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Prevalence of prediabetes in England from 2003 to 2011: population-based, cross-sectional study

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ABSTRACT

Objective: Prediabetes is a high-risk state for developing diabetes and associated complications. The purpose of this paper was to report trends in prevalence of prediabetes for individuals aged 16 and older in England without previously diagnosed diabetes.

Setting: Data collected by the Health Survey for England (HSE) in England in the years 2003, 2006, 2009 and 2011.

Participants: Individuals aged 16 and older who participated in the HSE and provided a blood sample.

Primary outcome variable: Individuals were classified as having prediabetes if glycated haemoglobin was between 5.7% and 6.4% and were not previously diagnosed with diabetes.

Results: The prevalence rate of prediabetes increased from 11.6% to 35.3% from 2003 to 2011. By 2011, 50.6% of the population who were overweight (body mass index (BMI)>25) and ≥40 years of age had prediabetes. In bivariate relationships, individuals with greater socioeconomic deprivation were more likely to have prediabetes in 2003 (p=0.0008) and 2006 (p=0.0246), but the relationship was not significant in 2009 (p=0.213) and 2011 (p=0.3153). In logistic regressions controlling for age, sex, race/ethnicity, BMI and high blood pressure, the second most socioeconomically deprived had a significantly elevated risk of having prediabetes (2011, OR=1.45; 95% CI 1.26 to 1.88).

Conclusions: There has been a marked increase in the proportion of adults in England with prediabetes. The socioeconomically deprived are at substantial risk. In the absence of concerted and effective efforts to reduce risk, the number of people with diabetes is likely to increase steeply in coming years.

Strengths and limitations of this study

- This is the first report to our knowledge of the prevalence of prediabetes in England.
- Inclusion of multiple years shows a rapid increase in prediabetes.
- The design of the Health Survey for England (HSE) allowed us to examine actual glycated haemoglobin instead of relying on self-report.
- We have no way of knowing if the people participating in the HSE had been identified as at risk, screened and received intervention from their healthcare providers through the health check system or other physician-directed screening, which impacts policy implications.
- Hypercholesterolaemia was removed from the logistic regression models in order to maintain a large enough and sufficiently representative sample size.

INTRODUCTION

Prediabetes is defined as blood glucose concentrations higher than normal, but lower than established thresholds for diabetes itself.[1] Prediabetes is a high-risk state for developing diabetes and associated complications. Although complications and target organ disease is more common with hyperglycaemia at the levels associated with diabetes, vascular complications, nephropathy, retinopathy and neuropathies are more common in people with prediabetes than individuals at normal blood glucose levels.[2–6] Furthermore, a substantial number of individuals with prediabetes progress to diabetes.[7] In particular, between 5% and 10% of people with prediabetes progress to diabetes each year.[8]

Despite its risks, prediabetes can be positively impacted by lifestyle interventions and medication.[1 9 10] Consequently the American Diabetes Association has screening recommendations for prediabetes.[11] Two broad approaches may be used by countries to reduce the numbers of people with prediabetes. The first is to target individuals and offer them advice and support. For example, in England, a scheme has been introduced to offer people between 40 and 74 years of age a health check for risk of heart disease, diabetes, stroke and kidney disease, in which

those found to have impaired fasting glucose or impaired glucose tolerance are offered advice on reducing their risk. The scheme is controversial, however, since randomised trial evidence does not show that health checks reduce morbidity or mortality.[12] [13] There is also continuing debate about the extent to which medicine is extending the boundaries of illness through new definitions of disorders, with a consequent risk of treating more people than necessary.[14] [15] The second approach involves interventions at population level to influence diet and lifestyle. In England, a scheme has been introduced to encourage voluntary steps by the food industry to reduce levels of fat and sugar in food.[16] However, the scheme has recently been criticised for being very modest and likely to have little impact.[17]

Globally, diabetes has been increasing, as has intermediate hyperglycaemia.[18] In the USA, the prevalence of prediabetes has been steadily increasing.[19] The 2010 estimate of prediabetes among adults in the USA was 36.2%. The 2010 prevalence of prediabetes among adults in China was even higher at 50.1%.[20] However, there has been no population-level prevalence estimate of trends in prediabetes among adults in England. Obtaining such estimates is critical to inform the ongoing debate about definitional boundaries of the illness and the value of interventions, such as the individual health checks and population-level programmes in England. Moreover, because diabetes is more prevalent among ethnic minorities and risk scores for diabetes in England include greater weight for being South Asian, it is important to understand the relationship between such risk factors and prediabetes.[21] [22] Therefore, in this study, we sought to determine prediabetes prevalence in England between 2003 and 2011.

METHODS
To assess prediabetes prevalence in England, we undertook an analysis of the Health Survey for England (HSE) in the years 2003, 2006, 2009 and 2011. At the time of the study, 2011 was the most recent available HSE data release. The HSE is sponsored by the Information Centre for Health and Social Care and the Department of Health. The HSE is an annual population-based survey that combines questionnaire-based answers with physical measurements and the analysis of blood samples. Samples are selected using a random probability sample, and every household address in England has the same probability of being selected each year. Owing to variation in sampling and the data collected each year, we were unable to examine data for each year between 2003 and 2011. The HSE provides different levels of weights for analysing different variables. For obtaining representative estimates of blood sample measures in the HSE, such as glycated haemoglobin (HbA1c), the survey designers recommend weighting analyses using the 'blood weight'. The blood weight is assigned to every HSE participant over the age of 16 who successfully provided a blood sample. Therefore, we used the 'blood weight' in our analysis. Use of weighting variables allows us to generalise from the sample to the adult population of England. The weighted sample size for 2003 was 7892. The weighted sample size for 2006 was 6385. The weighted sample size for 2009 was 2172. The weighted sample size for 2011 was 3690.

Previously diagnosed diabetes
The HSE defines previously diagnosed diabetes as having been told by a doctor that a patient had diabetes but excludes individuals who only had been diagnosed with gestational diabetes. For this study, we expanded this definition to also include individuals who did not recall being told by a doctor that they had diabetes but were currently on diabetic medications.

Prediabetes
We defined prediabetes among individuals without previously diagnosed diabetes using HbA1c cut-offs as specified by the American Diabetes Association, 5.7–6.4%.[1] This cut-off has been shown in a meta-analysis to be predictive of progression to diabetes.[7] We excluded individuals with previously diagnosed diabetes because the current glycaemic status of those patients may simply represent diabetes control.

Body mass index
Body mass index (BMI) was based on measured height and weight in the physical examination component of the HSE. BMI is computed as weight in kilograms divided by height in metres squared (kg/m^2). BMI was defined according to standard methods, normal (less than 25), overweight (25–29.99) and obese (30 or greater).[23] Missing data ranged from 6% to 10% depending on the year.

Race/ethnicity
The HSE collects ethnicity data by allowing respondents to select which racial/ethnic groups they identify with. There has been an evolution in how the HSE assesses ethnic origin. It has become increasingly detailed, increasing from 7 categories in 2003 to 18 categories in 2011. For this analysis, these categories were collapsed into four categories of interest: White, South Asian, Black and Mixed/other. Notably, South Asians have been identified as having a higher risk of developing type 2 diabetes mellitus.[24] However, the 2003 and 2006 HSE do not distinguish South Asians from others of Asian descent. Therefore, for those years, we used Asian ethnicity (excluding Chinese, as it was included with 'other ethnic group') as a proxy for South Asian. For any given year, 1% or less of the data for this variable was missing.

Deprivation
The HSE includes the English Indices of Deprivation. The overall index of multiple deprivation (IMD) is a

composite index of relative deprivation at small area level, based on seven domains of deprivation: income, employment, health deprivation and disability, education, skills and training, barriers to housing and services, crime and disorder and living environment. The HSE collapses this index into quintiles, ranked in ascending order of deprivation score (quintile 1 being least deprived). The 2003 and 2006 HSE used the 2004 IMD. The 2009 HSE used the 2007 IMD. The HSE documentation did not state which year's IMD was used in the 2011 HSE. For this study, we assigned individuals to the deprivation quintile to which their household had been allocated. No data for this variable were missing.

Hypercholesterolaemia and hypertension
The HSE assessed individuals' report of a previous diagnosis by a doctor of hypercholesterolaemia and previous diagnosis of hypertension. Hypercholesterolaemia is defined in the HSE questionnaire as being told by a physician that their cholesterol level is higher than normal. Hypertension is defined in the HSE questionnaire as having physician diagnosed high blood pressure. These variables have been suggested as indicators that could drive screening for diabetes/prediabetes.[1] Missing data for hypercholesterolaemia ranged between 57% and 67% in the 4 years studied. There was less than 1% in any year for hypertension.

Demographics
Information on individuals' age and sex was available. We collapsed age into two groups, less than 40 years old and 40 years old or older. We split the population into these two groups because the National Health Service Health Check focuses on glycaemic testing for individuals between 40 years and 74 years.[25] There was no missing data for either sex or age.

Analysis
We used SAS V.9.2 (Cary, North Carolina, USA) for all analyses. Initially, we computed prevalence estimates for prediabetes among individuals aged 16 and older for each of the four time periods. We also computed the mean HbA1c among individuals without previously diagnosed diabetes for each of the four time periods. These two measures allowed us to assess the proportion of the population within a defined disease category as well as to examine any trends in the glycaemic level of the overall population.

First, we computed bivariate relationships between prediabetes and race/ethnicity, obesity, age, deprivation, previously diagnosed hypercholesterolaemia and previously diagnosed hypertension. Owing to the ordered nature of the five-category deprivation scale, statistical significance of the overall IMD was determined using the Wilcoxon Two-Sample test. All other variables were tested for statistical significance using χ^2 tests. We also computed multivariate relationships for prediabetes in 2003 and 2011 to examine consistency in predictors of

prediabetes over time. We computed logistic regression models on the 2003 and 2011 data to examine these potential predictors (age, sex, race/ethnicity, BMI, social deprivation, previous diagnosis of hypertension) of prediabetes. To maximise our sample size, we had to remove hypercholesterolaemia from the logistic regression models because its inclusion reduced the effective sample size by over 50%.

RESULTS
The prevalence of previously diagnosed diabetes increased in each year. It rose from 3.55% in 2003 to 3.75% in 2006 to 4.49% in 2009 to 5.59% in 2011. Mean HbAlc among people who had never been diagnosed with diabetes by a physician also increased in each year of analysis. It rose from 5.23 in 2003, to 5.38 in 2006, to 5.54 in 2009, to 5.57 in 2011. Table 1 provides demographic information about the sample studied in each year.

Table 1 Weighted demographic characteristics of Health Survey for England respondents aged 16 and older who provided a blood sample and did not have diabetes for 2003, 2006, 2009 and 2011

Population characteristics, England	2003	2006	2009	2011
Gender (%)				
Male	48.5	48.6	48.3	48.3
Female	51.5	51.4	51.7	51.7
Age (%)				
16–39	41.8	44.6	40.0	40.5
40+	58.2	55.4	60.0	59.5
Ethnicity (%)				
White	92.6	90.5	92.2	85.3
South Asian	4.2	5.7	3.0	4.0
Black	1.6	1.9	2.9	3.0
Mixed/other	1.5	1.8	1.9	7.7
Social deprivation index (%)				
Quintile 1 (least deprived)	21.6	20.6	18.9	20.1
Quintile 2	20.8	20.2	22.7	23.1
Quintile 3	20.7	22.3	21.6	21.0
Quintile 4	19.8	20.4	20.3	18.1
Quintile 5 (most deprived)	17.0	16.5	16.5	17.7
BMI (%)				
BMI under 25	39.7	41.1	38.4	39.6
BMI 25–25.99	39.1	37.8	39.6	37.6
BMI 30 or over	21.2	21.2	22.1	22.8
High-blood pressure (diagnosed, %)				
High	22.1	19.8	20.5	22.5
Normal/low	77.9	80.2	79.5	77.5
Cholesterol level (diagnosed, %)				
High	27.8	26.3	NA	27.0
Low/normal	72.2	73.7	NA	73.0
Prediabetes (%)				
Prediabetes	11.6	20.4	32.6	35.3
Normoglycaemia	88.4	79.6	67.4	64.7

BMI, body mass index (calculated as weight in kilograms divided by height in metres squared).

The percentage of the sample that had prediabetes increased from 11.6% in 2003 to 35.3% in 2011 (figure 1). Table 2 shows the bivariate relationship between prediabetes, demographic variables and hypercholesteraemia and high blood pressure. There was no significant difference between men and women in any year. Social deprivation showed an impact in 2003 and 2006, but showed no impact in the 2009 and 2011 data. Age, overweight, obesity, blood pressure level and cholesterol level exhibited significant relationships to prediabetes. People who were overweight and at least 40 years old experienced more prediabetes than those under age 40 (figure 2).

Table 3 shows the ORs of the regression analysis for 2003 and 2011 data. The results for 2003 and 2011 indicate similar significant predictors of prediabetes in both time periods including age, ethnicity, having a higher than normal BMI, diagnosed high blood pressure and socioeconomic deprivation.

DISCUSSION

The results of this study indicate that there has been an extremely rapid rise in the proportion of adults who meet the criteria for prediabetes. The most recent levels indicate more than a third of adults in England have this condition which puts them at high risk for developing diabetes. The levels of prediabetes varied by ethnic group, although all groups irrespective of BMI had a fifth or more of adults with prediabetes. In contrast, it was only for the second most deprived quintile that deprivation was associated with prediabetes.

This rapid rise in such a short period of time is particularly disturbing because it suggests that large changes on a population level can occur in a relatively short period of time. If there is no coordinated response to the rise in prediabetes, an increase in numbers of people with diabetes will ensue, with consequent increase in health expenditure, morbidity and cardiovascular mortality. These findings are particularly problematic given the strong association of prediabetes with overweight and obesity, given recent remarks by CMO Sally Davies that overweight and obesity has become the new normal in England.[26] Therefore, the findings in this paper have important implications for the debate
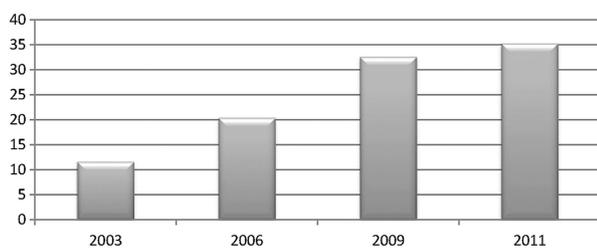
on health checks and other public health interventions now taking place in England. The findings are also relevant to other countries considering how to respond to increasing levels of prediabetes. Some data indicate that lifestyle interventions for prediabetes can return individuals to normoglycaemia.[9 10] Thus, it may be possible, although difficult, to try and create lifestyle changes to reverse this trend, although if heavy reliance is placed on individual-level interventions, it will be necessary to address concerns about the medicalisation of people's lives and lifestyles.[15]

In view of the doubts about the effects of the health checks scheme, and if the population-level intervention in England, reliant on voluntary action by the food industry, has as little impact as its critics allege, prospects look poor for containing the rise in prediabetes and reducing the numbers of people who will go on to develop diabetes. An effective and determined programme of policies and actions is required. Other countries such as the USA and China, which face similar levels of prediabetes in their populations, need such programmes as well.

These findings point the way towards detecting prediabetes better. This could help identify more people who have prediabetes and enable interventions to be offered before it progresses to diabetes. A large percentage of those who have prediabetes fall outside of the current health check system's cut-off for intervention, but they still bear the increased risk of complications and progression to diabetes. Adjusting the range allows these people to receive the intensive lifestyle counselling that could help them make the changes needed to return to healthy glucose regulation.

Electronic medical records could also help with detecting patients who are at risk of having prediabetes. Algorithms are available that could weigh risk factors present at the visit along with historical data, and could prompt a physician to offer testing to patients who would most benefit.[27] Electronic medical records also make it easier for measures like social deprivation to be calculated and used for guiding risk assessment.

Is the rapid rise a real phenomenon or is it an artefact of the study's methods? The 2011 proportion of adults with prediabetes in England is relatively similar to the proportion of adults in the USA. However, the recent rise in prevalence in England from 2003 to 2011 was much more dramatic than that found in the USA over a similar time period. The HSE calibrated the HbA1c machines using the Diabetes Control and Complications Trial standards with no impact on measured concentrations. The mean HbA1c showed an upward shift for the entire population across the time period suggesting that increasing glycaemia is a population phenomenon. The rapid rise could also be related to the rate of increase in BMI, which rose at a faster rate in the late 1990s than in the early 2000s.[28] This is consistent with the numbers of people who had prediabetes but were at the lower end of the range for prediabetes. Ageing and obesity, two

Figure 1 Per cent of adult population with prediabetes in England by year. Vertical axis: percentage of adult population with prediabetes. Horizontal axis: year of survey.

Table 2 Bivariate relationships—percentage of prediabetes by demographic and medical characteristics for adult English population in 2003, 2006, 2009 and 2011

	Prediabetic 2003	Binomial proportion 95% CI (%) 2003	p Value 2003	Prediabetic 2006	Binomial proportion 95% CI (%) 2006	p Value 2006	Prediabetic 2009	Binomial proportion 95% CI (%) 2009	p Value 2009	Prediabetic 2011	Binomial proportion 95% CI (%) 2011	p Value 2011
Gender (%)										0.8773		
Male	11.2	10.2 to 12.2	0.31	20.4	19.0 to 21.8	0.9726	33.8	30.9 to 36.6	0.265	35.5	33.2 to 37.7	0.88
Female	11.9	11.0 to 13.0		20.4	19.0 to 21.7		31.5	28.8 to 34.3		35.2	33.1 to 37.3	
Age (%)												
16–39	2.8	2.2 to 3.4	<0.0001	6.6	5.7 to 7.5	<0.0001	14.2	11.9 to 16.6	<.0001	15.6	13.8 to 17.5	<0.0001
40+	17.9	16.8 to 19.0		31.5	30.0 to 33.1		44.9	42.2 to 47.6		48.7	46.6 to 50.8	
Ethnicity (%)												
White	11.5	10.8 to 12.3		19.7	18.7 to 20.7		31.9	29.9 to 34.0		36.3	34.6 to 38.0	
South Asian	12.8	9.2 to 16.3	0.009	27.2	22.7 to 31.8	<0.0001	52.3	40.2 to 64.4	.001	39.2	31.3 to 47.2	0.0001
Black	18.7	12.0 to 25.5		34.7	26.3 to 43.1		42.2	29.9 to 54.4		35.0	26.0 to 44.0	
Mixed/other	5.2	1.2 to 9.2		14.5	8.1 to 21.0		19.6	7.3 to 31.8		23.0	18.1 to 27.9	
Social deprivation (%)												
Quintile 1 (least deprived)	10.4	8.9 to 11.8		19.7	19.8 to 24.2		34.4	32.6 to 41.6		36.6	36.1 to 42.7	
Quintile 2	11.4	9.8 to 12.9		20.0	17.83 to 22.19		32.3	28.2 to 36.4		35.3	32.1 to 38.5	
Quintile 3	11.5	10.0 to 13.1	0.0008	19.5	17.42 to 21.54	0.02	32.8	28.6 to 37.1	0.21	32.2	28.9 to 35.5	0.32
Quintile 4, %	11.7	10.1 to 13.3		20.8	18.58 to 22.99		33.1	28.7 to 37.5		35.4	31.8 to 39.0	
Quintile 5 (most deprived)	13.4	11.6 to 15.2		22.4	19.89 to 24.92		30.2	25.4 to 35.0		37.4	33.7 to 41.2	
BMI (%)												
25 or less*	6.1	5.3 to 7.0		12.8	11.5 to 14.1		22.1	19.2 to 25.1		25.9	23.6 to 28.3	
25–29.99	11.2	10.0 to 12.3	0.0001	21.6	19.9 to 23.3	0.0001	33.8	30.5 to 37.1	0.0001	37.6	35.0 to 40.3	0.0001
30 and over	19.9	17.9 to 21.9		29.8	27.3 to 32.3		44.2	39.6 to 48.9		47.9	44.3 to 51.4	
High blood pressure (diagnosed, %)												
High	20.9	19.0 to 22.8	<0.0001	33.3	30.7 to 25.9	<0.0001	47.5	42.9 to 52.2	<0.0001	52.9	49.6 to 56.3	<0.0001
Low/normal	8.9	8.2 to 9.7		17.2	16.2 to 18.2		28.8	26.6 to 30.9		30.2	28.5 to 31.9	
Cholesterol level (diagnosed, %)												
High	21.5	18.5 to 24.5	<0.0001	38.5	34.6 to 42.4	<0.0001	NA*	NA*		57.0	51.8 to 61.2	<0.0001
Low/normal	14.6	13.1 to 16.3		27.9	25.7 to 30.0		NA*	NA*		40.8	38.0 to 43.7	

*Cholesterol level was not available for 2009 Health Survey for England data.
BMI, body mass index; NA, not applicable.

Percentage of Prediabetes By BMI and Age
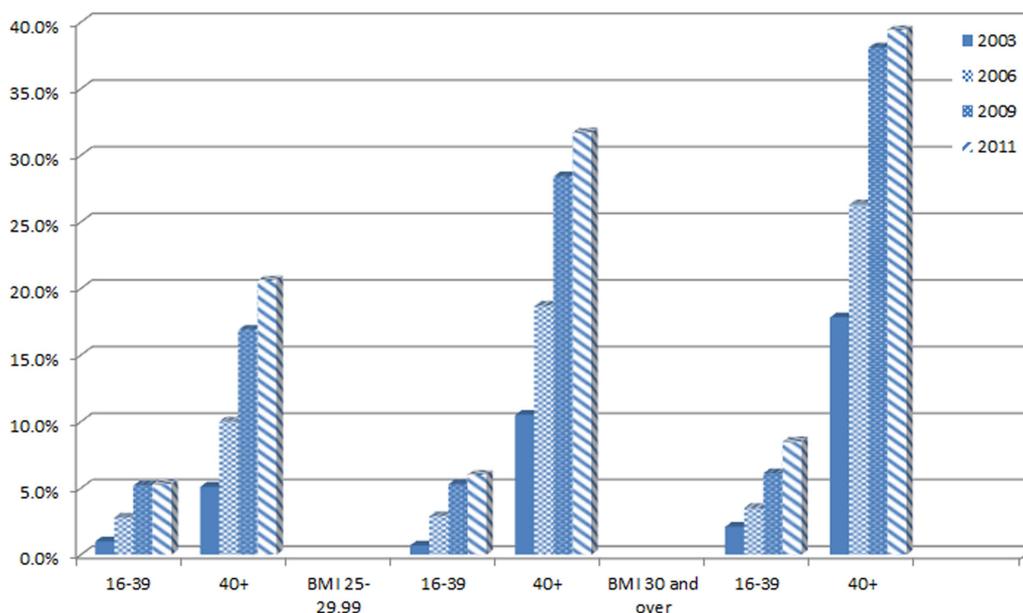
Figure 2 Percentage of prediabetes by body mass index (BMI) and age. Vertical axis: percentage of adult population with prediabetes. Horizontal axis: BMI level and age. Year indicators (below).

factors known to be related to hyperglycaemia, may have a lagged effect on the population prevalence of prediabetes but not a clear positive correlation with similar increases over time. In this study, the proportion of the population with a BMI of 30 or higher exhibited a slight increase, but not enough to fully explain the corresponding rise during prediabetes among that time. The proportion of the population aged 40 and older also

Table 3 ORs for risk of prediabetes in 2003 and 2011

Variable	2003 OR (95% CI)	2011 OR (95% CI)
Gender		
Female	1.00	1.00
Male	0.96 (0.83 to 1.12)	1.07 (0.91 to 1.25)
Age, years		
16–39	1.00	1.00
40+	6.82 (5.39 to 8.73)	4.871 (4.05 to 5.89)
Ethnicity		
White	1.00	1.00
South Asian	1.98 (1.36 to 2.83)	1.67 (1.12 to 2.50)
Black	2.28 (1.29 to 3.88)	1.45 (0.92 to 2.27)
Mixed/other	0.97 (0.37 to 2.10)	0.80 (0.57 to 1.11)
BMI		
Less than 25	1.00	1.00
25–29.99	1.41 (1.16 to 1.72)	1.21 (1.00 to 1.45)
30 or over	2.62 (2.13 to 3.22)	1.71 (1.39 to 2.11)
High blood pressure diagnosis		
Normal/low	1.00	1.00
High	1.59 (1.35 to 1.87)	1.60 (1.33 to 1.92)
Social deprivation		
First quintile (least deprived)	1.00	1.00
Second quintile	1.23 (0.97 to 1.56)	0.92 (0.72 to 1.17)
Third quintile	1.17 (0.92 to 1.49)	1.11 (0.86 to 1.42)
Fourth quintile	1.62 (1.26 to 2.07)	1.45 (1.21 to 1.88)
Fifth quintile	1.13 (0.89 to 1.43)	1.00 (0.79 to 1.26)

BMI, body mass index.

only slightly increased between 2003 and 2011, indicating that the effect we are seeing on the data is not due to an aging population during that time frame.

Limitations

The design of the HSE allowed us to examine actual HbA1c instead of relying on self-report. However, we have no way of knowing if the people participating in the HSE had been identified as at risk, screened and received intervention from their healthcare providers through the health check system or other physician-directed screening. While this does not change the population prevalence, it does potentially affect the policy implications. However, given that the health check system does not utilise the ADA range for prediabetes, we feel that the policy implications are still present for at least a portion of the population identified in this study as having prediabetes.

The second major limitation is the removal of the measure of hypercholesterolaemia from the logistic regression models. However, we feel that excluding this variable from the models strengthens the conclusions we are able to draw from the models, as it provided for a significantly larger and more representative sample.

The third limitation of this study is that the 2003 data predate the pay for performance scheme in the UK, and this could have an impact on interpretation of these findings. However, for those without a diagnosis of diabetes the number of people on the quality outcomes framework (QOF) registers is much less than expected, as is the case for the number of patients on the QOF register for obesity. Practices are not being successful in identifying most people with obesity. This may be explained to some extent by the pressure on time and resources.

CONCLUSION

In conclusion, there has been a marked increase in the proportions of adults in England with prediabetes. Although affecting all groups in the population, minority ethnic groups are particularly affected, as are the socioeconomically deprived. In the absence of concerted and effective efforts to reduce risk, the number of people with diabetes is likely to increase steeply in coming years.

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