19E00	Injection of triamcinolone	Probable
727C100	Injection of steroid into posterior segment of eye	Definite
7270200	Injection of vitreous substitute into vitreous body	Definite
7277600	Injection of therapeutic substance into macula	Definite
7270C00	Injection of vitreous substitute into vitreous body NEC	Definite
727C100	Injection of steroid into posterior segment of eye	Definite
7270400	Pars plana vitrectomy	Definite
727Cy00	Other specified operations on posterior segment of eye	Probable
727Cz00	Operations on posterior segment of eye NOS	Probable
7273000	Epiretinal dissection	Possible
727C000	Insertion sustained release device posterior segment of eye	Definite
7270y00	Other specified operation on vitreous body	Definite
7270800	Internal tamponade of retina using liquid	Possible
7270900	Internal tamponade of retina using oil	Possible
7270A00	Removal of internal tamponade agent from vitreous body	Possible
7270411	Vitrectomy using pars plana approach	Probable
7270500	Air/gas exchange of vitreous	Possible
7270600	Internal tamponade of retina using gas	Probable
7270200	Injection of vitreous substitute into vitreous body	Probable
7270300	Injection into vitreous body NEC	Definite
7270400	Pars plana vitrectomy	Definite
7270	Operations on vitreous body	Probable
7270100	Extirpation of vitreous body NEC	Probable
F4K2800	Vitreous haemorrhage	Definite
FyuH400	[X]Vitreous haemorrhage in diseases classified elsewhere	Definite
2BB8.00	O/E - vitreous haemorrhages	Definite
	Vision loss / blindness	
ZV52200	[V]Fitting or adjustment of artificial eye	Probable
ZV43000	[V]Has artificial eye globe	Probable
ZV43100	[V]Has artificial eye lens	Possible
FyuL.00	[X]Visual disturbances and blindness	Definite
F49z.11	Acquired blindness	Definite
F490900	Acquired blindness, both eyes	Definite
F495A00	Acquired blindness, one eye	Definite

F491.00	Better eye: low vision, Lesser eye: profound VI	Definite
F491500	Better eye: moderate VI, Lesser eye: blind, unspecified	Definite
F492300	Better eye: moderate VI, Lesser eye: low vision unspecified	Definite
F492500	Better eye: moderate VI, Lesser eye: moderate VI	Definite
F491700	Better eye: moderate VI, Lesser eye: near total VI	Definite
F491800	Better eye: moderate VI, Lesser eye: profound VI	Definite
F492400	Better eye: moderate VI, Lesser eye: severe VI	Definite
F491600	Better eye: moderate VI, Lesser eye: total VI	Definite
F490400	Better eye: near total VI, Lesser eye: near total VI	Definite
F490300	Better eye: near total VI, Lesser eye: total VI	Definite
F490200	Better eye: near total VI, Lesser eye: unspecified	Definite
F490700	Better eye: profound VI, Lesser eye: near total VI	Definite
F490800	Better eye: profound VI, Lesser eye: profound VI	Definite
F490600	Better eye: profound VI, Lesser eye: total VI	Definite
F490500	Better eye: profound VI, Lesser eye: unspecified	Definite
F491100	Better eye: severe VI, Lesser eye: blind, unspecified	Definite
F492100	Better eye: severe VI, Lesser eye: low vision unspecified	Definite
F491300	Better eye: severe VI, Lesser eye: near total VI	Definite
F491400	Better eye: severe VI, Lesser eye: profound VI	Definite
F492200	Better eye: severe VI, Lesser eye: severe VI	Definite
F491200	Better eye: severe VI, Lesser eye: total VI	Definite
8F62.00	Blind lead dog rehabilitation	Definite
8F6..11	Blind rehabilitation	Definite
8F61.00	Blind rehabilitation	Definite
ZN56800	Blind telephone user	Definite
F49..00	Blindness and low vision	Definite
F490z00	Blindness both eyes NOS	Definite
F490.00	Blindness, both eyes	Definite
F49A.00	Blindness, monocular	Definite
F495000	Blindness, one eye, unspecified	Definite
F490100	Both eyes total visual impairment	Definite
668C.00	Certificate of vision impairment	Definite
Fy1..00	Combined visual and hearing impairment	Definite
Fy1..12	Deafblind	Definite
ZN56A00	Deaf-blind telephone user	Definite
Fy1..11	Dual sensory impairment - deafblind	Definite
9m08.00	Exclu diab ret screen as blind	Definite
2BBr.00	Impair vision due diab retinop	Definite
F49..11	Impaired vision	Definite
ZK74.00	Issue of local authority blind registration	Definite
F494.00	Legal blindness USA	Definite
F496500	Lesser eye: moderate VI, Better eye: near normal vision	Definite
F496600	Lesser eye: moderate VI, Better eye: normal vision	Definite

F496400	Lesser eye: moderate VI, Better eye: unspecified	Definite
F495500	Lesser eye: near total VI, Better eye: near normal vision	Definite
F495600	Lesser eye: near total VI, Better eye: normal vision	Definite
F495400	Lesser eye: near total VI, Better eye: unspecified	Definite
F495800	Lesser eye: profound VI, Better eye: near normal vision	Definite
F495900	Lesser eye: profound VI, Better eye: normal vision	Definite
F495700	Lesser eye: profound VI, Better eye: unspecified	Definite
F496200	Lesser eye: severe VI, Better eye: near normal vision	Definite
F496300	Lesser eye: severe VI, Better eye: normal vision	Definite
F496100	Lesser eye: severe VI, Better eye: unspecified	Definite
F495200	Lesser eye: total VI, Better eye: near normal vision	Definite
F495300	Lesser eye: total VI, Better eye: normal vision	Definite
F495100	Lesser eye: total visual impairment, Better eye: unspecified	Definite
F49..12	Low vision	Definite
F492.00	Low vision, both eyes	Definite
F492z00	Low vision, both eyes NOS	Definite
F492000	Low vision, both eyes unspecified	Definite
F496.00	Low vision, one eye	Definite
F496z00	Low vision, one eye NOS	Definite
F496000	Low vision, one eye, unspecified	Definite
F498.00	Moderate visual impairment, binocular	Definite
F49C.00	Moderate visual impairment, monocular	Definite
2B7A.11	O/E - blind L-eye	Definite
2B6A.11	O/E - blind R-eye	Definite
22E6.11	O/E - false eye	Definite
22E6.00	O/E - glass (prosthetic) eye	Definite
22E6.12	O/E - glass eye	Definite
22EF.00	O/E - has one eye	Definite
2B7B.00	O/E - L-eye completely blind	Definite
2B7C.00	O/E - L-eye sees hand movements	Definite
2B7T.00	O/E - L-eye visual acuity (corrected) 1/60	Definite
2B7V.00	O/E - L-eye visual acuity (corrected) 2/60	Definite
2B7W.00	O/E - L-eye visual acuity (corrected) 4/60	Definite
2B7X.00	O/E - L-eye visual acuity (corrected) 5/60	Definite
2B7S.00	O/E - pinhole L-eye completely blind	Definite
2B7Q.00	O/E - pinhole L-eye counts fingers only	Definite
2B7R.00	O/E - pinhole L-eye perceives light only	Definite
2B7P.00	O/E - pinhole L-eye sees hand movements	Definite
2B6S.00	O/E - pinhole R-eye completely blind	Definite
2B6Q.00	O/E - pinhole R-eye counts fingers only	Definite
2B6R.00	O/E - pinhole R-eye perceives light only	Definite
2B6P.00	O/E - pinhole R-eye sees hand movements	Definite
2B7L.00	O/E - pinhole visual acuity L-eye=6/60	Definite

2B6L.00	O/E - pinhole visual acuity R-eye=6/60	Definite
22E6.13	O/E - prosthetic eye	Definite
2B6B.00	O/E - R-eye completely blind	Definite
2B6C.00	O/E - R-eye sees hand movements	Definite
2B6T.00	O/E - R-eye visual acuity (corrected) 1/60	Definite
2B6V.00	O/E - R-eye visual acuity (corrected) 2/60	Definite
2B6W.00	O/E - R-eye visual acuity (corrected) 4/60	Definite
2B6X.00	O/E - R-eye visual acuity (corrected) 5/60	Definite
2B7E.00	O/E - visual acuity L-eye=3/60	Definite
2B78.00	O/E - visual acuity L-eye=6/60	Definite
2B6E.00	O/E - visual acuity R-eye=3/60	Definite
2B68.00	O/E - visual acuity R-eye=6/60	Definite
2B79.00	O/E -L-eye counts fingers only	Definite
2B69.00	O/E -R-eye counts fingers only	Definite
2B7A.00	O/E-L-eye perceives light only	Definite
2B6A.00	O/E-R-eye perceives light only	Definite
F491000	One eye blind, one eye low vision	Definite
F491z00	One eye blind, one eye low vision NOS	Definite
Z9E2.00	Optical low vision aid provision	Definite
F49..13	Partial sight	Definite
F495z00	Profound impairment one eye NOS	Definite
F495.00	Profound impairment, one eye	Definite
Z96..00	Provision for visual and hearing impairment	Definite
Z9E5400	Provision of ancillary low vision aid	Definite
Z9E1100	Provision of artificial eye	Definite
Z962.00	Provision of communicator for visual and hearing impairment	Definite
Z9E5100	Provision of electronic low vision aid	Definite
Z961.00	Provision of guide help for visual and hearing impairment	Definite
Z9E3200	Provision of low vision hand magnifier	Definite
Z9E3400	Provision of low vision headband magnifier	Definite
Z9E3300	Provision of low vision stand magnifier	Definite
Z9E3100	Provision of magnifier low vision aid - near	Definite
Z9E5.00	Provision of non-optical low vision aid	Definite
Z9E4.00	Provision of optical low vision aid - distance	Definite
Z9E3.00	Provision of optical low vision aid - near	Definite
Z9E1200	Provision of removable artificial eye	Definite
Z9E3500	Provision of spectacle low vision aid - near	Definite
8HIE.00	Referral to visual impairment multidisciplinary team	Definite
6689	Registered blind	Definite
6688.11	Registered partially blind	Definite
6688	Registered partially sighted	Definite
6689.11	Registered severely sight impaired	Definite
668D.00	Registered sight impaired	Definite

8D36.00	Removable artificial eye	Definite
9Nfb.00	Requires deafblind block alphabet interpreter	Definite
9NfB.00	Requires deafblind communicator guide	Definite
9Nfc.00	Requires deafblind haptic communication interpreter	Definite
9Nfa.00	Requires deafblind manual alphabet interpreter	Definite
F497.00	Severe visual impairment, binocular	Definite
F49B.00	Severe visual impairment, monocular	Definite
F49..14	Sight impaired	Definite
F490000	Unspecified blindness both eyes	Definite
1a00000	Uses guide dog for the blind	Definite
F49D.00	Visual impairment	Definite
F493.00	Visual loss, both eyes unqualified	Definite
F49y.00	Visual loss, one eye, unqualified	Definite
F404200	Blind hypertensive eye	Definite
F404100	Blind hypotensive eye	Definite
Z9E3900	Near low vision aid - clip-on spectacle magnifier	Definite
Z9E3C00	Near low vision aid - clip-on spectacle telescope	Definite
Z9E3D00	Near low vision aid - extra cap for telescope	Definite
Z9E3800	Near low vision aid - integral spectacle magnifier	Definite
Z9E3B00	Near low vision aid - integral spectacle telescope	Definite
9NlD.00	Seen by visual impairment teacher	Definite
1B75.00	Loss of vision, Severe visual loss	Definite
1B77.00	Deteriorating vision, Severe visual loss	Definite

Unclassifiable

Code	Description
2BB5.00	O/E - retinal haemorrhages
2BB6.00	O/E - retinal exudates
2BBF.00	Retinal abnormality-diabetes related
2BBr.00	Impaired vision due diab retinop
C105.00	Diabetes mellitus with ophthalmic manifestation
C105000	Diabetes mellitus, juvenile type, + ophthalmic manifestation
C105100	Diabetes mellitus, adult onset, + ophthalmic manifestation
C105y00	Other specified diabetes mellitus with ophthalmic complicatn
C105z00	Diabetes mellitus NOS with ophthalmic manifestation
C108100	Insulin-dependent diabetes mellitus with ophthalmic comps
C108111	Type I diabetes mellitus with ophthalmic complications
C108112	Type 1 diabetes mellitus with ophthalmic complications
C108700	Insulin dependent diabetes mellitus with retinopathy
C108711	Type I diabetes mellitus with retinopathy
C108712	Type 1 diabetes mellitus with retinopathy
C109100	Non-insulin-dependent diabetes mellitus with ophthalm comps

C109111	Type II diabetes mellitus with ophthalmic complications
C109112	Type 2 diabetes mellitus with ophthalmic complications
C109600	Non-insulin-dependent diabetes mellitus with retinopathy
C109611	Type II diabetes mellitus with retinopathy
C109612	Type 2 diabetes mellitus with retinopathy
C10A300	Malnutrit-related diabetes mellitus wth ophthalmic complicat
C10E100	Type 1 diabetes mellitus with ophthalmic complications
C10E111	Type I diabetes mellitus with ophthalmic complications
C10E112	Insulin-dependent diabetes mellitus with ophthalmic comps
C10E700	Type 1 diabetes mellitus with retinopathy
C10E711	Type I diabetes mellitus with retinopathy
C10E712	Insulin dependent diabetes mellitus with retinopathy
C10F600	Type 2 diabetes mellitus with retinopathy
C10F611	Type II diabetes mellitus with retinopathy
F420.00	Diabetic retinopathy
F420600	Non proliferative diabetic retinopathy
F420z00	Diabetic retinopathy NOS
F421.11	Microvascular retinal changes
2BB5.00	O/E - retinal haemorrhages
2BBM.00	O/E - diabetic maculopathy absent both eyes

Appendix 4: Summary of Prevalence Trends 1998 to 2018

Decade	Prevalence estimate at the start of the decade	Prevalence estimate at the end of the decade	Percentage increase in prevalence within the decade	Percentage increase in prevalence between the decades
STR in T1DM in two decades				
1998 to 2007	8.15	17.57	216%	
2009 to 2018	20.54	30.22	147%	371%
STR in T2DM in two decades				
1998 to 2007	4.36	8.1	186%	
2009 to 2018	9.01	11.15	124%	256%
DR in T1DM in two decades				
1998 to 2007	26.62	40.32	151%	
2009 to 2018	45.39	57.75	127%	217%
DR in T2DM in two decades				
1998 to 2007	11.53	20.06	174%	
2009 to 2018	23.7	32.64	138%	283%
STR in DM in two decades				
1998 to 2007	4.87	8.84	182%	
2009 to 2018	9.86	12.48	127%	256%
DR in DM in two decades				
1998 to 2007	13.57	21.64	159%	
2009 to 2018	25.3	34.39	136%	253%
T1DM in two decades				
1998 to 2007	0.31%	0.32%	104%	
2009 to 2018	0.33%	0.41%	123%	132%
T2DM in two decades				
1998 to 2007	1.91%	3.65%	191%	
2009 to 2018	4.01%	5.24%	131%	273%

Appendix 5: Future projections

In the four figures below, the grey area is the prediction band (95% confidence interval) and signifies the uncertainty of the estimates.

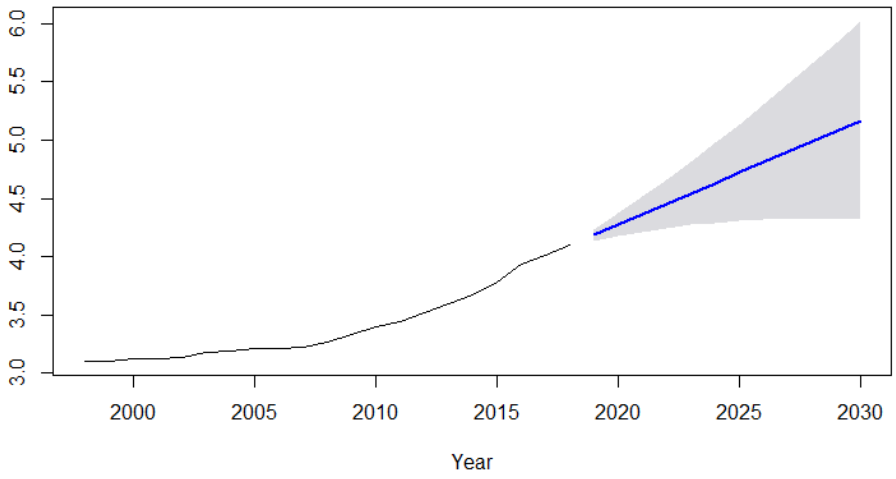

Figure 1: T1DM Projections / 1000 individuals

X axis is calendar years and Y axis is prevalence (cases per 1000 individuals general population), starts at 3.0

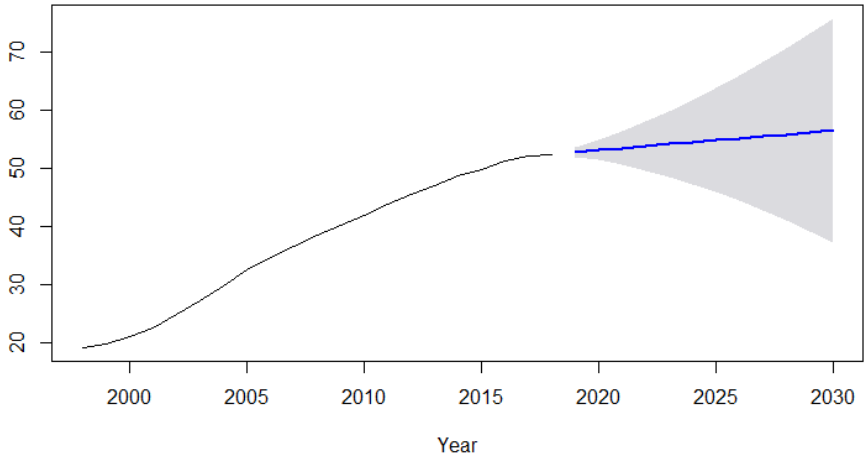

Figure 2: T2DM Projections / 1000 individuals

X axis is calendar years and Y axis is prevalence (cases per 1000 individuals general population) starts at 17

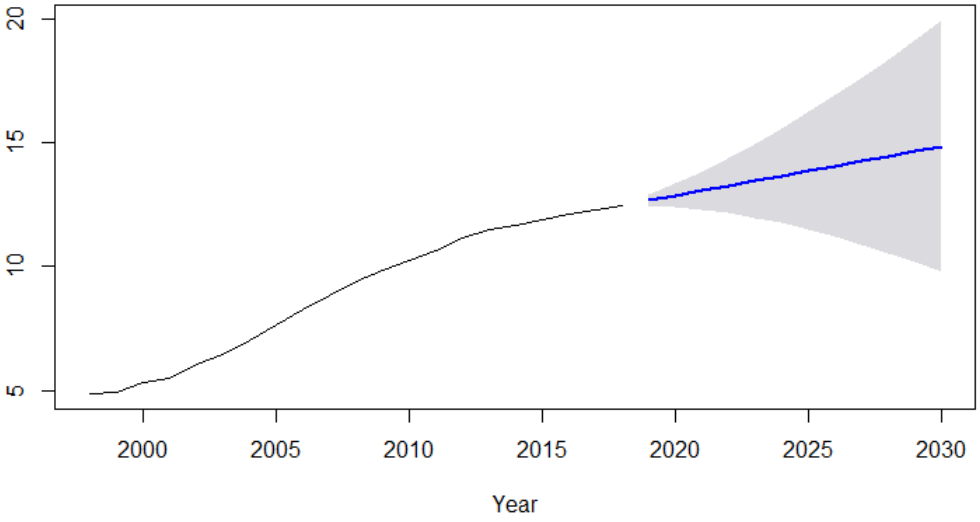

Figure 3: STR Projections (%)

X axis is calendar years and Y axis is prevalence (cases per 100 individuals with diabetes) starts at 4

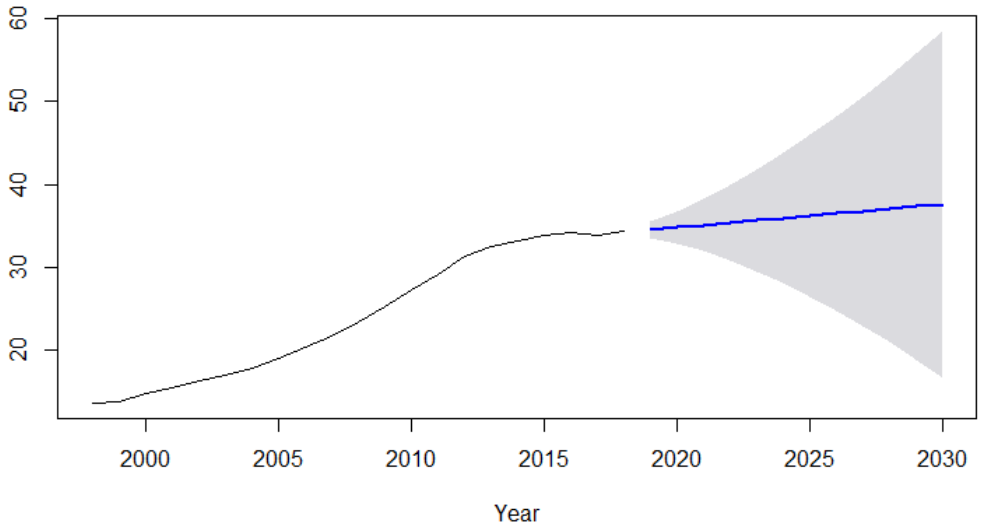

Figure 4: DR Projections (%)

X axis is calendar years and Y axis is prevalence (cases per 100 individuals with diabetes), starts at 10

Annual Prevalence Diabetes Mellitus per 1000 Population and Diabetic Retinopathy per 100 diabetic population (95% PI)

	T1DM Forecast			**T2DM Forecast**			**DR Forecast**			**STR Forecast**		
Year	**Forecast**	**Low 95**	**High 95**	**Forecast**	**Low 95**	**High 95**	**Forecast**	**Low 95**	**High 95**	**Forecast**	**Low 95**	**High 95**
2019	4.2	4.1	4.2	52.7	51.9	53.6	34.5	33.5	35.5	12.7	12.4	12.9
2020	4.3	4.2	4.4	53.1	51.4	54.8	34.8	32.9	36.7	12.9	12.4	13.3
2021	4.4	4.2	4.5	53.4	50.6	56.3	35.1	31.9	38.2	13.1	12.3	13.8
2022	4.5	4.2	4.7	53.8	49.6	57.9	35.4	30.8	39.9	13.3	12.2	14.4
2023	4.5	4.3	4.8	54.1	48.5	59.7	35.6	29.5	41.8	13.5	12.0	15.0
2024	4.6	4.3	5.0	54.4	47.2	61.6	35.9	28.1	43.8	13.7	11.8	15.6
2025	4.7	4.3	5.1	54.8	45.8	63.7	36.2	26.5	45.9	13.9	11.5	16.2
2026	4.8	4.3	5.3	55.1	44.3	65.9	36.5	24.7	48.2	14.1	11.2	16.9
2027	4.9	4.3	5.5	55.4	42.7	68.2	36.8	22.9	50.6	14.3	10.9	17.6
2028	5.0	4.3	5.7	55.8	41.0	70.6	37.0	20.9	53.2	14.5	10.5	18.4
2029	5.1	4.3	5.8	56.1	39.1	73.1	37.3	18.8	55.8	14.7	10.2	19.1
2030	5.2	4.3	6.0	56.4	37.2	75.7	37.6	16.7	58.5	14.9	9.8	19.9

Appendix 6: Previous prevalence studies compared with IMRD based analysis

Publication	Population	T1DM	T2DM	Any DM
Younis et al (1)	Liverpool diabetic retinopathy screening programme 1991 to 1999 – baseline prevalence at entry into the programme	Any DR 45.7% STED 16.4% PDR 3.7%	Any DR 25.3% STED 6.0% PDR 0.5%	
Misra et al (2)	Norwich Diabetic retinopathy screening programme 2006 with dynamic cohort design with repeated measures			Any DR 25.6% STDR 0.6% PPDR 4.6% PDR 0.08% Maculopathy 0.44% Referable (R2, R3, M1) retinopathy 4.7%
Thomas (3) and Minassian et al (4)	Welsh Diabetic retinopathy screening programme 2005 to 2009 and application to England	Any DR 56.3% STDR 11.2%	Any DR 30.9% STDR 2.9%	Any DR 32.4% STDR 3.4% Diabetic Macular Oedema 7.12%
Looker et al (5)	Newly diagnosed type 2 diabetes attending Scottish National screening programme 2005 to 2008. prevalence at first screening		Any DR 19.3% Referable DR 1.9% PPDR ± any maculopathy 0.4% PDR ± any maculopathy 0.3%	

Mathur et al (6)	CPRD based UK wide study 2014 - crude prevalence rate	Any DR 54.8% Severe DR 8.1%	Any DR 30.6% Severe DR 1.2%	Any DR 32.6% Severe DR 1.8%
The present study	IMRD based cross sectional study - 2017	Any DR 57.8% STR 30.2% Any maculopathy 19.62%	Any DR 32.6% STR 11.2% Any maculopathy 6.99%	Any DR 34.4% STR 12.3% Any maculopathy 7.86%

References:

1. Younis N, Broadbent DM, Harding SP, Vora JR. Prevalence of diabetic eye disease in patients entering a systematic primary care-based eye screening programme. Diabetic medicine : a journal of the British Diabetic Association. 2002;19(12):1014-21.
2. Misra A, Bachmann MO, Greenwood RH, Jenkins C, Shaw A, Barakat O, et al. Trends in yield and effects of screening intervals during 17 years of a large UK community-based diabetic retinopathy screening programme. Diabetic medicine : a journal of the British Diabetic Association. 2009;26(10):1040-7.

3. Thomas RL, Dunstan FD, Luzio SD, Chowdhury SR, North RV, Hale SL, et al. Prevalence of diabetic retinopathy within a national diabetic retinopathy screening service. The British journal of ophthalmology. 2015;99(1):64-8.

4. Minassian DC, Owens DR, Reidy A. Prevalence of diabetic macular oedema and related health and social care resource use in England. The British journal of ophthalmology. 2012;96(3):345-9.

5. Looker H, Nyangoma S, Cromie D, Olson J, Leese G, Black M, et al. Diabetic retinopathy at diagnosis of type 2 diabetes in Scotland. Diabetologia. 2012;55(9):2335-42.
6. Mathur R, Bhaskaran K, Edwards E, Lee H, Chaturvedi N, Smeeth L, et al. Population trends in the 10-year incidence and prevalence of diabetic retinopathy in the UK: a cohort study in the Clinical Practice Research Datalink 2004-2014. BMJ open. 2017;7(2):e014444.

Appendix 7: Previous publications reporting trends in prevalence rates of DR in the UK compared with IMRD based analysis

Publication	Population	T1DM	T2DM	Any DM
Misra et al (1)	Norwich Diabetic retinopathy screening programme 1990 to 2006 (Mostly Type 2) with dynamic cohort design with repeated measures			All DR prevalence increased from 23.2% to 25.3% Referable DR increased from 2 to 4.7%
Mathur et al (2)	CPRD based UK wide study population from 2004 to 2014	All DR remained stable at 55% Severe DR increased from 3.5% in 2004 to 8.0% in 2014	All DR reduced from 24.6% in 2004 to 23.1% in 2014 Severe DR increased from 0.3% in 2004 to 0.9% in 2014	All DR prevalence decreased from 2.6% to 2.2% Severe DR remained stable at 0.1%
This study	IMRD based serial cross-sectional studies 1998 to 2018			

References:

1. Misra A, Bachmann MO, Greenwood RH, Jenkins C, Shaw A, Barakat O, et al. Trends in yield and effects of screening intervals during 17 years of a large UK community-based diabetic retinopathy screening programme. Diabetic medicine : a journal of the British Diabetic Association. 2009;26(10):1040-7.

2. Mathur R, Bhaskaran K, Edwards E, Lee H, Chaturvedi N, Smeeth L, et al. Population trends in the 10-year incidence and prevalence of diabetic retinopathy in the UK: a cohort study in the Clinical Practice Research Datalink 2004-2014. BMJ open. 2017;7(2):e014444.