Public Health England

Protecting and improving the nation's health

NHS Diabetes Prevention Programme (NHS DPP) Non-diabetic hyperglycaemia

Produced by: National Cardiovascular Intelligence Network (NCVIN)

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Public Health England
Wellington House
133-155 Waterloo Road
London SE1 8UG
Tel: 020 7654 8000
www.gov.uk/phe
Twitter: @PHE_uk
Facebook: www.facebook.com/PublicHealthEngland

Any enquiries regarding this publication should be sent to us at publications@phe.gov.uk

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Background

This analysis was produced by the National Cardiovascular Intelligence Network (NCVIN) and supports the NHS Diabetes Prevention Programme initiated by PHE, NHS England and Diabetes UK.

Non-diabetic hyperglycaemia, also known as pre-diabetes or impaired glucose regulation, refers to raised blood glucose levels, but not in the diabetic range. People with non-diabetic hyperglycaemia are at increased risk of developing Type 2 diabetes.[1,2] They are also at increased risk of other cardiovascular conditions.[3]

In 2011, the World Health Organization (WHO) recommended that glycated haemoglobin (HbA1c) could be used as an alternative to standard glucose measures to diagnose a person with type 2 diabetes and that HbA1c levels of 6.5% (48mmol/mol) or above indicated that a person has type 2 diabetes.[4] A report from a UK expert group on the implementation of the WHO guidance recommended using HbA1c values between 6.0–6.4% (42-47mmol/mol) to indicate that a person is at high risk of type 2 diabetes,[5] ie non-diabetic hyperglycaemia.

NICE public health guidance 38 'Preventing type 2 diabetes risk',[6] recommends a two stage approach to identify people at high risk of developing diabetes. This involves:

1. using a validated risk assessment score to identify people at high risk of developing diabetes.
2. a blood test for those identified at high risk to assess more accurately their future risk of diabetes.

Risk assessment tools use routinely available patient level data and offer a non-invasive way of identifying those at high risk of developing diabetes. There are four commonly used risk assessment tools available in the UK that can be used to identify people at high risk of developing diabetes; the Cambridge risk score, the Leicester Risk Assessment Score, the Leicester Practice Risk score and QDiabetes. NICE does not advise using any particular risk assessment tool. In addition to the four risk assessment tools evaluated here, alternative approaches to identifying risk are being used. The NHS Health Check programme currently uses a diabetes filter based on BMI, ethnicity and blood pressure. A comparable evaluation of this approach will be completed in the future.

This analysis uses a population representative sample of people with valid measurements to indicate non-diabetic hyperglycaemia. It is made up of three elements:

- An analysis of the number and characteristics of people with non-diabetic hyperglycaemia
- An analysis of the sensitivity and specificity of the four main nationally available risk scores
- Estimates of the number of people with non-diabetic hyperglycaemia at a local level

Methodology

This analysis was carried out using Health Survey for England (HSE) data. The HSE is an annual survey of adults aged 16 and over living in private households in England. The samples of the surveys are designed to be representative of the population living in private households in England and are weighted to match Office for National Statistics population estimates (ONS) by age, sex and region. Those living in private institutions are outside the scope of the survey. Each survey consists of a series of core questions conducted by an interview followed by a visit from a nurse for all those who agreed. The nurse visit includes measurements and collection of blood and saliva samples, as well as additional questions.

Five years of HSE data were combined in the analyses, 2009 to 2013, giving a combined dataset size of 54,644. Non-diabetic hyperglycaemia was defined as an HbA1c value between 6.0% (42mmol/mol) and 6.4% (47mmol/mol), excluding those who had already been diagnosed with diabetes with an HbA1c value in this range.

HbA1c is calculated using the results of the blood data. However, not all respondents interviewed agreed to a nurse visit and not all who had a nurse visit agreed to a blood test. Different non-response weights are included in the HSE dataset including weighting factors for respondents who had a blood sample. The blood weight adjusts for selection, non-response and the population profile of the sample that receives the nurse visit. All analyses therefore were weighted using the blood weight included in the HSE dataset. Confidence intervals, however, were calculated using unweighted data so as to not under-estimate the standard error.

All data were analysed using SPSS Version 19. In calculating the precision of the estimates, SPSS assumes that the data come from a random sample, however, the HSE uses a clustered, stratified multi-stage sample design. One of the effects of using a complex design and weighting is that the standard errors are generally higher than the standard errors that would be derived from an unweighted simple random sample of the same size. This means that the reported precision, ie the standard error, of the estimates calculated in this analysis may be smaller than they actually are.

Previous analysis of non-diabetic hyperglycaemia

There has been previous analysis of non-diabetic hyperglycaemia in England using HSE data. Mainous lll AG et al[7] examined four years of HSE data, 2003, 2006, 2009 and 2011 in order to study trends in the prevalence of ‘prediabetes’ for individuals 16 and over who had not been previously diagnosed with diabetes. The analysis showed an increase in prediabetes from 11.6% in 2003 to 35.3% in 2011. Results of logistic regression found significant predicators of prediabetes to be age, ethnicity, overweight or obese, diagnosed high blood pressure and socio-economic deprivation, although socio-economic deprivation was only found significant in 2003 and 2006. The definition used to identify ‘prediabetes’ however, was HbA1c 5.7% - 6.4% as specified by the American Diabetes Association (ADA).

Rosella LC et al[8] have produced estimates of the prevalence of undiagnosed diabetes and prediabetes in Canada using the Canadian Health Measures Survey. The prevalence of prediabetes was estimated using both fasting plasma glucose (FPG) of >6.0 and <7.0 mmol/L and HbA1c of 6.0% to 6.4%. Using FPG-only, the prevalence of prediabetes was estimated to be 4.3%. Using HbA1c-only, the prevalence of prediabetes was estimated to be 12.5%. Prevalence was also calculated using the criteria specified in the ADA, FPG 5.6–7.0mmol/l and/or HbA1c 5.7–6.5%, and prediabetes prevalence was estimated to be significantly higher at 13.3% and 33.1% respectively.

Section 1. An analysis of the number and characteristics of people with non-diabetic hyperglycaemia

Prevalence in England

There were 54,644 people in the combined HSE dataset, of which 18,406 had a valid HbA1c value. Non-diabetic hyperglycaemia was defined as an HbA1c value between 6.0% and 6.4%, excluding those who had already been diagnosed with diabetes with an HbA1c value in this range. A prevalence in England of 10.7% (95% confidence interval: 10.2% - 11.1%) was calculated for non-diabetic hyperglycaemia from the weighted data. Graph 1 shows the distribution of the HbA1c results and Table 1 summarises this.

Graph 1. Distribution of HbA1c results

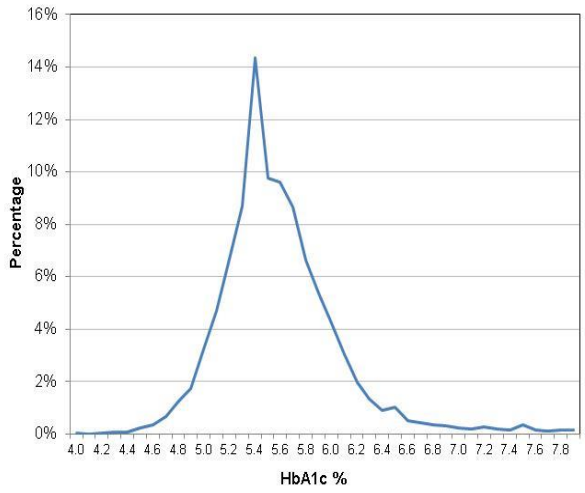


Table 1. Summary of HbA1c results

HbA1c results	Prevalence	95% confidence interval lower	upper
Normal (4.0 – 5.9%)	81.8%	81.2%	82.3%
Non-diabetic hyperglycaemia (6.0-6.4%)	10.7%	10.2%	11.1%
Diagnosed diabetes	5.2%	4.9%	5.5%
Undiagnosed diabetes (>=6.5%)	2.3%	2.1%	2.6%

The HbA1c results were examined by HSE year, Table 2. While there has been some variation in the prevalence of non-diabetic hyperglycaemia, no significant increasing or decreasing trend was found over time. The increase in the prevalence of diagnosed diabetes is in line with the prevalence of diabetes recorded in the Quality and Outcomes Framework (QOF)[9]. There has been no significant change in the prevalence of undiagnosed diabetes between 2009 and 2013.

Table 2. HbA1c results by HSE year

Year	2009	2010	2011	2012	2013
% Normal	82.7%	82.0%	80.1%	82.5%	81.5%
% non-diabetic hyperglycaemia	10.4%	11.2%	11.9%	9.9%	10.1%
% diagnosed diabetes	4.5%	4.9%	5.6%	5.0%	5.9%
% undiagnosed diabetes	2.4%	1.8%	2.4%	2.6%	2.4%

Non-diabetic hyperglycaemia was examined by HbA1c value, Table 3. The proportion of individuals with non-diabetic hyperglycaemia decreases as the HbA1c value increases, from 38.4% of individuals with non-diabetic hyperglycaemia with a HbA1c value of 6.0% to 6.6% of individuals with a HbA1c value of 6.4%. There is little change in the proportions of HbA1c by HSE year.

Table 3. Non-diabetic hyperglycaemia by HbA1c value and HSE year

Year	6.0%	6.1%	6.2%	6.3%	6.4%
2009-2013	38.4%	27.0%	16.7%	11.3%	6.6%

Characteristics of people with non-diabetic hyperglycaemia

The risk factors for developing Type 2 diabetes are well known and include:

- aged over 40
- male
- Asian or black ethnic background
- a family history of diabetes
- an increased BMI and/or waist circumference
- ever had high blood pressure, a heart attack or a stroke
- socioeconomic deprivation

These risk factors were used to examine the characteristics of people with non-diabetic hyperglycaemia, with the exception of family history of diabetes which is not included in the HSE dataset. Age, body mass index (BMI) and waist circumference were grouped into categorical data. Smoking status was also examined.

Analyses of the risk factors for non-diabetic hyperglycaemia were calculated using the weighted data. Statistical significance between the risk factor variables and non-diabetic hyperglycaemia were assessed using a chi-squared test with a p-value less than 0.05 to indicate a statistically significant result. Statistical significance for the

categories within each variable were assessed using 95% confidence intervals. Confidence intervals were calculated using the unweighted data so as to not underestimate the standard error. Table 4 summarises the characteristics of people with non-diabetic hyperglycaemia and people with total diabetes (diagnosed and undiagnosed).

The prevalence of non-diabetic hyperglycaemia did not significantly vary by sex: 10.5% for men and 10.8% for women (p value=0.259). Prevalence significantly varied by age group with a prevalence of less than 3% for people aged between 16 and 39, 8% for people aged between 40 and 49, 16% for ages 50-69 and 26% for ages 70 and over. There were higher proportions of people with non-diabetic hyperglycaemia in Asian and black ethnic groups compared to white, mixed and other ethnic groups; 14.2% and 13.1% compared to 10.4% respectively (although only the Asian ethnic group has a significantly higher prevalence). There were no differences in the prevalence of non-diabetic hyperglycaemia by quintiles of deprivation (p value = 0.919).

Prevalence of non-diabetic hyperglycaemia significantly varied by BMI with a prevalence of 6% for people with a BMI less than 25, 10.6% for people with a BMI between 25 and 30 and 16% for people with a BMI greater than 30. Prevalence also significantly varied by waist circumference with a prevalence of 5.9% for people with a waist circumference less than 90cm increasing to 18.2% for people whose waist circumference is greater than 110 cm. Non-diabetic hyperglycaemia was significantly higher in people with cardiovascular disease compared to those without: 20.1% compared to 9.6% respectively. It was also higher in people who had hypertension: 17.4% compared to 8.5% respectively. The prevalence of non-diabetic hyperglycaemia significantly varied by smoking status. Significantly higher prevalence of non-diabetic hyperglycaemia was observed in people who used to smoke compared to those who have never smoked; 12.6% compared to 9.6% respectively. The prevalence of current smokers was 10.6%.

Comparison with diabetes

The characteristics of people with non-diabetic hyperglycaemia were compared to the characteristics of people who have diabetes (diagnosed and undiagnosed). There was little difference in the characteristics of people with non-diabetic hyperglycaemia compared to the characteristics of people with diabetes for ethnic group, waist circumference, CVD status, ‘ever had hypertension’ and smoking status.

There were several key differences however for other variables. While there was no difference in the prevalence of non-diabetic hyperglycaemia by sex, males have a significantly higher prevalence of diabetes compared to females. There was also no difference in prevalence by quintile of deprivation for non-diabetic hyperglycaemia, while the prevalence of the diabetes increases as deprivation quintile increases. Non-diabetic hyperglycaemia and diabetes prevalence both increase as BMI increases, however, while the prevalence of diabetes continues to rise as BMI increases from 30 onwards, there is no such increase in non-diabetic hyperglycaemia. There is no significant difference in the prevalence of non-diabetic hyperglycaemia for people with a BMI between 30 and 34.9 compared to those with

a BMI greater than 30, 16.5% and 16.2% respectively. Likewise, prevalence's for non-diabetic hyperglycaemia and diabetes both increase as age increase, however, while the prevalence for non-diabetic hyperglycaemia continues to rise for people aged 80 and over; there is no corresponding increase in prevalence for people with diabetes.

Ethnicity

Additional analyses of the risk factors were carried out, stratifying by ethnicity. Due to small numbers, ethnic groups white, mixed and other were grouped into one ethnic group and ethnic groups Asian and black were grouped into another.

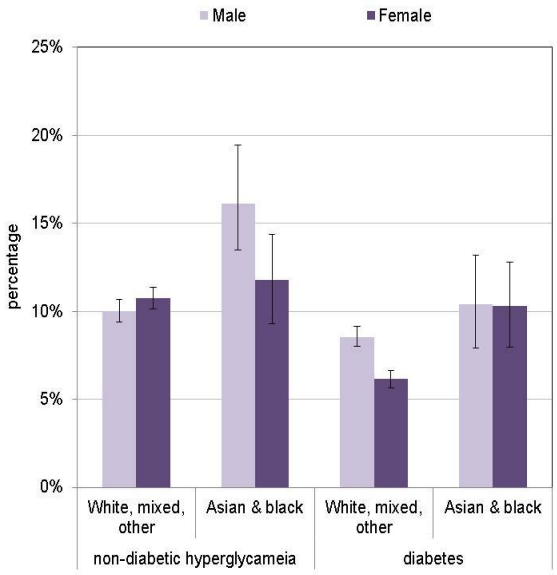
The prevalence of non-diabetic hyperglycaemia significantly varied by sex when stratified by ethnicity. Prevalence was significantly higher in females in the 'white, mixed or other' ethnic group, 10.7% versus 10.0% (although only just, p value = 0.022) while prevalence was significantly higher in males in the 'black or Asian' ethnic group, 16.1% versus 11.8% (p value = 0.000), graph 2. This differs to the characteristics of people who have diabetes (diagnosed and undiagnosed). Diabetes prevalence was significantly higher in males in the 'white, mixed or other' ethnic group while there was no significant difference by sex in the 'black and Asian' ethnic group.

Prevalence significantly varied by age group when stratified by ethnicity. For both ethnic groups, the prevalence of non-diabetic hyperglycaemia increased as the age group increased, however, prevalence was significantly higher in the lower age ranges for the 'black and Asian' ethnic group compared to the 'white, mixed or other' ethnic group; 9.7% compared to 1.7% for ages 16 to 39, 17.7% compared to 6.8% for ages 40 to 49 and 22.6% compared to 13.9% for ages 50 to 59 (graph 3). There were no differences in the prevalence's between ethnic groups in older age ranges. This differs to the characteristics of people who have diabetes which has significantly higher prevalence's in the older age ranges for the 'black and Asian' ethnic group.

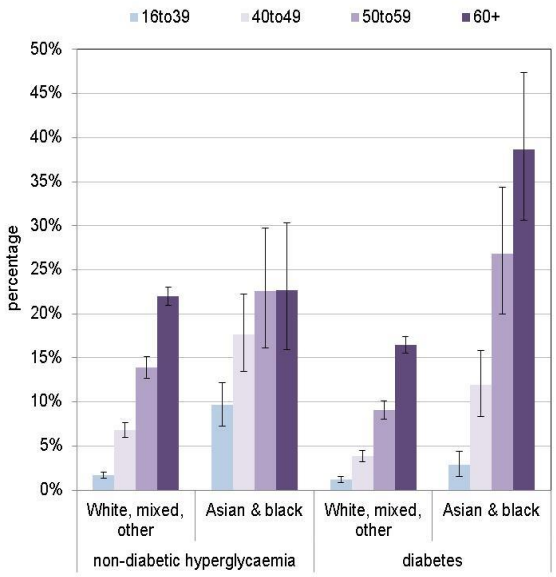
Prevalence significantly varied by BMI when stratified by ethnicity. For both ethnic groups, the prevalence of non-diabetic hyperglycaemia increased as the BMI group increased. Where BMI > 25, the 'black or Asian' ethnic group has higher prevalence's of non-diabetic hyperglycaemia compared to the 'white, mixed or other' ethnic group (graph 4). There were no differences in the prevalence of non-diabetic hyperglycaemia by ethnicity where BMI < 25. This is similar to the characteristics of people with diabetes, with the exception of an increase in prevalence in the 'white, mixed and other' ethnic group where BMI > 30. A similar pattern was observed for waist circumference.

There were no differences in the prevalence of non-diabetic hyperglycaemia for individuals who have hypertension compared to individuals who do not in the 'black or Asian' ethnic group (p value = 0.072). There was a significant difference in the 'white, mixed or other' group (p value = 0.000), graph 5. This differs to the characteristics of people with diabetes for the 'black and Asian' ethnic group which has a significantly higher prevalence for those who have hypertension. A similar pattern was also observed for cardiovascular disease.

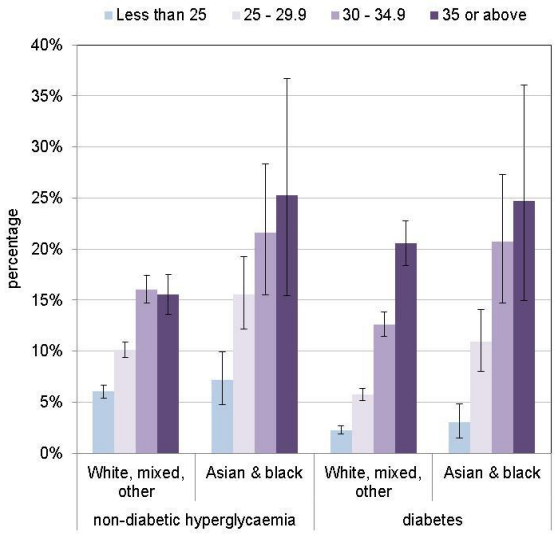
Graph 2. Sex



Graph 3. Age group



Graph 4. BMI



Graph 5. Hypertension

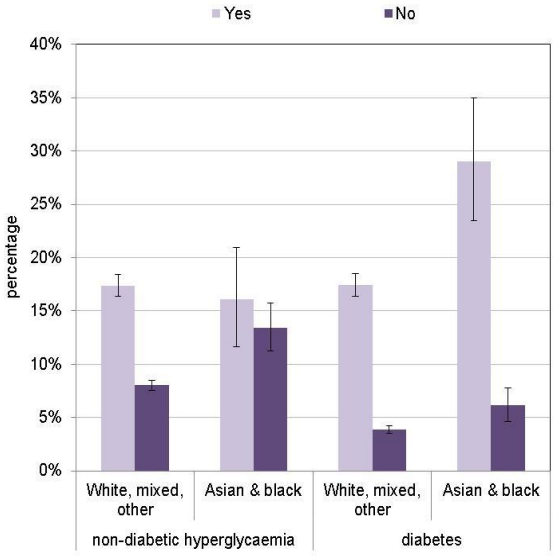


Table 4. Characteristics of people with non-diabetic hyperglycaemia and diabetes (diagnosed and undiagnosed)

		Non-diabetic hyperglycaemia				Diabetes (diagnosed and undiagnosed)			
			95% confidence interval		Chi-square p-value		95% confidence interval		Chi-square p-value
		Prevalence	lower	upper		Prevalence	lower	upper	
Sex	Male	10.5%	9.8%	11.2%	0.259	8.7%	8.1%	9.3%	0.000
	Female	10.8%	10.2%	11.5%		6.5%	6.0%	6.9%	
Age group	16 to 39	2.6%	2.2%	3.1%	0.000	1.4%	1.1%	1.7%	0.000
	40 to 49	7.8%	7.0%	8.7%		4.6%	3.9%	5.3%	
	50 to 59	14.4%	13.2%	15.6%		10.0%	9.0%	11.1%	
	60 to 69	18.4%	17.1%	19.7%		13.7%	12.6%	14.9%	
	70 to 79	23.2%	21.4%	25.0%		20.3%	18.6%	22.0%	
	80+	30.4%	27.6%	33.4%		19.9%	17.4%	22.4%	
Ethnic group	Asian	14.2%	11.8%	16.8%	0.000	10.2%	8.1%	12.5%	0.000
	Black	13.1%	9.7%	16.8%		10.7%	7.6%	14.1%	
	White, mixed, other	10.4%	9.9%	10.8%		7.3%	6.9%	7.7%	
Quintile of deprivation	1 (least deprived)	10.8%	9.8%	11.7%	0.919	5.8%	5.1%	6.5%	0.000
	2	10.9%	9.9%	11.8%		7.1%	6.3%	7.9%	
	3	10.7%	9.8%	11.7%		7.3%	6.5%	8.2%	
	4	10.5%	9.5%	11.5%		8.5%	7.6%	9.5%	
	5 (most deprived)	10.5%	9.4%	11.6%		9.2%	8.2%	10.3%	
BMI	Less than 25	6.1%	5.5%	6.8%	0.000	2.3%	1.9%	2.7%	0.000
	25 - 29.9	10.6%	9.8%	11.3%		6.2%	5.6%	6.8%	
	30 - 34.9	16.5%	15.2%	17.9%		13.2%	12.0%	14.4%	
	35 or above	16.2%	14.3%	18.1%		20.7%	18.6%	22.9%	
Waist circumference	<90	5.9%	5.4%	6.4%	0.000	2.1%	1.8%	2.4%	0.000
	90to99.9	13.1%	12.2%	14.1%		6.0%	5.4%	6.7%	
	100to109	14.4%	13.2%	15.6%		13.0%	11.9%	14.1%	
	110+	18.2%	16.6%	19.8%		23.0%	21.3%	24.8%	
Smoking status	Never smoked	9.6%	9.0%	10.2%	0.000	6.4%	5.9%	6.9%	0.000
	Ex smoker	12.6%	11.8%	13.4%		10.0%	9.3%	10.8%	
	Current smoker	10.6%	9.5%	11.7%		6.8%	5.9%	7.6%	
Cardiovascular disease	Yes	20.1%	16.7%	19.9%	0.000	24.7%	22.9%	26.5%	0.000
	No	9.6%	3.4%	4.0%		5.5%	5.2%	5.9%	
Have or had hypertension	Yes	17.4%	16.4%	18.4%	0.000	18.1%	17.1%	19.2%	0.000
	No	8.5%	8.0%	9.0%		4.1%	3.7%	4.4%	

Characteristics by HbA1c cut-off

The characteristics of people with non-diabetic hyperglycaemia were examined by different cut-off values of HbA1c; 6.1-6.4%, 6.2-6.4%, 6.3-6.4% and 6.4%, table 5. Little change was observed in the characteristics of people by cut-off value. For each cut off value there was significant difference in the prevalence of non-diabetic hyperglycaemia for age, ethnicity, BMI, waist circumference, smoking status, CVD and 'ever had hypertension'. There was no difference in the prevalence by sex and quintile of deprivation for the majority of cut-off values.

Table 5. Characteristics of people by HbA1c cut-off value

		6.0-6.4%	6.1-6.4%	6.2-6.4%	6.3-6.4%	6.4%
	Overall	10.7%	6.6%	3.7%	1.9%	0.7%
Sex	Male	10.5%	6.7%	3.9%	2.0%	0.7%
	Female	10.8%	6.4%	3.5%	1.8%	0.7%
Age group	16 to 39	2.6%	1.4%	0.6%	0.3%	0.1%
	40 to 49	7.8%	4.1%	2.3%	1.0%	0.4%
	50 to 59	14.4%	8.4%	4.4%	2.3%	1.0%
	60 to 69	18.4%	11.8%	7.0%	3.5%	1.2%
	70 to 79	23.2%	15.9%	9.0%	4.3%	1.4%
	80+	30.4%	20.9%	12.7%	8.1%	3.2%
Ethnic group	Asian	14.2%	7.7%	4.4%	2.6%	1.5%
	Black	13.1%	9.5%	5.5%	3.1%	0.9%
	White, mixed, other	10.4%	6.4%	3.6%	1.8%	0.7%
Quintile of deprivation	1 (least deprived)	10.8%	6.4%	3.7%	2.1%	0.6%
	2	10.9%	6.8%	3.9%	1.9%	0.6%
	3	10.7%	6.8%	3.7%	1.8%	0.9%
	4	10.5%	5.8%	3.2%	1.6%	0.7%
	5 (most deprived)	10.5%	7.1%	3.9%	2.2%	0.7%
BMI	Less than 25	6.1%	3.5%	1.7%	0.8%	0.3%
	25 - 29.9	10.6%	6.2%	3.5%	1.7%	0.5%
	30 - 34.9	16.5%	10.9%	6.1%	3.4%	1.5%
	35 or above	16.2%	10.3%	6.4%	3.3%	1.1%
Waist circumference	<90	5.9%	3.3%	1.6%	0.7%	0.2%
	90to99.9	13.1%	7.9%	4.6%	2.3%	0.9%
	100to109	14.4%	9.2%	5.3%	2.8%	1.0%
	110+	18.2%	12.3%	7.2%	4.0%	1.5%
Smoking status	Never smoked	9.6%	5.7%	3.1%	1.7%	0.6%
	Ex smoker	12.6%	8.2%	4.8%	2.2%	0.9%
	Current smoker	10.6%	6.5%	3.5%	1.9%	0.6%
Cardiovascular disease	Yes	20.1%	13.9%	8.6%	4.5%	1.6%
	No	9.6%	5.7%	3.1%	1.6%	0.6%
Have or had hypertension	Yes	17.4%	11.3%	6.7%	3.4%	1.1%
	No	8.5%	5.0%	2.7%	1.4%	0.6%

Multivariate analysis

A multivariate logistic analysis of the data was carried out in order to examine the relationship of the risk factors with non-diabetic hyperglycaemia, adjusting for the effects of the other variables.

Any data records with missing values were excluded from the multivariate analysis, giving an unweighted sample size of 16,766. The variables age, sex, ethnicity, quintile of deprivation, BMI, waist circumference, smoking status, cardiovascular disease and 'ever had hypertension' were all considered for inclusion in the model. Forward logistic regression was used with a probability of 0.05 for inclusion of the variable in the model. Age, BMI and waist circumference were included as continuous variables. All other variables were categorical. For categorical variables the effects were estimated relative to the reference category which was assigned as the largest category.

Variables found to be significant in the model were age, BMI, smoking status and, ethnicity. While waist circumference was also found significant, it was removed from the final model due its high correlation with BMI (pearsons correlation = 0.837, p value = 0.000). Sex was also found significant, but only just (p value = 0.044) therefore was removed from the final model. The variables quintile of deprivation, cardiovascular disease and 'ever had hypertension' were not significant. Table 6 summarises the model output of the final model.

Table 6. Multivariate model output

Variable	Coefficient	Wald chi-square test	P value	Odds ratio	CI lower	CI upper
Age	.055	2354.8	.000	1.057	1.054	1.059
BMIval	.060	346.7	.000	1.061	1.055	1.068
Smoking status (never)		160.4	.000	1.00		
Smoking status (ex)	-.003	.006	.937	.997	.920	1.080
Smoking status (current)	.565	140.1	.000	1.760	1.602	1.932
Ethnic (white,mixed,other)				1.00		
Ethnic (Asian, black)	1.088	303.6	.000	2.969	2.627	3.356
Constant	-6.960	3353.1	.000	.001		

The adjusted odds ratio for age of 1.057 implies that a one year increase in age increases the odds of non-diabetic hyperglycaemia by 5.7%, adjusting for the effects of the other variables. For BMI, a one unit increase in BMI increases the odds by 6.1%. The reference category for smoking was 'never smoked', and for current smokers the odds of non-diabetic hyperglycaemia increases by 76.0% relative to those who have never smoked. There was no significant difference for ex-smokers. For ethnic group, the reference category was the 'white, mixed or other' ethnic group, and for the 'Asian and black' ethnic group, the odds ratio implies an increase of nearly three times relative to the reference group.

Validation of the model was carried out by re-fitting the model on 80% of the data (randomly selected) and using the remaining 20% to assess model fit. Good agreement was found between the coefficients produced using the full dataset compared to the refit model. Using the validation data, a sensitivity of 78.1% and specificity of 66.5% was found using a cut-off value of 0.1. Approximately 34% of individuals in the validation dataset had a score >0.1 and 20.1% of those had non-diabetic hyperglycaemia. These individuals were more than 7 times more likely to have non-diabetic hyperglycaemia than individuals with a score <0.1. The area under the curve (AUC) was 0.78.

Section 2. Risk assessment tools

Risk assessment tools use routinely available patient level data and offer a non-invasive way of identifying those at high risk of developing diabetes. There are four commonly used risk assessment tools available in the UK that can be used to identify people at high risk of developing diabetes; the Cambridge risk score, the Leicester Risk Assessment Score, the Leicester Practice Risk score and QDiabetes. All use different approaches; the Cambridge risk score was originally developed to identify those at risk of undiagnosed diabetes, QDiabetes estimates an individual's ten-year risk of developing diabetes and the Leicester risk assessment score and the Leicester Practice Risk score were developed to identify those at high risk of impaired glucose regulation and Type 2 diabetes. While the Leicester risk assessment score is a questionnaire completed by members of the public without intervention from healthcare professionals, the Leicester practice risk score was developed for use within primary care databases.

Risk scores were calculated using the four risk assessment tools for all individuals in the HSE dataset with a valid HbA1c value. The sensitivity (the proportion of true positives correctly identified as such) and specificity (the proportion of true negatives correctly identified as such) were calculated for each risk assessment tool to compare how well they predict people with non-diabetic hyperglycaemia. People with diabetes (diagnosed and undiagnosed) were excluded. It is noted that the Cambridge risk score and QDiabetes were not designed to predict non-diabetic hyperglycaemia but rather undiagnosed diabetes and an individual's ten-year risk of developing diabetes respectively. A novel aspect of this analysis is that the risk scores were applied to a generalised sample of the England population, rather than a primary care database or specific cohort.

Using a single sensitivity and a single specificity as measures of accuracy for each risk score can be problematic since these measures depend on a cut-off for positivity which may have different criteria for each risk score. Receiver operating characteristic (ROC) analysis calculates different levels of sensitivity and 1 - specificity for different levels of risk so that the relative accuracies of the risk scores are not distorted by differences in cut off value. The accuracy of each risk assessment tool can be quantified by measuring the area under the ROC curve, known as the area under the curve (AUC). The value of AUC lies between 0.5 (random chance) and 1 (perfect accuracy).

Variables required for risk assessment tools

The four risk assessment tools use combinations of the following variables: age, sex, ethnicity, family history of diabetes, BMI, waist circumference, Townsend deprivation score, smoking status, cardiovascular disease, prescribed steroids, and high blood pressure. Tables 7 summarises the variables required for each risk assessment tool.

Table 7. Variables required for each risk assessment tool

Variable	Cambridge risk score	Leicester risk assessment score	Leicester practice risk score	QDiabetes
Age	required	required	required	required
Sex	required	required	required	required
Ethnicity	-	required	required	required
Family history of diabetes	required	required	required	required
BMI	required	required	required	required
Waist circumference	-	required	-	-
Townsend deprivation score	-	-	-	required
Smoking status	required	-	-	required
Cardiovascular disease	-	-	-	required
Prescribed steroids	required	-	-	required
High blood pressure or prescribed hypertensive medicine	required	required	required	required

The HSE variables used to populate the risk scores are summarised in table 8.

The variables age and sex are required for all risk assessment tools. These variables are available in the HSE dataset without any modification other than grouping the age variable for use in the Leicester risk assessment score (<49, 50-59, 60-69, >70). Age was used a continuous variable in the other risk assessment tools. There were no missing data for age and gender.

For ethnicity, there were 16 ethnicity categories in the 2009 and 2010 HSE datasets and 18 ethnic categories in the 2011, 2012 and 2013 HSE datasets. For the Leicester risk assessment tool and Leicester practice risk score, the ethnic categories were collapsed into two groups, ‘white’ and ‘other’ (ie all ethnic group categories other than white), while for QDiabetes, the ethnic categories were collapsed into nine groups, ‘white or not stated’, ‘Indian’, ‘Pakistani’, ‘Bangladeshi’, ‘other Asian’, ‘black Caribbean’, ‘black African’, ‘Chinese’ and ‘other including mixed’. Ethnicity was not included as a variable in the Cambridge risk score. Missing data for ethnic group accounted for less than 1% of the data.

BMI is required for all risk assessment tools and is calculated through standard measures in the HSE dataset (weight in kilograms divided by height in metres squared). The variable ‘BMI validated’ was used from the HSE dataset and uses

valid BMI measurements if an individual's weight <130Kg and estimated weight if >130kg. BMI is required as a categorical variable in the Cambridge risk score (<25kg, 25-27.49kg, 27.5-29.99kg, >30kg) and a continuous variable for all others. Missing BMI data accounted for 8.6% of the data.

Waist circumference is required only for the Leicester risk assessment tool. The variable 'Waist circumference validated' was used from the HSE dataset and is calculated from the mean of three valid waist measurements. The variable was grouped into four categories, <90cm, 90-99.9cm, 100-109.9cm and >110cm. Missing waist circumference data accounted for approximately 1% of the data.

All risk assessment tools require a measure of hypertension; a prescription for antihypertensive medication or diagnosis of hypertension. The variable 'EverBP' was used from the HSE dataset, which is defined as all individuals who have or ever had hypertension. Missing data for this variable accounted for less than 1% of the data.

A diagnosis of cardiovascular disease at baseline was required for the QDiabetes score. This was derived from the variable COMPM7 in 2009, 2010 and 2011 and COMPLST7 in 2012 and 2013 from the HSE dataset which is whether or not the individual has a cardiovascular long standing illness. Missing data for this variable accounted for less than 1% of the data.

Smoking status is required for the Cambridge risk score and QDiabetes. This variable was derived using a combination of "cigst1" (smoking status – never, ex-regular, ex-occasional and current) and "cigst2" (current smokers – light smokers (<10), moderate (10-20), heavy smokers (>20) and unknown amount smoked a day, which for the purpose of this analysis were grouped as moderate smokers.) Missing data accounted for less than 1% of the data.

The variable prescribed steroids is required for the Cambridge risk score and QDiabetes. This variable was derived using the drug codes of medicines prescribed by doctors in the last seven days. The drug codes used to define prescribed steroids were 60301 and 60302. However, only 74 people (0.4%) were picked up from the HSE dataset using this method.

Missing variables

Family history of diabetes is required for all risk scores; however this variable is not available in the HSE dataset. Family history of diabetes has a significant impact on risk. In general, if you have Type 2 diabetes and you were diagnosed before the age of 50, the risk of your child getting diabetes is one in seven. If you were diagnosed after the age of 50, this risk is one in 13.[10]

Townsend deprivation score is required for QDiabetes; however, it is not available in the HSE dataset. Quintiles of index of multiple deprivations (IMD) are available in the HSE dataset, however, the variables used to create the Townsend deprivation score (unemployment, non-car ownership, non-home ownership and household overcrowding) do not match the variables used to create the IMD score (income, employment, health deprivation, education, housing, crime and living environment), so is not a suitable to use one as a proxy for the other.

Table 8. Health survey for England variables used to score the risk assessment tools

Variable	Health survey for England variable used	Description
Age	Age	Age last birthday of individual
Gender	Sex	Sex of individual
Ethnicity	Origin	Ethnic origin of individual – 16 ethnicity categories in 2009 and 2010, 18 ethnicity categories in 2011, 2012 and 2013
Family history of diabetes	-	-
BMI	BMIval	Valid BMI measurements using estimated weight if measured weight >130kg
Waist circumference	WSTval	Valid mean waist (cm)
Townsend deprivation score	-	-
Smoking status	cigST1 and cigst2	cigST1: Cigarette Smoking Status - Never/Ex-reg/Ex-occ/Current cigST2: Banded current smokers – light / moderate / heavy
Cardiovascular disease	COMPLST7 (2013 and 2012), COMPM7 (2011, 2010, 2009)	Long standing illness: Heart & circulatory system
Prescribed steroids	MEDBI01 to MEDBI22 where drug code equalled 60301 or 60302	Drug code of medicines prescribed by doctor
High blood pressure or prescribed hypertensive medicine	EverBP	Do you have or ever had high blood pressure (hypertension)?

Risk score results

Cambridge risk score

The Cambridge risk score was originally developed to identify those at risk of undiagnosed diabetes and was developed from general practices in Ely and Wessex. [11] The risk score was calculated using logistic regression including data on age, sex, prescription steroids and anti-hypertensive medication, family history of diabetes, BMI and smoking status. The study cohort used to develop the risk score was predominately white and therefore ethnicity was not included as a variable in the model. A subsequent study assessed the effectiveness in identifying those at risk of developing Type 2 diabetes. [12] The results of this study showed that individuals in the top quintile, using a cut-off >0.37, were 22 times more likely to develop diabetes than those in the bottom quintile. More than half (54%) of individuals with diabetes had a risk score in the top quintile.

Table 9 summarises the results of the Cambridge risk score scored using the HSE dataset to predict non-diabetic hyperglycaemia. The variable family history of diabetes is not available in the HSE dataset and was set to null for all individuals scored. The variable prescribed steroids was predominately set to null as only 74 individuals (0.4%) were picked up from the HSE dataset with prescribed steroids use. Any data records with missing values were excluded, leaving 16,753 individuals that were scored (unweighted count). Using a cut-off >0.37, as in the subsequent study, gave a sensitivity of 43.4% and specificity of 85.9%. Approximately 17% of individuals scored had a risk score >0.37 and 27.9% of those had non-diabetic hyperglycaemia.

Optimising both sensitivity and specificity with respect to predicting non-diabetic hyperglycaemia gives a risk score cut-off score of 0.15 (sensitivity, 70.3% and specificity, 68.9%). Approximately 36% of individuals had a Cambridge risk score >0.15 and 22.1% of those had non-diabetic hyperglycaemia. These individuals were five times more likely to have non-diabetic hyperglycaemia than individuals with risk score < =0.15 (odds ratio, 5.2, 95% CI, 4.9 – 5.6). The AUC was 0.76.

Table 9. Performance of the Cambridge risk score

Risk score threshold	>N %	%correctly predicted non-diabetic hyperglycaemia	sensitivity	specificity
>0.0	100.0%	11.2%	100.0%	0.0%
>0.15	35.5%	22.1%	70.3%	68.9%
>0.3	21.3%	26.8%	51.0%	82.5%
>0.45	13.5%	29.4%	35.5%	89.3%
>0.6	8.1%	30.8%	22.3%	93.7%
>0.75	3.7%	34.6%	11.5%	97.3%

AUC = 0.76

Leicester risk assessment score

The Leicester risk assessment score is a questionnaire completed by members of the public without intervention from healthcare professionals and was developed to identify those at high risk of impaired glucose regulation and Type 2 diabetes.[13] Participants were aged between 40 and 75 and from a multi-ethnic background, 76% white European, 22% South Asian, 3% Other (N = 6,390). The risk score was developed using logistic regression and variables included in the model were age, sex, ethnicity, family history of diabetes, antihypertensive therapy, BMI and waist circumference. The model was externally validated on 3,171 individuals from a separate study.

The Leicester risk assessment score is based on a points based system, which, when added together gives a risk score which is classified from low risk (0-6 points), increased risk (7-15), moderate risk (16-24) to high risk (>25). The minimum score is 0 and the maximum score 47 (although the maximum score that can be reached using the HSE dataset is 42 due to the missing family history of diabetes variable).

Table 10 summarises the results of the Leicester risk assessment score scored using the HSE dataset to predict non-diabetic hyperglycaemia. The variable family history of diabetes is not available in the HSE dataset and was set to null for all individuals scored. 16,611 individuals from the HSE dataset were scored (unweighted count). Using a cut-off >15 (moderate to high risk) gives a sensitivity of 63.5% and specificity of 76.6%. Approximately 28% of individuals scored were classified as moderate to high risk and 25.2% of those had non-diabetic hyperglycaemia. Using a cut-off >24 (high risk) gives a sensitivity of 21.3% and specificity of 94.9%. Approximately 7% of individuals scored were classified as high risk and 34.1% of those had non-diabetic hyperglycaemia.

Optimising both sensitivity and specificity with respect to predicting non-diabetic hyperglycaemia gives a risk score cut-off score of 13 (sensitivity, 77.9% and specificity, 66.1%). Approximately 39% of all individuals scored had a Leicester risk assessment score >=13 and 22.2% of those had non-diabetic hyperglycaemia. Individuals with a risk score >= 13 were nearly seven times more likely to have non-diabetic hyperglycaemia than individuals with risk score < 13 (odds ratio, 6.9, 95% CI 6.3to 7.4). The AUC was 0.78.

Table 10. Performance of the Leicester risk assessment score

Risk score threshold	>N %	%correctly predicted non-diabetic hyperglycaemia	sensitivity	specificity
>0 (low risk)	100.0%	11.0%	100%	0%
>7 (increased risk)	64.2%	16.1%	93.6%	39.4%
>16 (moderate risk	27.9%	25.2%	63.5%	76.6%
>24 (high risk)	6.9%	34.1%	21.3%	94.9%

AUC = 0.78

Leicester practice risk score

The Leicester practice risk score was developed from the same data as that of the Leicester risk assessment score but developed for use within primary care databases.[14] The main difference between the two scores is that the Leicester practice risk score does not include the variable waist circumference as this is not routinely available on primary care databases. The score is calculated by summing the coefficients which when added together can range from one to approximately ten. The results of the model show that 66% of a population would need to be invited for testing to detect impaired glucose regulation using HbA1c with 80% sensitivity. If the top 10% where invited for testing then there would be a 28% positive predictive value.

Table 11 summarises the results of the Leicester practice risk score scored using the HSE dataset to predict non-diabetic hyperglycaemia. The variable family history of diabetes is not available in the HSE dataset and was set to null for all individuals scored. 16,766 individuals from the HSE dataset were scored (unweighted count).

Optimising both sensitivity and specificity with respect to predicting non-diabetic hyperglycaemia gives a risk score cut-off score of 4.6 (sensitivity, 79.7% and specificity, 66.8%). 39% of all individuals scored had a Leicester practice risk score >4.6 and 23.0% had non-diabetic hyperglycaemia. Individuals with a risk score > 4.6 were nearly eight times more likely to have non-diabetic hyperglycaemia than individuals with risk score < =4.6 (odds ratio, 7.8, 95% CI 7.2to 8.5). The AUC was 0.8.

Table 11. Performance of the Leicester practice risk score

Risk score threshold	>N %	%correctly predicted non-diabetic hyperglycaemia	sensitivity	specificity
>2	100.0%	11.1%	100.0%	0.0%
>3	89.8%	12.4%	99.8%	11.5%
>4	59.8%	17.6%	94.7%	44.5%
>5	26.1%	26.5%	62.5%	78.4%
>6	5.2%	36.3%	16.9%	96.3%
>7	0.3%	35.2%	0.8%	99.8%

AUC: 0.80

QDiabetes

QDiabetes estimates a ten-year risk of acquiring Type 2 diabetes and was developed from a prospective open cohort study from 355 general practices in England.[15] Participants were aged between 25 and 79 from an ethnically and socioeconomically diverse population (n = 2,540,753). The risk score was calculated using a cox proportional hazards model for men and women separately. Variables included in the model were self-assigned ethnicity, age, BMI, smoking status, family history of diabetes, Townsend deprivation score, treated hypertension, cardiovascular disease and current use of corticosteroids. The model was validated on a cohort of 1,261,419 individuals.

Individuals in the HSE dataset were scored using the QDiabetes batch processor supplied by QDiabetes. QDiabetes was designed for use on patients aged between 25 and 84 and therefore the batch processor would only score individuals aged in this range. However, in order to be consistent with the other risk assessment tools where risk scores were produced for all individuals in the HSE dataset with a valid HbA1c value, patients aged less than 25 were set to 25 and patients aged greater than 84 were set to 84 in order for a risk score to be calculated.

Table 12 summarises the results of QDiabetes scored using the HSE dataset to predict non-diabetic hyperglycaemia. The variables family history of diabetes and townsend deprivation score are not available in the HSE dataset and were set to null for all individuals scored. 16,724 individuals from the HSE dataset were scored (unweighted count).

Optimising both sensitivity and specificity with respect to predicting non-diabetic hyperglycaemia, gives a risk score cut-off score of 4% (sensitivity, 77.6% and specificity, 65.6%). 39% of all individuals scored had a QDiabetes score >4% and 22.1% of those had non-diabetic hyperglycaemia. Individuals with a QDiabetes risk score >4% were nearly seven times more likely to have non-diabetic hyperglycaemia than individuals with risk score <=4% (odds ratio, 6.6, 95% CI 6.1 to 7.2). The AUC was 0.78.

Table 12. Performance of QDiabetes

Risk score threshold	>N %	%correctly predicted non-diabetic hyperglycaemia	sensitivity	specificity
>0	100.0%	11.2%	100.0%	0.0%
>10	17.3%	28.1%	43.6%	86.0%
>20	5.5%	31.7%	15.6%	95.8%
>30	1.7%	34.9%	5.3%	98.7%
>40	0.6%	33.6%	1.8%	99.5%
>50	0.2%	32.5%	0.6%	99.8%

AUC: 0.78

Comparison of risk assessment scores

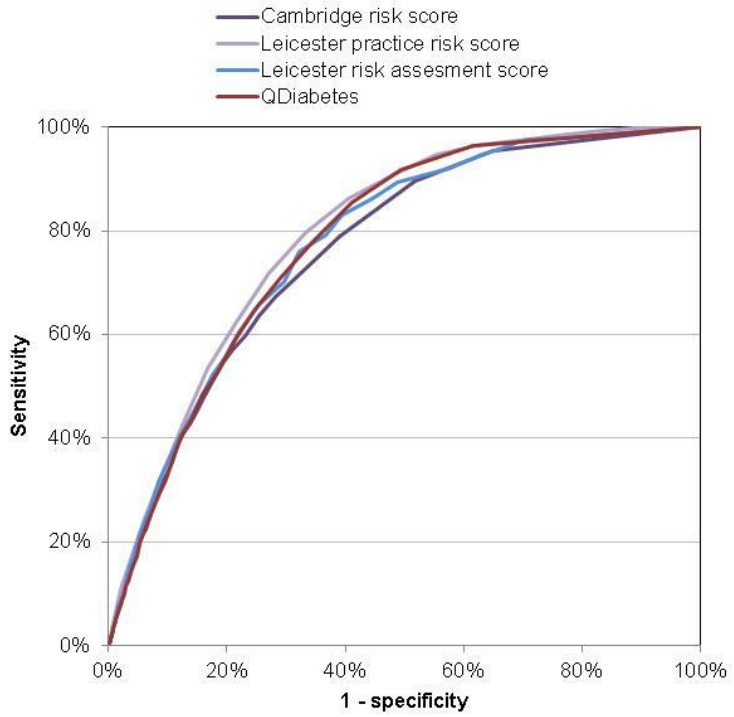
A comparison of the performance of the four risk assessment scores on the HSE dataset are shown in table 13 and a comparison of the ROC in graph 6. Sensitivity and specificity have been optimised with respect to predicting non-diabetic hyperglycaemia. Optimising for sensitivity and specificity with respect to predicting non-diabetic hyperglycaemia, all scores demonstrated a comparable level of performance, (although there were some small differences in the individuals scored due to missing variables). The Leicester practice risk score gives the highest level of sensitivity, ROC and highest percentage correctly predicted when optimising for sensitivity and specificity.

It is noted that there other possible ways of comparing the scores, for example by using alternative threshold values.

Table 13. Comparison of the performance of the risk assessment scores optimising for sensitivity and specificity with respect to predicting non-diabetic hyperglycaemia (NDH)

	Cambridge risk score	Leicester risk assessment score	Leicester practice risk score	QDiabetes
% N	35.5%	38.7%	38.5%	39.2%
Sensitivity	70.3%	77.9%	79.7%	77.6%
Specificity	68.9%	66.1%	66.8%	65.6%
% predicted NDH	22.1%	22.2%	23.0%	22.1%
ROC	0.76	0.78	0.80	0.78

Graph 6. Comparison of ROC



All risk scores will under estimate the risk of non-diabetic hyperglycaemia in individuals with a family history of diabetes, and in QDiabetes, in individuals from deprived areas. The University of Leicester have carried out analysis comparing the performance of the Leicester risk assessment score including and excluding family history. Using a cut-off >=16, the score does perform slightly worse when excluding family history in terms of sensitivity and ROC, however, the difference is not large (table 14). In addition, all risk assessment tools have the same disadvantage making comparisons between the scores justified. The optimal cut-off values calculated from this analysis are likely to be lower than if the family history variable was included, as the range of scores will be lower.

Table 14. Comparison of performance Leicester risk assessment score including and excluding family history of diabetes

	All variables	Excluding Family history
Sensitivity	85.7%	78.2%
Specificity	38.4%	50.1%
ROC	0.70	0.69

Overlap between individuals scored

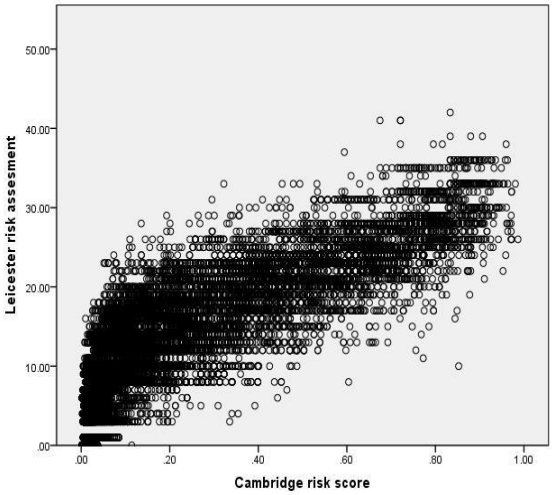
The extent as to which the four risk assessment tools identified the same or different individuals was investigated. Each pair of risk scores was compared in turn using the cut-off values previously determined to optimise sensitivity and specificity with respect to non-diabetic hyperglycaemia. For each pair of risk scores, the percentage of individuals identified as being at high risk by both risk scores was calculated as a percentage of the individuals identified by either score or both, Table 15. The measure ranges from 0% (both risk scores identify completely different individuals) to 100% (both risk scores identify exactly the same individuals). The overlap ranged from 66.0%, between the Cambridge risk score and Leicester risk assessment score to 80.8%, between the Leicester practice risk score and QDiabetes, only just slightly higher than between Leicester practice risk score and Leicester risk assessment score at 80.2%.

Table 15. Overlap between individuals identified as being at high risk of non-diabetic hyperglycaemia

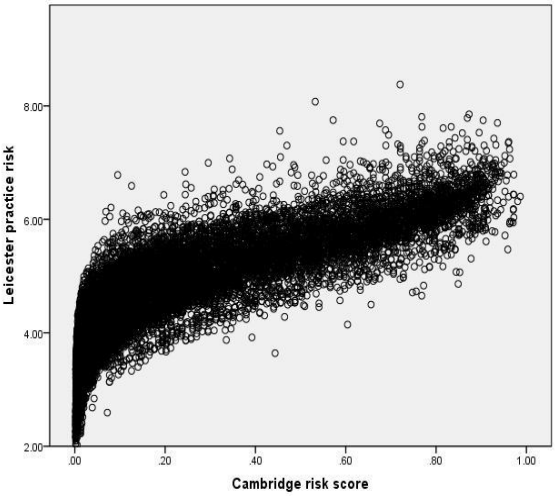
Risk score	Cambridge	Leicester risk assessment	Leicester practice risk	QDiabetes
Cambridge	1			
Leicester risk assessment	66.0%	1		
Leicester practice risk	67.9%	80.2%	1	
QDiabetes	73.8%	74.0%	80.8%	1

A plot of each pair of risk scores was also made, graphs 7–12. The plots show a clear relationship between each pair of risk scores, which in most cases displays some degree of non-linearity.

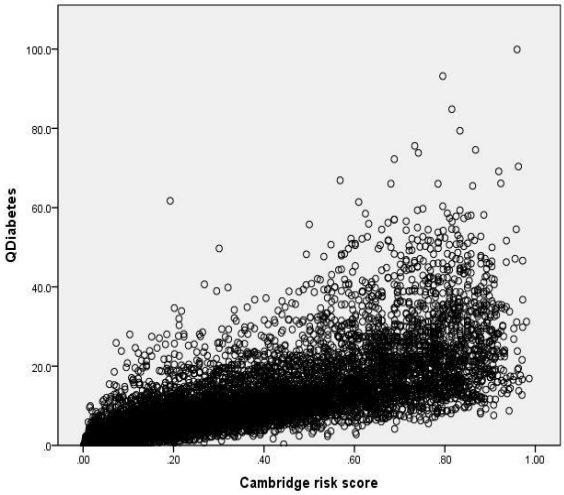
Graph 7. Cambridge v Leicester risk assessment



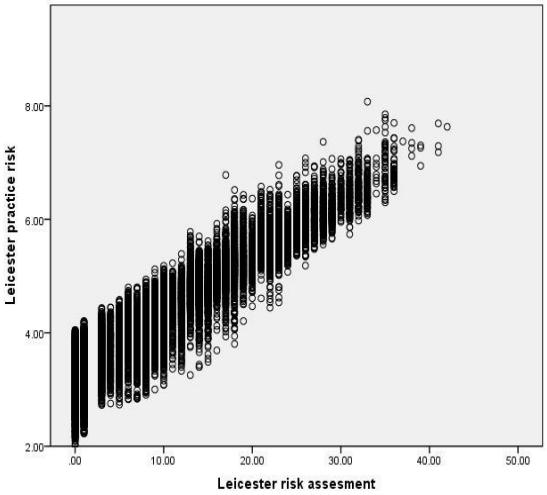
Graph 8. Cambridge v Leicester practice risk



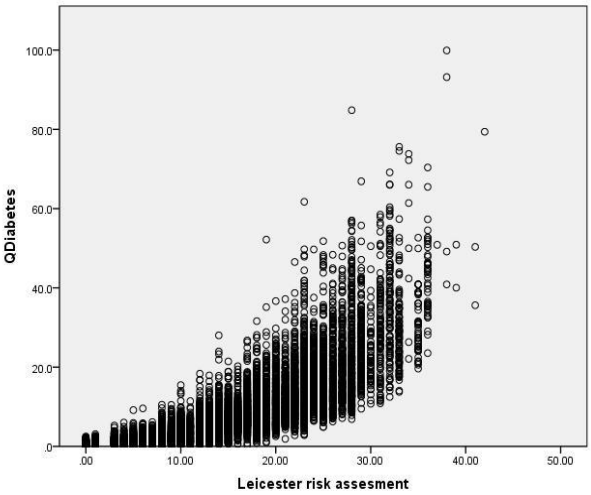
Graph 9. Cambridge v QDiabetes



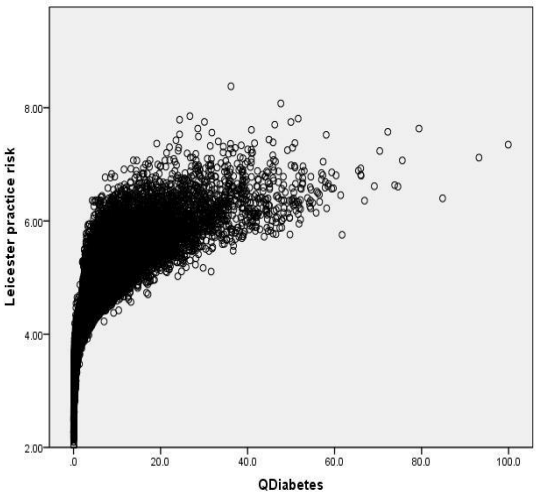
Graph 10. Leicester risk assessment v Leicester practice risk



Graph 11. Leicester risk assessment v QDiabetes



Graph 12. QDiabetes v Leicester practice risk



Section 3. Local level estimates

A logistic regression model was used to produce local level estimates of the number of people with non-diabetic hyperglycaemia. While an optimal model would include all significant variables, only a limited number of variables can be estimated at local authority population level. These variables are age, sex, ethnicity and modelled estimates of BMI. These variables therefore were all considered for inclusion in the local model. Forward logistic regression was used with a probability threshold of 0.05 for the inclusion of a variable in the model. Age was included as a continuous variable while BMI was included as a categorical variable due to the nature of the available data (<25, 25-29.9 and >30). Sex and ethnicity were also included as categorical variables. For categorical variables, effects were estimated relative to a reference category. Variables found to be significant in the model were age, BMI and ethnicity and were therefore included in the final model. Table 17 summarises model output.

Table 17. Model summary of local model

Variable	Coefficient	Wald chi-square test	P value	Odds ratio	CI lower	CI upper
Age	.052	2277.7	0.00	1.053	1.051	1.056
Ethnic (White,mixed,other)				1.000		
Ethnic (Asian, black)	1.020	277.9	0.00	2.773	2.459	3.126
BMI (<25)		336.7	0.00	1.000		
BMI (25 – 29.9)	0.316	47.3	0.00	1.371	1.253	1.500
BMI (>30)	0.821	311.2	0.00	2.272	2.074	2.489
Constant	-5.369	5363,2	0.00	0.005		

An adjusted odds ratio of 1.053 implies that a one year increase in age increases the odds of non-diabetic hyperglycaemia by 5.3%, adjusting for the effects of the other variables. For ethnic group, the reference category was ‘white, mixed or other’ and for the ‘Asian and black’ ethnic group, the odds ratio implies an increase of nearly three times relative to the reference group. For BMI, the reference category was BMI <25, and for the BMI group 25-29.9, the odds ratio implies an increase of 137% relative to the reference group. For the >30 BMI group, the odds ratio implies an increase of 227% relative to the reference group.

Validation was carried out by re-fitting the model on 80% of the data (randomly selected) and using the remaining 20% to assess model fit. Good agreement was found between the coefficients produced using the full dataset compared to the refitted model. Using the validation data, a sensitivity of 77.4% and specificity of 66.8% was found using a cut-off value of 0.1. Approximately 38% of individuals in the validation dataset had a score >0.1 and 20.1% of those had non-diabetic hyperglycaemia. These individuals were nearly seven times more likely to have non-diabetic hyperglycaemia than individuals with a score <0.1. The area under the curve (AUC) was 0.77.

2015 ONS population projections by single year of age were used as a basis to produce the population estimates at local authority.[16] Estimates of ethnicity by local authority and single year of age were derived from Hospital Episode Statistics[17] (HES) admissions between 2011/12 to 2013/14 excluding patients of unknown ethnicity. Overall estimates of BMI by local authority were calculated using the results of the 2012 Active Sports Survey Estimates.[18] The distribution of BMI by age was calculated using the Health Survey for England data. It was assumed there was no difference in the distribution of BMI by ethnicity.

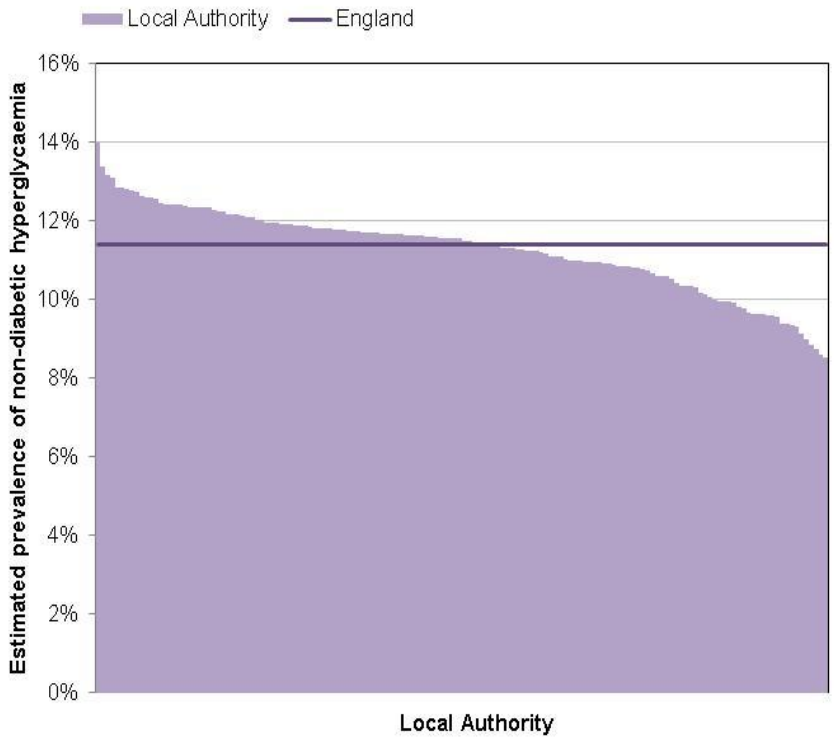
The logistic regression model was applied to the population estimates at local authority level to create prevalence estimates of non-diabetic hyperglycaemia. The estimates are available to download at: www.ncvin.org.uk

Results of the model

The prevalence model estimated that in 2015 there are 5.0 million people aged 16 years and over with non-diabetic hyperglycaemia. This equals 11.4% of the population of this age group. This differs from the prevalence estimate of 10.7% calculated directly from the HSE dataset due to differences in population year and population mix. In addition, there are uncertainties associated with both these estimates.

At local authority level, non-diabetic hyperglycaemia ranges from 8.5% to 14.0% (1.6-fold variation), Graph 13.

Graph 13. Estimates by local authority



The quintiles of non-diabetic hyperglycaemia are shown in Map 1 by local authority. The highest quintiles are mainly situated in the North, Eastern and Southern Coastal areas and areas of London.

Local authorities with high estimated prevalence of non-diabetic hyperglycaemia have high elderly populations, high proportions of black and Asian ethnic groups or combinations of both. For example, local authorities with high estimated prevalence include Harrow, Brent and Redbridge which have high proportions of black and Asian ethnic groups, however, Dorset, Torbay and East Sussex also have high estimated prevalence and have low proportions of black and Asian groups, but high elderly populations. Local authorities with low estimated prevalence of non-diabetic hyperglycaemia have lower elderly populations; for example Brighton and Hove and Islington. The local authorities with the highest estimated prevalence of non-diabetic hyperglycaemia and the local authorities with the lowest estimated prevalence are shown in tables 18 and 19 respectively.

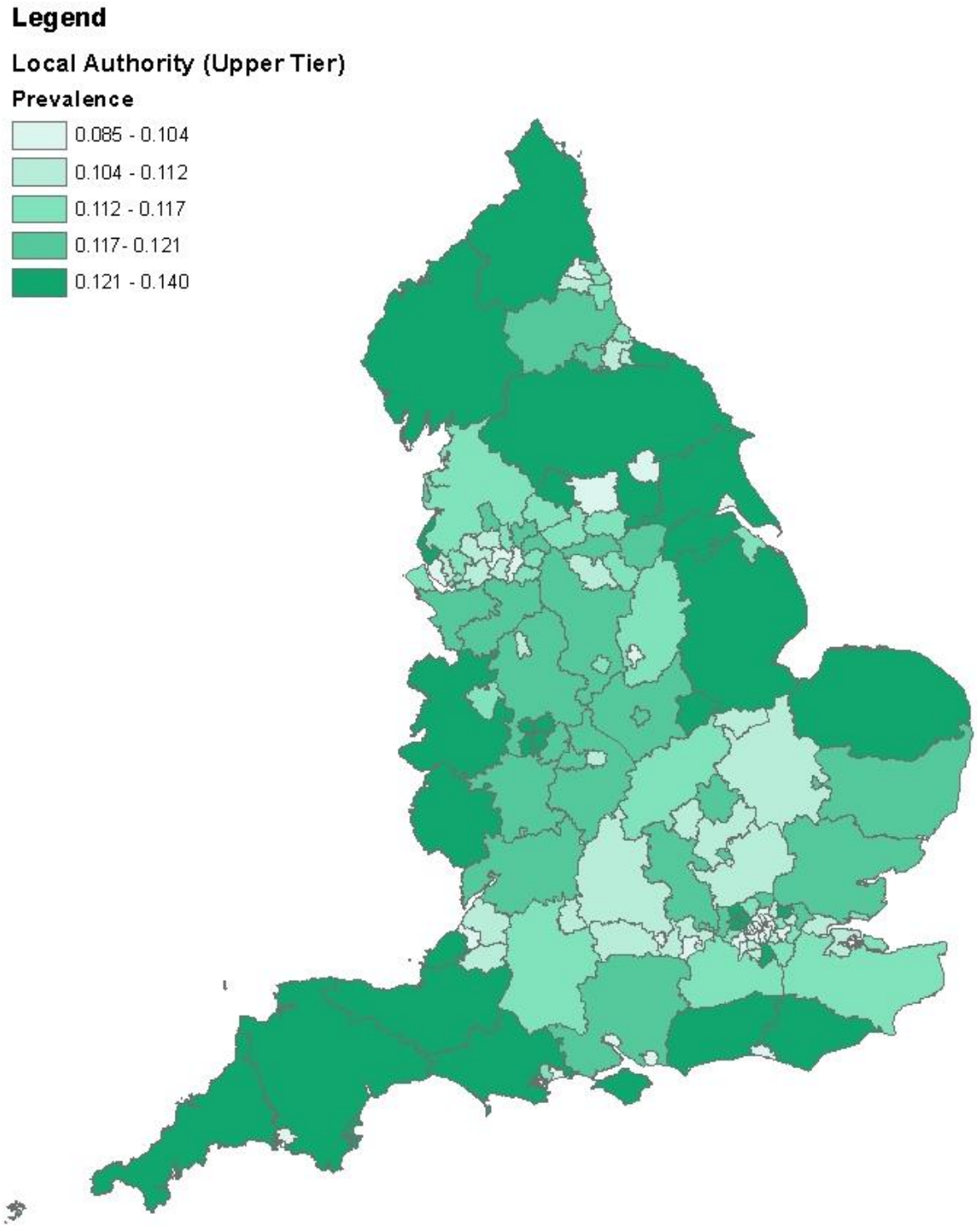
Table 18. Local authorities with the highest prevalence of non-diabetic hyperglycaemia

	Number	Prevalence
Harrow	27,935	14.0%
Dorset	46,899	13.4%
Wolverhampton	26,684	13.2%
Torbay	14,530	13.1%
East Sussex	57,645	12.9%
Brent	32,951	12.9%
Isle of Wight	15,106	12.8%
Redbridge	29,674	12.8%
Walsall	27,691	12.7%
Rutland	3,840	12.6%

Table 19. Local authorities with the lowest prevalence of non-diabetic hyperglycaemia

	Number	Prevalence
Portsmouth	16,252	9.4%
Nottingham	24,003	9.4%
Hackney	19,542	9.4%
Manchester	38,952	9.3%
Camden	17,921	9.1%
Wandsworth	23,522	9.0%
Tower Hamlets	20,002	8.8%
Hammersmith	13,044	8.7%
Islington	16,192	8.6%
Brighton and Hove	20,190	8.5%

Map 1. Estimates of non-diabetic hyperglycaemia by local authority (upper tier) in 2015



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