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Sociodemographic disparities in non-diabetic hyperglycaemia and the transition to type 2 diabetes: evidence from the English Longitudinal Study of Ageing

G. Chatzi[1], T. Mason[1], T. Chandola[2], W. Whittaker[1], E. Howarth[1], S. Cotterill[3], R. Ravindrarajah[4], E. McManus[4], M. Sutton[4] and P. Bower[4]

[1]Manchester Centre for Health Economics, [2]Cathie Marsh Institute for Social Research, [3]Centre for Biostatistics, and [4]Centre for Primary Care and Health Services Research, University of Manchester, Manchester, UK

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Abstract

Aim To explore whether there are social inequalities in non-diabetic hyperglycaemia (NDH) and in transitions to type 2 diabetes mellitus and NDH low-risk status in England.

Methods Some 9143 men and women aged over 50 years were analysed from waves 2, 4, 6 and 8 (2004–2016) of the English Longitudinal Study of Ageing (ELSA). Participants were categorized as: NDH 'low-risk' [HbA_{1c} < 42 mmol/mol (< 6.0%)], NDH [HbA_{1c} 42–47 mmol/mol (6.0–6.4%)] and type 2 diabetes [HbA_{1c} > 47 mmol/mol (> 6.4%)]. Logistic regression models estimated the association between sociodemographic characteristics and NDH, and the transitions from NDH to diagnosed or undiagnosed type 2 diabetes and low-risk status in future waves.

Results NDH was more prevalent in older participants, those reporting a disability, those living in deprived areas and in more disadvantaged social classes. Older participants with NDH were less likely to progress to undiagnosed type 2 diabetes [odds ratio (OR) 0.27, 95% confidence interval (CI) 0.08, 0.96]. NDH individuals with limiting long-standing illness (OR 1.72, 95% CI 1.16, 2.53), who were economically inactive (OR 1.60, 95% CI 1.02, 2.51) or from disadvantaged social classes (OR 1.63, 95% CI 1.02, 2.61) were more likely to progress to type 2 diabetes. Socially disadvantaged individuals were less likely (OR 0.64, 95% CI 0.41, 0.98) to progress to NDH low-risk status.

Conclusions There were socio-economic differences in NDH prevalence, transition to type 2 diabetes and transition to NDH low-risk status. Disparities in transitions included the greater likelihood of disadvantaged social groups with NDH developing type 2 diabetes and greater likelihood of advantaged social groups with NDH becoming low-risk. These socio-economic differences should be taken into account when targeting prevention initiatives.

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Introduction

The number of adults with diabetes is increasing worldwide, due to both increasing prevalence within age groups and ageing populations [1]. In the UK, increasing prevalence of type 2 diabetes mellitus has been attributed in part to changes in the population age profile and increased life expectancy [2,3]. Type 2 diabetes was estimated to account for ~ 10% of total UK health expenditure in 2010/2011, and this is projected to rise to ~ 17% in 2035/2036 [4]. Evidence suggests that there are inequalities in type 2 diabetes across various sociodemographic factors; incidence in the UK has been found to be higher among men, those in ethnic minorities, in disadvantaged social groups, and to increase with age and deprivation [2–7]. Various factors have been identified to explain the pathways between socio-economic differences in the onset of type 2 diabetes. Stress [8], unhealthy diet [9] and lack of physical activity [10] are some of the mechanisms through which socio-economic position influences the onset of type 2 diabetes.

Non-diabetic hyperglycaemia (NDH), sometimes described as prediabetes, is an indicator measure when HbA_{1c} levels are higher than normal but not high enough for a diagnosis of type 2 diabetes. The range of HbA_{1c} defining NDH varies internationally, in the UK this is defined by the

Correspondence to: Georgia Chatzi.
E-mail: georgia.chatzi@manchester.ac.uk

What's new?

- Sociodemographic differences exist in the transitions from non-diabetic hyperglycaemia to type 2 diabetes and to 'low-risk' status in older adults.
- Participants with non-diabetic hyperglycaemia who had a disability, who were economically inactive, and those living in socio-economic disadvantage were more likely to develop type 2 diabetes in the future.
- Participants with non-diabetic hyperglycaemia who were living in socio-economic disadvantage were less likely to transition to low-risk status in the future.
- Findings from this study could inform researchers in diabetes prevention programmes about the selection of participants into these programmes and the effectiveness of these programmes for disadvantaged social groups.

National Institute for Health and Care Excellence (NICE) as 42–47 mmol/mol (6.0–6.4%) [11]. The population with NDH has been found to have a higher risk of developing type 2 diabetes compared with those with normal HbA_{1c} [12,13]. An English study examining a 10-year cumulative incidence of diabetes found that participants with normoglycaemia (low-risk) had an incidence rate of 2.4 [95% confidence interval (CI) 1.2, 4.8] per 1000 person-years, whereas in participants with NDH the rate was 17.5 (95% CI 12.5, 24.5) [14].

Prevalence of NDH in the English population aged ≥ 16 years was estimated to be 10.7% (95% CI 10.2, 11.1) and was approximately stable for the period 2009–2013 [15]. Prevalence of NDH was found to be higher among minority ethnic groups and to increase with age but, by contrast with the known risk factors for diabetes, was not associated with gender or deprivation [15]. Two alternative studies found a higher prevalence of NDH among the lowest social class groups [16,17]. These disparities suggest that the risk of developing type 2 diabetes may be heterogeneous across subpopulations.

Programmes to prevent or delay the onset of type 2 diabetes have focused on interventions to support behavioural changes [18,19]. In England, the National Diabetes Prevention Programme (NDPP) targets adults with NDH. Early results suggest that, compared with their presence in the English population, adults from minority ethnic groups were more likely to attend the NDPP than white Europeans, and adults living in the middle-income quintile of deprivation were less likely to attend than those from more affluent areas [20]. The socio-economic discrepancies could be influenced by the approach taken to identify the eligible NDH population. Differential participation rates across socio-economic groups could lead to a widening of social inequalities in diabetes as a result of the programme. An evaluation of the NDPP is ongoing and will include assessment into whether these may be the result of the approaches taken to identify the NDH population and/or the result of participant selection into the programme [21].

Currently, there is a lack of evidence to assess whether prevention programmes such as the NDPP should target groups of the population to reduce inequalities in health. For example, little is known regarding transition to low-risk status (free from NDH) and to diabetes in a NDH population. This information may help identify groups of the population that have a greater/reduced need for prevention programmes. Studies that have assessed transitions from low-risk status to type 2 diabetes for different sociodemographic groups have typically included health behaviours and health-related characteristics as predictor variables [14,22]. For example, smoking and alcohol consumption were found to explain 33–45% of the association between social inequalities and incidence of type 2 diabetes [23]. However, this study does not adjust for health-related characteristics in the models.

We aimed to explore whether there are social inequalities in NDH prevalence in England, and in the transition to diabetes and to low-risk status. The study builds on existing evidence by providing the first study of transitions to type 2 diabetes in English adults with NDH, and by the exclusion of health measures that may confound sociodemographic inequalities in existing studies. The findings of the analyses could inform whether prevention programmes for type 2 diabetes should implement sociodemographic stratified targeting.

Methods

Sample and study design

The English Longitudinal Study of Ageing (ELSA) collects information on the health, social, well-being and economic circumstances of the English population aged ≥ 50 years living in private households. At the outset of ELSA, participants were drawn from the Health Survey for England (HSE) 1998, 1999 and 2001 cohorts [24]. Participants completed a main interview every 2 years, with additional nurse assessment and blood samples undertaken every 4 years. ELSA participants could be core members, proxies or partners; however, only core members who completed the main interview were eligible for a nurse visit. Sociodemographic and biomarker data were used from waves 2, 4, 6 and 8 (2004 to 2016). In total, 15 782 core members eligible for nurse visit and blood sample were identified but only 10 343 (66.1%) had at least one HbA_{1c} biomarker measurement in four ELSA waves. Fewer than 1% had missing values in limiting long-standing illness, ethnicity, paid employment and Index of Multiple Deprivation (IMD); 1.2% had missing age data; and 3% had missing social class data. All participants with missing values were excluded and missing data were assumed to be missing completely at random. Because our analyses concern the population at risk of developing type 2 diabetes,

additional exclusion criteria included participants who were diagnosed with diabetes in baseline measurements. The final sample comprised a panel of 9143 individuals who were observed at least twice over a period of 12 years, therefore random effects were used because participants with NDH could be observed multiple times within the period of data collection. Some 7174 (79%) individuals were normoglycaemic (low-risk status), 1407 (15%) had NDH at any wave, and 562 (6%) transitioned to total type 2 diabetes, of whom 349 (62%) had diagnosed type 2 diabetes (self-reported diabetes) and 213 (38%) undiagnosed type 2 diabetes (diabetes detected from biomarker data).

Biomarker measures and diabetes definitions

HbA_{1c} was measured in waves 2, 4, 6 and 8 in ELSA. For those with NDH [HbA_{1c} in the range 42–47 mmol/mol (6.0–6.4%) inclusive], transitions to type 2 diabetes and low-risk status were observed. We measured type 2 diabetes in three ways: 'total type 2 diabetes', participants whose HbA_{1c} was > 47 mmol/mol (6.4%) who reported ever having been diagnosed with type 2 diabetes; 'diagnosed type 2 diabetes', participants who reported having been diagnosed with type 2 diabetes; and 'undiagnosed type 2 diabetes', participants whose HbA_{1c} was > 47 mmol/mol (6.4%) and who did not report being diabetic. Low-risk status was categorized when HbA_{1c} was < 42 mmol/mol (6.0%).

Participant characteristics

We used data on sociodemographic measures of age (≤54, 55–64, 65–74 and ≥75), gender, disability (limiting long-standing illness), employment status, ethnicity (white British and minority ethnic), area deprivation (IMD grouped into quintiles), and social class based on current or last occupation (managerial and professional, intermediate, small employer and own account, lower supervisory and technical, and semi-routine and routine occupations).

Data analyses

A logistic regression model was estimated to explore NDH status in relation to sociodemographic characteristics in wave 2 (0: not NDH status, 1: NDH status). Logistic regression models (random effects) estimated the transition from NDH at any wave (waves 2, 4 and 6) to (1) total, diagnosed and undiagnosed type 2 diabetes at the subsequent wave (waves 4, 6 and 8); and (2) low-risk condition at the subsequent wave. We generated four binary indicators, one for each logistic regression model. The first regression model describing transitions to total type 2 diabetes was constructed as: 0 = no type 2 diabetes at the subsequent measurement and 1 = type 2 diabetes at the subsequent measurement. The second regression model describing transitions to diagnosed type 2 diabetes included only self-report data from participants and was constructed as: 0 = no type 2 diabetes and 1 = type 2 diabetes at the subsequent measurement. In this model, participants with undiagnosed diabetes were excluded from this analysis. The third regression model describing transitions to undiagnosed type 2 diabetes included measurements from biomarker data only and was constructed as: 0 = no type 2 diabetes and 1 = type 2 diabetes at the subsequent measurement; therefore, participants with self-reported diagnosed diabetes were excluded. The fourth regression model describing transitions to low risk condition was constructed as: 0 = not low-risk and 1 = low-risk. All models were adjusted for participant age, gender, disability, employment status, ethnicity, area deprivation and social class. Estimates were presented as odds ratios (OR) with robust standard errors (SE). Data from refreshment ELSA samples were used and so applying longitudinal survey weights in the analyses was not possible. All models were estimated in Stata v.14.1 (StataCorp, College Station, TX, USA).

In the UK Household Longitudinal Study (UKHLS), 12 135 of 56 000 individuals (21.6%) aged ≥ 16 years had HbA_{1c} measurement collected in waves 2 and 3. Participants in the UKHLS with HbA_{1c} < 42 mmol/mol (6.0%) were categorized as normoglycaemic, those with HbA_{1c} 42–47mmol/mol (6.0–6.4%) as NDH and those with HbA_{1c} > 47 mmol/mol (6.4%) as having diabetes. Logistic regression models with blood sample weights estimated the sociodemographic differences in NDH status and the transition to diabetes. More information on sample, study design, biomarker measures and participants' characteristics can be found in the Table S2.

Ethical approval

ELSA was approved by the London Multicentre Research Ethics Committee (MREC/01/2/91), and informed consent was obtained from all participants.

The University of Essex ethics committee has approved all data collection on Understanding Society main study and innovation panel waves. Approval for the collection of biosocial data by trained nurses in waves 2 and 3 of the main survey was obtained from the National Research Ethics Service (Understanding Society – UK Household Longitudinal Study: A Biosocial Component, Oxfordshire A REC, Reference: 10/H0604/2).

Results

Sociodemographic inequalities in NDH status

Table 1 contains descriptive statistics for 5179 study participants with baseline biomarker HbA_{1c} measurement in wave 2 of ELSA. Seven per cent (373) had NDH. The NDH sample had higher percentages of people in older age groups, with disability, not in employment, from minority ethnic groups, living in more deprived areas and from lower social classes.

Table 1 Summary statistics of full and sample with non-diabetic hyperglycaemia in wave 2 of ELSA

	Full sample		Non-diabetic hyperglycaemia only	
	N	%	*N*	%
Age, years				
≤ 54	515	10	22	6
55–64	2152	42	122	33
65–74	1523	29	128	34
≥ 75	989	19	101	27
Gender				
Male	2329	45	177	47
Female	2850	55	196	53
Disability				
No	3568	69	228	61
Yes	1611	31	145	39
In paid employment				
Yes	1884	36	108	29
No	3294	64	265	71
Ethnicity				
White British	5113	99	367	98
Minority ethnic	66	1	6	2
Index of Multiple Deprivation				
Least deprived	1400	27	98	26
4th quintile	1170	23	83	22
3rd quintile	1062	21	54	15
2nd quintile	940	18	73	20
Most deprived	607	11	65	17
Social class				
Managerial and professional	1689	33	98	25
Intermediate	759	15	55	15
Small employers and own account workers	590	11	52	14
Lower supervisory and technical occupations	565	11	43	12
Semi-routine and routine occupations	1576	30	125	34
NDH status				
No	4806	93	0	0
Yes	373	7	373	100
Total	5179		373	

NDH, non-diabetic hyperglycaemia.

Table 2 shows the results of the logistic regression model which examined the NDH status in relation to sociodemographic characteristics in ELSA wave 2. Older participants (≥ 75 years) had higher odds (OR 2.58, 95% CI 1.52, 4.37) of NDH status compared with younger participants. Participants with disability had higher odds of having NDH status (OR 1.30, 95% CI 1.04, 1.63) compared with those without disability. Participants living in the most deprived areas were more likely to have NDH (OR 1.47, 95% CI 1.04, 2.07) compared with those living in the least-deprived areas. In comparison with participants in managerial and professional occupations, small employers and own account workers were more likely to have NDH (OR 1.53, 95% CI 1.08, 2.19). No significant differences in NDH status were found in the data for gender, ethnicity or employment status.

Sociodemographic inequalities in transitions to type 2 diabetes and low-risk status

Table 3 displays unadjusted rates of subsequent type 2 diabetes status for participants who had NDH (Table S1 displays rates of transitions to NDH, type 2 diabetes and low-risk status in the subsequent wave). In these unadjusted rates, transitions to diagnosed type 2 diabetes were greater for those with disability and transitions to undiagnosed type 2 diabetes were greater for people in the semi-routine and routine occupation social class.

Estimates from the logistic regressions of the transitions among ELSA participants from NDH to total, diagnosed and undiagnosed type 2 diabetes and to the low-risk status among ELSA participants with NDH in the next wave are described in Table 4. Key results include:

- Older people (≥ 75 years) were less likely to transition to undiagnosed type 2 diabetes (OR 0.27, 95% CI 0.08, 0.96) compared with younger participants (≤ 54 years).
- Participants with disability were more likely to transition to total type 2 diabetes (OR 1.72, 95% CI 1.16, 2.53) and to diagnosed type 2 diabetes (OR 1.93, 95% CI 1.13, 3.35) compared with healthier participants.

- Participants not in paid employment were more likely to transition to total type 2 diabetes (OR 1.60, 95% CI 1.0, 2.51) and to undiagnosed type 2 diabetes (OR 2.10, 95% CI 1.01, 1.47) compared with those in paid employment.
- Compared with participants in managerial and professional occupations, people in semi-routine and routine occupations were more likely (OR 1.63, 95% CI 1.02, 2.61) to transition to type 2 diabetes and particularly to undiagnosed type 2 diabetes (OR 2.10, 95% CI 0.99, 4.44), and less likely (OR 0.64, 95% CI 0.41, 0.98) to become low-risk in the next waves.
- After controlling for other socio-economic variables, there appeared to be no effect of gender, ethnicity or area deprivation on transitions to other states.

Sociodemographic inequalities in non-diabetic hyperglycaemia and transitions to type 2 diabetes in UKHLS

Table S3 shows the probability of having NDH in relation to sociodemographic characteristics in waves 2 and 3 in UKHLS. Older participants (OR 25.67, 95% CI 9.85, 66.88) were more likely to have NDH compared with younger participants. Participants with disability were more likely to have NDH (OR 1.41, 95% CI 1.16, 1.72). Compared to white participants, those in minority ethnic groups had higher odds of having NDH. Those living in deprived areas had higher odds (OR 2.05, 95% CI 1.54, 2.73) compared with those living in more affluent areas. Participants in the 'other' social class were twice as likely to be diagnosed with NDH (OR 2.37 95% CI 1.36, 4.13) compared with those in managerial and professional occupations. Table S4 reports the transition to diabetes for participants with NDH.

Key results include:

- Participants living in the most deprived quintiles were more likely to progress to diabetes compared with the least-deprived quintile; however, the effect was statistically different only in the third quintile of area deprivation (OR 2.46, 95% CI 1.20, 5.05).
- Those in lower supervisory and technical occupations (OR 0.07, 95% CI 0.01, 0.87) and those in semi-routine and routine occupations were less likely (OR 0.36, 95% CI 0.15, 0.87) to be diagnosed with diabetes in the following years compared with those in managerial and professional occupations.

Table 2 Logistic regression of sociodemographic characteristics associated with non-diabetic hyperglycaemia among ELSA wave 2 participants

	Odds ratio	$P > z$	95% confidence intervals	
Age, years				
≤ 54	1 (reference)			
55–64	1.36	0.204	0.85	2.17
65–74	2.10	0.004	1.27	3.48
≥ 75	2.58	< 0.001	1.52	4.37
Gender				
Male	1 (reference)			
Female	0.86	0.191	0.69	1.08
Disability				
No	1 (reference)			
Yes	1.30	0.023	1.04	1.63
In paid employment				
Yes	1 (reference)			
No	0.92	0.607	0.69	1.25
Ethnicity				
White British	1 (reference)			
Minority ethnic	1.30	0.554	0.55	3.06
Index of Multiple Deprivation				
Least deprived	1 (reference)			
4th quintile	1.00	0.975	0.73	1.35
3rd quintile	0.69	0.033	0.49	0.97
2nd quintile	1.07	0.698	0.77	1.47
Most deprived	1.47	0.030	1.04	2.07
Social class				
Managerial and professional	1 (reference)			
Intermediate	1.27	0.192	0.89	1.81
Small employers and own account workers	1.53	0.018	1.08	2.19
Lower supervisory and technical occupations	1.15	0.469	0.79	1.68
Semi-routine and routine occupations	1.27	0.105	0.95	1.70
Intercept	0.04	<0.001	0.02	0.06
R-squared*	0.023			
Total	5179			

*Pseudo-R-squared for logistic regression.

Discussion

We sought to explore whether sociodemographic inequalities exist in NDH and transitions from NDH to type 2 diabetes or low-risk status in England and in the UK. Our findings suggest the NDH prevalence and transition to type 2 diabetes for this population varied according to sociodemographic characteristics. Non-diabetic hyperglycaemia was more prevalent in older participants, participants with disability, participants living in deprived areas, and among small employers and own account workers.

Among those with NDH, transition to type 2 diabetes was more likely for those who reported disability, being economically inactive, and those in semi-routine and routine occupations. Furthermore, participants with NDH in semi-routine and routine occupations were less likely to become low risk in subsequent years. Older participants (≥ 75 years) with NDH were less likely to progress to type 2 diabetes.

Our observations for NDH prevalence were consistent with previous findings regarding the increase of NDH prevalence with age [15]. Furthermore, our findings suggest that older people with NDH were less likely to progress to

Table 3 Proportions of participants who have non-diabetic hyperglycaemia/type 2 diabetes/low-risk status in the next ELSA nurse visit wave among ELSA participants with non-diabetic hyperglycaemia at waves 2, 4 or 6

	N (%)	Non-diabetic hyperglycaemia	Diagnosed type 2 diabetes	Undiagnosed type 2 diabetes	Low-risk status
Age, years					
≤ 54	107 (8)	47	8	11	34
55–64	536 (38)	46	15	11	28
65–74	494 (35)	56	9	8	27
≥ 75	270 (19)	54	9	7	30
Gender					
Male	590 (42)	52	12	9	27
Female	817 (58)	51	10	9	30
Disability					
No	949 (67)	53	9	8	30
Yes	458 (33)	47	15	11	27
In paid employment					
Yes	503 (36)	50	11	8	31
No	904 (64)	52	11	10	27
Ethnicity					
White British	1370 (97)	51	11	9	29
Minority ethnic	37 (3)	57	11	8	24
Index of Multiple Deprivation					
Least deprived	377 (27)	49	12	9	30
4th quintile	327 (23)	54	8	8	30
3rd quintile	276 (20)	54	8	8	30
2nd quintile	238 (17)	48	15	11	26
Most deprived	189 (13)	51	13	12	24
Social class					
Managerial and professional	466 (33)	49	10	7	34
Intermediate	196 (14)	51	12	10	27
Small employers & own account workers	183 (13)	56	8	10	26
Lower supervisory & technical occupations	149 (11)	55	11	7	27
Semi-routine & routine occupations	413 (29)	50	12	12	26
Total	1407	719	154	130	404

Values are percentages unless stated otherwise.

type 2 diabetes and these findings were similar to another study which suggested that mostly healthy individuals remain longer in studies [25]. We also suggest the possibility of attrition due to death, which is a common form of attrition in ageing studies. However, findings from adults > 65 years of age suggest that older adults tend to have more consultations with family physicians compared with younger people [26], i.e. they are monitored more frequently and this may explain the lower likelihood to transition to type 2 diabetes for older participants.

Similar to other studies [16,27,28] we found no gender differences between participants with NDH in progression to type 2 diabetes. Participants diagnosed with disability were more likely to have NDH and progress to type 2 diabetes in the next years. We found that participants from minority ethnic groups were more likely to have NDH compared with white populations. These findings were similar to a previous report which suggested that NDH prevalence was higher in Asian and black populations [15] and in non-white ethnic groups in the UK [28]. However, we found no differences between ethnic groups in the transition to type 2 diabetes or becoming low-risk. We note that minority ethnic groups are underrepresented compared with white participants in ELSA and the small sample of this group may limit the ability to identify a significant relationship (where one exists) on the data. All minority ethnic groups have been combined into one category, which will include both minorities at higher risk, such as those from African Caribbean or Asian backgrounds, but also other backgrounds at similar risk to the white British population.

Consistent with previous findings, there is a positive association between living in socio-economic disadvantage and NDH prevalence [16,17]. Our observations suggested that there were inequalities in transition to type 2 diabetes; however, there are no prior findings, to our knowledge, to suggest that discrepancies between the most and least advantaged social groups exist in transition from NDH to type 2 diabetes. However, we found that participants in disadvantaged social groups were less likely to progress to the NDH low-risk status compared with those in the most advantaged social group. This suggests that social inequalities in type 2 diabetes occur partly because of the increased risk that disadvantaged social groups have in the transition from NDH to type 2 diabetes, and partly because of the increased likelihood that advantaged social groups become low-risk if they have NDH at some point in their lives. In the

Table 4 Odds ratios of transition to type 2 diabetes and low-risk status in the next ELSA nurse visit wave among ELSA participants with non-diabetic hyperglycaemia at baseline

	Odds ratio (95% CI)			
	Total type 2 diabetes	Diagnosed type 2 diabetes	Undiagnosed type 2 diabetes	Low-risk status
N	1407	1277	1253	1407
Age, years				
≤ 54	1 (reference)	1 (reference)	1 (reference)	1 (reference)
55–64	1.46 (0.73, 2.87)	2.41 (0.84, 6.95)	0.78 (0.30, 2.03)	0.75 (0.41, 1.35)
65–74	0.65 (0.31, 1.35)	1.02 (0.36, 2.82)	0.36 (0.12, 1.08)†	0.77 (0.40, 1.49)
≥ 75	0.55 (0.25, 1.23)	0.93 (0.31, 2.77)	0.27 (0.08, 0.96)*	0.99 (0.48, 2.05)
Gender				
Male	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Female	0.71 (0.49, 1.05)	0.68 (0.41, 1.13)	0.76 (0.43, 1.35)	1.26 (0.90, 1.79)
Disability				
No	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Yes	1.72 (1.16, 2.53)*	1.93 (1.13, 3.35)*	1.46 (0.84, 2.56)	0.87 (0.61, 1.23)
In paid employment				
Yes	1 (reference)	1 (reference)	1 (reference)	1 (reference)
No	1.60 (1.02, 2.51)*	1.34 (0.76, 2.32)	2.10 (1.01, 1.47)*	0.84 (0.55, 1.25)
Ethnicity				
White British	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Minority ethnic	0.69 (0.23, 2.05)	0.79(0.21, 3.06)	0.51(0.09, 2.92)	0.72(0.25, 2.01)
Index of Multiple Deprivation				
Least deprived	1 (reference)	1 (reference)	1 (reference)	1 (reference)
4th quintile	0.73 (0.45, 1.19)	1.65 (0.32, 1.16)	0.90 (0.44, 1.86)	0.90 (0.58, 1.38)
3rd quintile	0.64 (0.38, 1.08)†	0.56 (0.28, 1.12)	0.76 (0.35, 1.65)	1.001 (0.63, 1.58)
2nd quintile	1.21 (0.72, 2.01)	1.20 (0.64, 2.25)	1.21 (0.54, 2.69)	0.87 (0.53, 1.43)
Most deprived	0.93 (0.53, 1.65)	0.84 (0.41, 1.73)	1.08 (0.45, 2.59)	0.82 (0.47, 1.43)
Social class				
Managerial and professional	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Intermediate	1.75 (0.98, 3.10)	1.62 (0.77, 3.39)	2.12 (0.86, 5.26)	0.59 (0.35, 1.02)†
Small employers and own account workers	1.15 (0.64, 2.03)	0.73 (0.33, 1.60)	1.95 (0.80, 4.76)	0.66 (0.39, 1.13)
Lower supervisory and technical occupations	1.01 (0.54, 1.88)	1.11 (0.52, 2.36)	0.88 (0.32, 2.41)	0.66 (0.37, 1.19)
Semi-routine and routine occupations	1.63 (1.02, 2.61)*	1.39 (0.77, 2.48)	2.10 (0.99, 4.44)†	0.64 (0.41, 0.98)*
Intercept	0.13 (0.06, 0.34)*	0.05 (0.007, 0.30)*	0.04 (0.006, 0.23)*	0.58 (0.30, 0.13)
Random parameters				
Intercept variance (person level)	1.63	1.85	3.39	1.93
Intraclass correlation	0.33	0.36	0.51	0.37

*Statistically significant at the 5% level; †statistically significant at the 10% level.

absence of national diabetes prevention programmes like the NDPP, men and women with NDH belonging to professional and managerial social classes appear to be able to reduce their levels of HbA_{1c}. The question that remains is whether NDPP can similarly enable those in more disadvantaged social groups to become low-risk. Furthermore, we argue that it is problematic to adjust for health-related characteristics of participants because these are very likely to lie on the causal pathway between socio-economic position and HbA_{1c}, and thus generate biased inference for studies seeking to understand whether there are sociodemographic inequalities in NDH and transition to type 2 diabetes.

We replicated our analyses using the UKHLS (Doc. S1). The survey is a representative sample of households in the UK and contains a richer set of sociodemographic measures, however, the analysis is limited in that blood samples exist at only one time point of the survey, which limits the ability to identify transitions which are defined using self-reported diabetes status. In UKHLS, NDH was more prevalent in older adults, participants with disabilities and participants living in deprived areas. NDH was more prevalent in minoriy ethnic minority and in the most socio-economically disadvantaged group. Like ELSA, older people with NDH were less likely to progress to diabetes. Women with NDH were less likely to develop type 2 diabetes. Participants with disability and those living in deprived areas were more likely to develop diabetes, and the likelihood of developing diabetes was lower in NDH participants in lower supervisory and technical occupations. Although we found that the most disadvantaged social classes in the UKHLS sample were less likely to be diagnosed with diabetes, this could be explained by the lower propensity of disadvantaged individuals to attend to health screenings that diagnose diabetes [29].

This study has a number of strengths. First, we used data from ELSA which is representative of the English population aged 50 years and over. ELSA includes multiple biomarker

collections and therefore, it was possible to examine undiagnosed progression to type 2 diabetes and progression to low-risk status. We also include results from UKHLS, a representative study of the UK population. Second, using data from health examination surveys provided information on biomarker data and socio-economic variables (e.g. social class and area deprivation) to examine the issue of socio-economic inequalities in NDH prevalence and transition to undiagnosed and diagnosed type 2 diabetes.

However, this study has several limitations. Conclusions about minority ethnic groups should be drawn carefully as in both studies, the sample size of minority ethnic groups is small and groups known to have varying rates of type 2 diabetes have been collapsed into one category. In UKHLS, it is impossible to differentiate participants with type 1 and type 2 diabetes, and therefore our conclusions should also be drawn with caution, particularly for younger participants. Although we adjust in the analyses for disability (i.e. use of limiting long-standing illness variable), we cannot distinguish mental and physical disabilities.

Conclusion

Differences in prevalence of NDH, transition to undiagnosed and diagnosed type 2 diabetes and transition to low-risk status exist in relation to the socio-economic characteristics of participants. Therefore, it is suggested that interventions such as the National Diabetes Prevention Programme, target participants with specific characteristics, for example: participants with disabilities, who are economically inactive, and from disadvantaged social classes. Interventions which do not account for these discrepancies in populations may broaden the inequalities in NDH and transition to type 2 diabetes.

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Competing interests

None declared.

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Author contributions

WW, TC, TM and GC participated in the study conceptualization and design. GC, TM and TC conducted all the analyses. EH drafted part of the introduction. GC interpreted the results and drafted the manuscript. TM, WW, TC, EH, SC, RR, EM, MS and PB critically revised the manuscript for important intellectual content. All authors have read and approved the final manuscript. GC, TM, TC and WW had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Doc S1. UK Household Longitudinal Survey.
Table S1. Proportions of participants who have non-diabetic hyperglycaemia/type 2 diabetes/low-risk status in the next ELSA nurse visit wave among ELSA participants at waves 2,4 or 6.
Table S2. Summary statistics of full and sample with non-diabetic hyperglycaemia in UK Household Longitudinal Survey.
Table S3. Logistic regression of sociodemographic characteristics associated with non-diabetic hyperglycaemia in UK Household Longitudinal Survey.
Table S4. Logistic regression of sociodemographic characteristics associated with transitions to diagnosed diabetes in UK Household Longitudinal Survey.

Author/s:
Chatzi, G; Mason, T; Chandola, T; Whittaker, W; Howarth, E; Cotterill, S; Ravindrarajah, R; McManus, E; Sutton, M; Bower, P

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