



**Type 2 diabetes: a cohort study of treatment, ethnic and social group influences on glycated haemoglobin.**

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Complete List of Authors:	James, Gareth; Barts and The London School of Medicine and Dentistry, Queen Mary University of London, Centre for Primary Care and Public Health Mathur, Rohini; Barts and The London School of Medicine and Dentistry, Queen Mary University of London, Centre for Primary Care and Public Health Baker, Peter; Barts and The London School of Medicine and Dentistry, Queen Mary University of London, Centre for Primary Care and Public Health Hull, Sally; Barts and The London School of Medicine and Dentistry, Queen Mary University of London, Centre for Primary Care and Public Health Badrick, Ellena; Barts and The London School of Medicine and Dentistry, Queen Mary University of London, Centre for Primary Care and Public Health Robson, John; Barts and The London School of Medicine and Dentistry, Queen Mary University of London, Centre for Primary Care and Public Health
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**Type 2 diabetes: a cohort study of treatment, ethnic and social group influences on glycosylated haemoglobin.**

**Authors**

Gareth James            Research Associate / Statistician  
Peter Baker             Foundation Year 2 Clinician  
Ellena Badrick         Research fellow  
Rohini Mathur         Research fellow  
Sally Hull                Reader  
John Robson             Reader

**Address**

Centre for Primary Care and Public Health,  
St Barts and the London School of Medicine and Dentistry,  
Queen Mary University of London,  
Yvonne Carter Building,  
58 Turner Street,  
London E1 2AB

Corresponding author: John Robson

Email address: [j.robson@qmul.ac.uk](mailto:j.robson@qmul.ac.uk)

Tel: 0207 882 2553

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Type 2 diabetes; ethnic group; deprivation; HbA1c; diabetes treatment

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## Article summary

### Article focus

- Variation in HbA1c improvement by ethnic and social group, in people with poorly controlled type 2 diabetes (HbA1c > 7.5%).
- HbA1c improvement with different types of diabetes treatment by ethnic group.

### Key messages

- South Asian people have less improvement in HbA1c than white or black African/Caribbeans.
- This is true in all treatment categories whether on metformin alone, combined oral or insulin.

### Strengths and limitations

- This closed cohort is less subject to bias that may occur in cross-sectional studies or open cohorts where new individuals with diabetes may join or subjects may leave.
- It is representative of people routinely cared for by general practitioners in community settings.
- Duration of diabetes is an important influence on HbA1c and treatment response with longer duration in South Asians. We were unable to reliably ascertain duration of diabetes and cannot confirm whether duration is the cause of our findings.

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## Abstract

### Objectives

To assess whether in people with poorly controlled type 2 diabetes (HbA1c > 7.5%) improvement in HbA1c varies by ethnic and social group.

### Design

Prospective two year cohort of type 2 diabetes treated in general practice

### Setting and participants

All patients with type 2 diabetes in 100 out of the 101 general practices in two London boroughs. The sample consisted of an ethnically diverse group with uncontrolled type 2 diabetes aged 37 to 71 years in 2007 and with HbA1c recording in 2008-9.

### Outcome measure

Change from baseline HbA1c in 2007 and achievement of HbA1c control in 2008 and 2009 were estimated for each ethnic, social and treatment group using multilevel modelling.

### Results

The sample consisted of 6,104 people; 18% were white, 63% south Asian, 16% black African/Caribbean and 3% other ethnic groups. HbA1c was lower after one and two years in all ethnic groups but south Asian people received significantly less benefit from each diabetes treatment. After adjustment, south Asian people were found to have 0.15% less reduction in HbA1c compared to white people (95% CI: 0.05%, 0.25%) and white people were 1.6 (95% CI: 1.3, 2.0) times more likely to achieve HbA1c controlled to 7.5% or less relative to south Asian people. HbA1c reduction and control in black African/Caribbean and white people did not differ significantly. There was no evidence that social deprivation influenced HbA1c reduction or control.

### Conclusion:

In all treatment groups, south Asian people with poorly controlled diabetes are less likely to achieve controlled HbA1c, with less reduction in mean HbA1c than white or black African/Caribbean people.

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## Introduction

An estimated two million (4%) people in the UK have Type 2 diabetes. It is a leading cause of cardiovascular and related morbidity and reduces life expectancy by 10 years(1, 2). Higher HbA1c values are associated with greater mortality and morbidity (3, 4).

Ethnic and social differences in diabetes prevalence are substantial and increasing particularly among south Asian people in whom onset is a decade earlier, with higher levels of HbA1c and increased morbidity in comparison to white people (1, 5). In 2004, initiatives to improve care targeted the most socially disadvantaged 'Spearhead' Primary Care Trusts (PCT). In addition national guidance was supported by a national Quality and Outcomes Framework (QoF) with financial incentives to general practitioners who achieved HbA1c levels controlled to 7.5% or less (6, 7). From 2004 to 2010 more intensive drug treatment was associated with improved HbA1c control in all ethnic groups, but differences between ethnic groups persisted (8-13). The 2009 national UK diabetes audit recorded 70% of white people with controlled HbA1c levels, compared to 58% of south Asian people (1).

There have been no trials to evaluate whether diabetes treatments to control HbA1c levels are variably effective by ethnic and social group (14-16). Using primary care data in an ethnically diverse population, we assessed whether HbA1c is equally responsive to different categories of diabetes treatment in different ethnic and social groups in people with poorly controlled type 2 diabetes.

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## Methods

This study is based on the electronic medical records of all 101 general practices in Newham and Tower Hamlets Primary Care Trusts (PCT) which serve 440,000 people. The same computer system and pre-specified codes for recording data are used by all practitioners. The data was accessed via EMIS web ([www.emis-online.com](http://www.emis-online.com)) in August 2010.

Individual self-reported ethnicity was recorded by general practices using the groups identified in the 2001 UK census and collapsed into four categories; white (British, Irish, other white), south Asian (Bangladeshi, Indian, Pakistani, other Asian, mixed Asian), black African/Caribbean (African, Caribbean, black British, mixed black), and other (any other recorded ethnic group). This enabled comparison with existing studies in the UK. Social deprivation was measured using the Townsend score, derived from Census data on unemployment, car and home ownership and overcrowding at lower superoutput area level (approximately 400 households) linked to individual patient postcode (17, 18).

Body Mass index (BMI) and serum cholesterol were estimated using the latest recording in 2007. The latest HbA1c value and all diabetes prescriptions within each annual 12 month period were recorded. Variables were marked as missing if values lay outside specified limits.

Broadly speaking there are four clinical stages of treatment to reduce HbA1c levels in patients with diabetes; diet only, metformin, other oral hypoglycaemic medication with or without metformin and insulin alone or in combination with oral hypoglycaemic agents. We extracted all prescriptions during the study period for the cohort. We categorised treatment as; "Metformin Only" if the patient received only metformin for the whole study period, "Combined Oral" if the patient received any other oral hypoglycaemic either without or in addition to metformin for the whole study period; "Insulin" if the patient received insulin for the whole study period; "Metformin Only to Combined Oral" if the patient changed from Metformin to Combined Oral over the study period; "Any to Insulin" if the patient changed from Metformin only, or Combined Oral over the study period. We did not include patients without any prescriptions in a given year as we were unable to ascertain whether

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3 they had in fact left the practice. The sample was drawn from all people diagnosed  
4 with type 2 diabetes in the 101 general practices, aged 37 to 71 years in 2007, who  
5 had uncontrolled diabetes (HbA1c >7.5%) in 2007 and who also had HbA1c  
6 recorded in 2008 and 2009. Patients were excluded if treatment was missing during  
7 one or more years or treatment did not fit in any of the cohort treatment categories  
8 described. The lower age limit excluded misclassified type 1 diabetes and older ages  
9 were excluded because intensive treatment may be clinically inappropriate (19, 20).

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11 Two outcome measures were used to assess treatment effectiveness; change from  
12 baseline HbA1c (CfB) and HbA1c control. HbA1c values in 2007 were taken as the  
13 baseline covariate values. Thus a patient's CfB HbA1c for 2008 was their 2008 value  
14 minus their 2007 value; CfB HbA1c 2009 was their 2009 value minus their 2007  
15 HbA1c value. A patient was considered to achieve HbA1c control in 2008 if their  
16 2008 HbA1c value was 7.5% or less and in 2009 if their 2009 HbA1c value was 7.5%  
17 or less.

### 28 **Statistical Analysis**

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30 Analysis was performed using Stata 12.0 ([www.stata.com](http://www.stata.com)). Demographic statistics  
31 for each ethnic group were calculated. Data were structured with variation at four  
32 levels; the lowest level was year, level 2 was person, level 3 was practice, level 4  
33 was Primary Care Trust (PCT). A linear multilevel model was used to estimate the  
34 CfB HbA1c in 2008 and 2009 and confidence intervals (21). A logistic multilevel  
35 model was used to estimate the probability of achieving HbA1c control in 2008 and  
36 2009. The models were adjusted for baseline HbA1c (2007 HbA1c value), age, sex,  
37 year, BMI, serum cholesterol, cohort treatment, Townsend category and ethnic group  
38 as these variables were considered likely to influence HbA1c improvement. Duration  
39 of diabetes was not available in this study. Patients with 'Other' ethnic groups  
40 recorded were not included in the model construction as they consisted of many  
41 different ethnic groups and were small in number.

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43 An ethnicity\*treatment interaction was added to each model to assess whether  
44 ethnicity was a factor in HbA1c reduction and HbA1c control for each treatment. An  
45 ethnicity\*year interaction were added to the models to assess if the difference in  
46 HbA1c reduction and achievement of HbA1c control between ethnic groups changed  
47 between 1 and 2 years. Significance was set at the 5% level.

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## Results

In August 2010 data was collected from 100 of the 101 practices in Tower Hamlets and Newham. One practice declined participation. Over the three years of the study, a total of 28,041 people in the study age range were diagnosed with Type 2 diabetes and 17,670 (63%) had an HbA1c recording in 2007. Of these 17,670 people, 8,864 (50%) had uncontrolled diabetes (HbA1c > 7.5%) of whom 42% were white, 50% were black African/Caribbean and 53% were south Asian. Among the 8864 uncontrolled patients, 6,464 (73%) also had HbA1c values in 2008 and 2009. Of those excluded because of missing HbA1c records, 30% were white, 25% south Asian and 27% black African/Caribbean people; 27-28% were in each social deprivation group. Finally 207 (3%) people were excluded because they had missing treatment information in one or more years and 153 (2%) did not fit into any of the cohort treatment categories described in the methods.

The final sample therefore consisted of 6,104 (68.9%) out of the 8,864 people with uncontrolled diabetes HbA1c >7.5%. Of these, 6,017 (99%) had ethnicity recorded, 6087 (>99%) people had Townsend score recorded. Age and sex was recorded in everyone and serum cholesterol in 95% and BMI in 94%. In total there were 1,101 (18%) white, 3785 (63%) south Asian, 993 (16%) black African/Caribbean and 160 (3%) other ethnic groups in the sample. Only 2% of people fell in the two least deprived quintiles, so the least three quintiles were combined and categorized as 'Least' deprived (N=1,204, 20%), 'High' deprivation if they were in the most deprived quintile (N=1,858, 31%) and 'Medium' (N=3025, 50%) otherwise.

Table 1 describes the variable mean or percentage in each category for each demographic group. Baseline HbA1c was similar between ethnic groups. After 1 and 2 years mean HbA1c decreased in each ethnic group but the mean reduction in HbA1c from baseline was less in south Asian patients than other ethnic groups and these patients had the least chance of achieving HbA1c controlled to 7.5% or less. A similar proportion of each ethnic group fell into each deprivation category.

Altogether, 7% of patients remained on 'Metformin Only' for the whole study, 46% on 'Combined Oral' and 33% on 'Insulin'. Treatment intensity increased in 15% of patients during the study. Despite similar baseline HbA1c, treatment categories between ethnic groups differed significantly ( $p < 0.001$ ); there were a greater



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3 proportion of south Asian people on 'Combined Oral treatment' 50% than white 35%  
4 or black African Caribbean 44% and a greater proportion of south Asian 80% and  
5 black African/Caribbean people 79% started and remained on more intensive  
6 treatment (either Combined oral or insulin) than white 75%.  
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10 Fewer south Asian people, 36% started or changed to insulin compared to black  
11 African/Caribbean 42% and white people 49%. A sub-analysis indicated white  
12 people were significantly more likely to increase their treatment intensity 30%, than  
13 south Asian 19% and black people 22% ( $p<0.001$ ).  
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18 Tables 2a and 2b describe the statistical models to estimate CfB HbA1c and HbA1c  
19 control. Person, practice, and PCT were all significant ( $p<0.001$ ) and were included  
20 in the final models. Baseline HbA1c, age, serum cholesterol, ethnicity, sex and  
21 cohort treatment had a significant effect on CfB HbA1c and HbA1c control.  
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24 Townsend category and BMI were not significant but were retained in the models as  
25 variables of interest. The ethnicity\*treatment and ethnicity\*year interactions were not  
26 significant and were not included in either model.  
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30 The interpretation of the model coefficients in Tables 2a/b can be illustrated by  
31 considering two patients similar for all variables except treatment. One patient is on  
32 'Metformin Only' and the other on 'Insulin'. In 2008 the patient on 'Insulin' will have  
33 their HbA1c reduced by 1.14 less than the patient on 'Metformin Only' treatment. The  
34 same comparison in Table 2b indicates a patient on 'Insulin' treatment has an odds  
35 ratio of 0.04 meaning that a patient on Metformin is 25 ( $1/0.04$ ) times as likely to  
36 achieve HbA1c control than a patient on Insulin.  
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43 In people with uncontrolled HbA1c at baseline, after one and two years on treatment;  
44 south Asian people had 0.15% less reduction in mean HbA1c than white people  
45 ( $p=0.004$ ) and white people were 1.7 times ( $p<0.001$ ) as likely to achieve HbA1c  
46 control relative to south Asian people. White and black African/Caribbean people had  
47 no significant difference in CfB HbA1c ( $p=0.805$ ) or HbA1c control achievement  
48 ( $p=0.355$ ). There was no evidence that social deprivation affected HbA1c reduction  
49 or HbA1c control achievement.  
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55 The ethnicity\*treatment interaction was not significant, indicating that in each of the  
56 different treatment groups, south Asian people had the smallest reduction in HbA1c  
57 and the lowest probability of achieving HbA1c control after 1 and 2 years. This also  
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3 indicates white and black African/Caribbean people have a similar response to each  
4 treatment.  
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7 Figure 1 illustrates that for an individual with HbA1c 9% at baseline on 'Metformin  
8 Only' and 'Insulin' treatments, that south Asian people had the least reduction in  
9 HbA1c for each treatment.  
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## Discussion

This observational study is the first to assess whether HbA1c responds equally to different types of diabetes treatment in different ethnic and social groups. We found HbA1c improved in all ethnic groups over a two year period, but HbA1c improved less in south Asian people for each treatment relative to other ethnic groups. We found no association between social deprivation and HbA1c improvement after adjustment for other variables.

Higher HbA1c in south Asians has been confirmed in most studies which also confirm their higher intensity of oral treatment and lower use of insulin (15, 22-24). Poor HbA1c control in African Americans has also been reported in the USA, though our study found no such disparity in black African/Caribbean people (14, 16, 25, 26).

Our study is unable to differentiate the reasons why south Asian patients respond less favourably to treatment. It could be lack of treatment efficacy in these patients. Alternatively it could be due to duration of diabetes where HbA1c control has been shown to deteriorate despite treatment in all categories over time (27). South Asian people have earlier onset of diabetes as reflected in our study by the younger mean age; 56 years in south Asians compared to 60 years in white and 58 years in black African/Caribbean people. At the start of the study more black African/Caribbean 79% and south Asian patients 80% were already on higher intensity treatment (either Combined oral or insulin) than white patients 75%. During the study period a significantly higher proportion of white people ( $p < 0.001$ ) increased their intensity of treatment than black African/Caribbean or south Asian people and this may also have contributed to less reduction in HbA1c in the latter.

Our study is large and included almost all those diagnosed with type 2 diabetes in the age range in a contiguous geographical area. It has high numbers of people in each ethnic group allowing for precise comparisons between ethnic groups and the extent and quality of ethnic group and social deprivation recording was high. For all adjustment variables used, less than 10% of data was missing. All patients had longitudinal HbA1c values allowing us to examine the change in HbA1c over time.

Our study is a closed cohort and meets some of the concerns regarding potential bias from using open cohorts of general practice populations that include people who

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3 leave the cohort or who join through registration with the general practitioner or as  
4 new diagnoses(13).  
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7 The different ethnic groups had similar mean baseline HbA1c suggesting diabetes  
8 severity was similar across ethnic groups. HbA1c increases with duration of diabetes  
9 but information on this was unavailable. The inclusion of age and treatment in the  
10 statistical models explains some but not all of the effect of diabetes duration on  
11 HbA1c. Longer diabetes duration could therefore be an explanation for the observed  
12 ethnic group differences.  
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18 A limitation of the study was the exclusion of 31% of those with uncontrolled diabetes  
19 because of missing treatment or HbA1c records which may have introduced bias.  
20 However, fewer south Asians were excluded for this reason which suggests that as a  
21 group, they were more likely to be more concordant with care. Selection bias was an  
22 unlikely cause of the smaller reduction of HbA1c in south Asian people in this study.  
23 Finally, there is no evidence to suggest that south Asian people are less likely to  
24 respond to change in lifestyle factors such as diet or physical activity as compared to  
25 other ethnic groups.  
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### 32 **Conclusion**

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34 This study provides evidence that south Asian people with poorly controlled type 2  
35 diabetes are on higher intensity treatment than white or black African/Caribbean  
36 people. South Asians tend to achieve less HbA1c reduction over time than other  
37 ethnic groups from all types of diabetes treatment whether this is metformin alone,  
38 combined oral treatment or insulin alone or in combination. While the reasons for this  
39 remain uncertain, this finding is relevant to clinicians seeking to achieve HbA1c  
40 control below 7.5%, particularly in areas with large south Asian populations.  
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47 **Ethics:** Ethical committee consent was not required for review of non-identifiable  
48 routinely collected data.  
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52 **Declaration of Competing Interests:** Nothing to declare.  
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**Contributors:** G. James designed the analysis and undertook data extraction, analysis and interpretation, P. Baker undertook the literature review. All authors contributed to the drafting of the paper and development of core ideas. J. Robson and S. Hull were principal investigators who initiated and supervised the study.

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**Data sharing statement:** No additional data available

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## Tables

Table 1: Demographic and clinical characteristics by ethnic group

Variable	Category	white	S Asian	black	All
<b>N</b>	-	1,101	3,785	971	6,104
<b>%</b>	-	18	63	16	-
<b>Baseline HbA1c%</b>	-	9.2	9.1	9.3	9.2
<b>CfB HbA1c% after 1 year</b>	-	-0.7	-0.5	-0.8	-0.6
<b>CfB HbA1c% after 2 years</b>	-	-0.6	-0.4	-0.7	-0.5
<b>HbA1c control after 1 year (%)</b>	HbA1c Controlled	33	29	33	30
<b>HbA1c control after 2 years (%)</b>	HbA1c Controlled	34	29	33	30
<b>Mean age at baseline (years)</b>	-	60	56	58	57
<b>Serum cholesterol mmol/l</b>	-	4.3	4.1	4.4	4.2
<b>BMI</b>	-	34	28	31	29
<b>Sex (%)</b>	Male	59	52	47	53
<b>Townsend group (%)</b>	Least	19	19	20	20
	Medium	52	48	54	50
	High	29	33	26	31
<b>Treatment group (%)</b>	Metformin Only	7	7	7	7
	Combined Oral	35	50	44	46
	Insulin	40	30	35	33
	Metformin to Combined Oral	10	7	7	8
	Any to Insulin	9	6	7	7

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Table 2: Statistical Model Parameter Estimates

a: Linear multilevel regression model to estimate Change from baseline HbA1c (%)

Variable	Category	Effect on CFB HbA1c %	95% CI	Category p-value	Variable p-value
<b>Baseline HbA1c</b>	-	-0.53	(-0.56, -0.51)	-	<0.001
<b>Age</b>	-	-0.01	(-0.02, -0.01)	-	<0.001
<b>Serum cholesterol</b>	-	0.09	(0.06, 0.13)	-	<0.001
<b>BMI</b>	-	0.00	(-0.01, 0.01)	-	0.805
<b>Year</b> (2008= Ref)	2009	0.11	(0.07, 0.15)	<0.001	<0.001
<b>Sex</b> (Female = Ref)	Male	0.14	(0.07, 0.21)	<0.001	<0.001
<b>Ethnicity</b> (white = Ref)	S Asian	0.15	(0.05, 0.25)	0.004	0.001
	black	-0.01	(-0.13, 0.10)	0.805	
<b>Townsend</b> (Least = Ref)	Medium	0.06	(-0.03, 0.15)	0.169	0.330
	High	0.07	(-0.04, 0.18)	0.183	
<b>Treatment</b> (Metformin Only = Ref)	Combined Oral	0.67	(0.53, 0.80)	<0.001	<0.001
	Insulin	1.14	(1.00, 1.28)	<0.001	
	Metformin to Combined Oral	0.37	(0.20, 0.55)	<0.001	
	Any to Insulin	1.25	(1.06, 1.43)	<0.001	

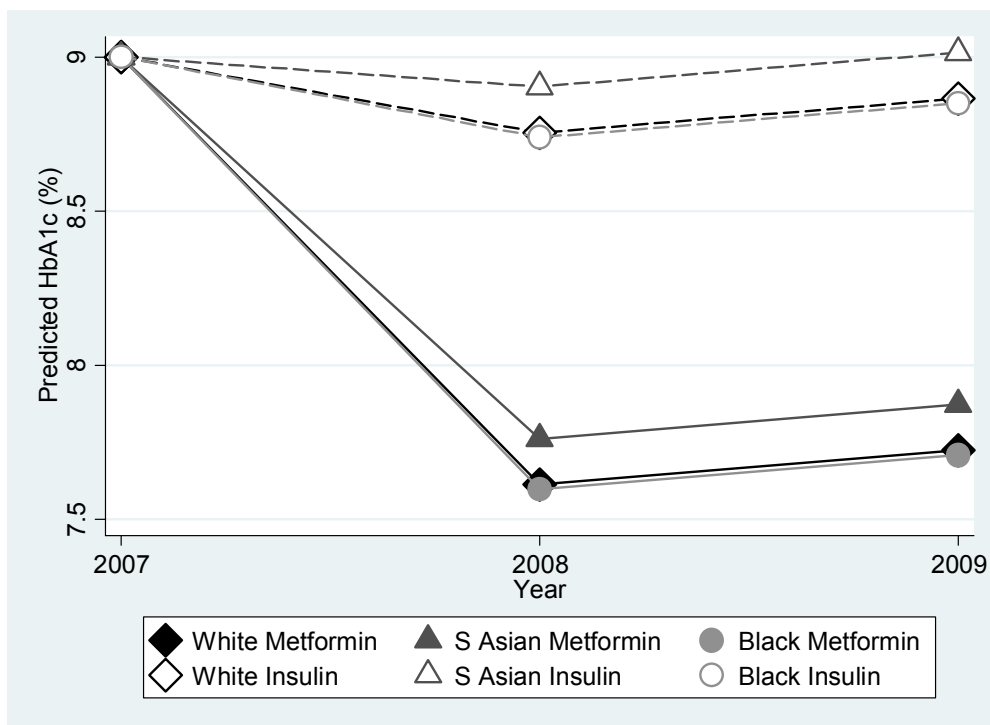
b: Logistic multilevel regression model to estimate HbA1c Control

Variable	Category	OR	95% CI OR	Category p-value	Variable p-value
<b>Baseline HbA1c</b>	-	0.56	(0.52, 0.60)	-	<0.001
<b>Age</b>	-	1.03	(1.02, 1.04)	-	<0.001
<b>Serum cholesterol</b>	-	0.89	(0.82, 0.96)	-	0.003
<b>BMI</b>	-	1.01	(1.00, 1.03)	-	0.119
<b>Year</b> (2008= Ref)	2009	0.95	(0.85, 1.06)	0.396	0.396
<b>Sex</b> (Female = Ref)	Male	0.83	(0.7, 0.97)	0.022	0.022
<b>Ethnicity</b> (white = Ref)	S Asian	0.62	(0.49, 0.79)	<0.001	<0.001
	black	0.88	(0.67, 1.16)	0.355	
<b>Townsend</b> (Least = Ref)	Medium	0.94	(0.76, 1.16)	0.568	0.560
	High	0.82	(0.63, 1.06)	0.135	
<b>Cohort Treatment</b> (Metformin Only = Ref)	Combined Oral	0.16	0.12, 0.22)	<0.001	<0.001
	Insulin	0.04	(0.03, 0.06)	<0.001	
	Metformin to Combined Oral	0.23	(0.16, 0.35)	<0.001	
	Any to Insulin	0.05	(0.03, 0.08)	<0.001	

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Figures

Figure 1: Expected HbA1c for each ethnic group on 'Metformin Only' and 'Insulin' treatment



review only



**Type 2 diabetes: a cohort study of treatment, ethnic and social group influences on glycated haemoglobin.**

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Cohort v15 GJ 27 7 12

**Type 2 diabetes: a cohort study of treatment, ethnic and social group influences on glycated haemoglobin.**

**Authors**

Gareth James            Research Associate / Statistician  
Peter Baker             Foundation Year 2 Clinician  
Ellena Badrick         Research fellow  
Rohini Mathur         Research fellow  
Sally Hull               Reader  
John Robson             Reader

**Address**

Centre for Primary Care and Public Health,  
St Barts and the London School of Medicine and Dentistry,  
Queen Mary University of London,  
Yvonne Carter Building,  
58 Turner Street,  
London E1 2AB

Corresponding author: John Robson

Email address: [j.robson@qmul.ac.uk](mailto:j.robson@qmul.ac.uk)

Tel: 0207 882 2553

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## Article summary

### Article focus

- Variation in HbA1c improvement by ethnic and social group, in people with poorly controlled type 2 diabetes (HbA1c > 7.5%).
- HbA1c improvement with different types of diabetes treatment by ethnic group.

### Key messages

- South Asian people have less improvement in HbA1c than white or black African/Caribbeans.
- This is true in all treatment categories whether on metformin alone, combined oral or insulin.

### Strengths and limitations

- .
- It is representative of people routinely cared for by general practitioners in community settings.
- Duration of diabetes is an important influence on HbA1c and treatment response with longer duration in South Asians. We were unable to reliably ascertain duration of diabetes and cannot confirm whether duration is the cause of our findings.

## Abstract

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## Objectives

To assess whether in people with poorly controlled type 2 diabetes (HbA1c > 7.5%) improvement in HbA1c varies by ethnic and social group.

## Design

Prospective two year cohort of type 2 diabetes treated in general practice

## Setting and participants

All patients with type 2 diabetes in 100 out of the 101 general practices in two London boroughs. The sample consisted of an ethnically diverse group with uncontrolled type 2 diabetes aged 37 to 71 years in 2007 and with HbA1c recording in 2008-9.

## Outcome measure

Change from baseline HbA1c in 2007 and achievement of HbA1c control in 2008 and 2009 were estimated for each ethnic, social and treatment group using multilevel modelling.

## Results

The sample consisted of 6,104 people; 18% were white, 63% south Asian, 16% black African/Caribbean and 3% other ethnic groups. HbA1c was lower after one and two years in all ethnic groups but south Asian people received significantly less benefit from each diabetes treatment. After adjustment, south Asian people were found to have 0.14% less reduction in HbA1c compared to white people (95% CI: 0.04%, 0.24%) and white people were 1.6 (95% CI: 1.2, 2.0) times more likely to achieve HbA1c controlled to 7.5% or less relative to south Asian people. HbA1c reduction and control in black African/Caribbean and white people did not differ significantly. There was no evidence that social deprivation influenced HbA1c reduction or control in this cohort.

## Conclusion:

In all treatment groups, south Asian people with poorly controlled diabetes are less likely to achieve controlled HbA1c, with less reduction in mean HbA1c than white or black African/Caribbean people.

## Introduction

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An estimated two million (4%) people in the UK have Type 2 diabetes. It is a leading cause of cardiovascular and related morbidity and reduces life expectancy by 10 years(1, 2). Higher HbA1c values are associated with greater mortality and morbidity (3, 4).

Ethnic and social differences in diabetes prevalence are substantial and increasing particularly among south Asian people in whom onset is a decade earlier, with higher levels of HbA1c and increased morbidity in comparison to white people (1, 5). In 2004, initiatives to improve care targeted the most socially disadvantaged 'Spearhead' Primary Care Trusts (PCT). In addition national guidance was supported by a national Quality and Outcomes Framework (QoF) with financial incentives to general practitioners who achieved HbA1c levels controlled to 7.5% or less (6, 7). From 2004 to 2010 more intensive drug treatment was associated with improved HbA1c control in all ethnic groups, but differences between ethnic groups persisted (8-13). The 2009 national UK diabetes audit recorded 70% of white people with controlled HbA1c levels, compared to 58% of south Asian people (1).

There have been no trials to evaluate whether diabetes treatments to control HbA1c levels are variably effective by ethnic and social group (14-16). We aimed to assess, if improvement in HbA1c in people with poorly controlled type 2 diabetes (HbA1c > 7.5%) varies by ethnic and social group using primary care data in an ethnically diverse population.



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## Methods

This study is based on the electronic medical records of all 101 general practices in Newham and Tower Hamlets Primary Care Trusts (PCT) which serve 440,000 people. The same computer system and pre-specified codes for recording data are used by all practitioners. The data was accessed via EMIS web ([www.emis-online.com](http://www.emis-online.com)) in August 2010.

Individual self-reported ethnicity was recorded by general practices using the groups identified in the 2001 UK census and collapsed into four categories; white (British, Irish, other white), south Asian (Bangladeshi, Indian, Pakistani, other Asian, mixed Asian), black African/Caribbean (African, Caribbean, black British, mixed black), and other (any other recorded ethnic group). This enabled comparison with existing studies in the UK. Social deprivation was measured using the Townsend score, which is routinely available in these electronic medical records. This score is derived from Census data on unemployment, car and home ownership and overcrowding at lower superoutput area level (approximately 400 households) linked to individual patient postcode (17, 18). The score indicates the spectrum of deprivation within small geographical areas where the most deprived are likely to be unemployed, without a car and living in rented, overcrowded accommodation.

Body Mass index (BMI) and serum cholesterol were estimated using the latest recording in 2007. The latest HbA1c value and all diabetes prescriptions within each annual 12 month period were recorded. Variables were marked as missing if values lay outside specified limits.

Broadly speaking there are four clinical stages of treatment to reduce HbA1c levels in patients with diabetes; diet only, metformin, other oral hypoglycaemic medication with or without metformin and insulin alone or in combination with oral hypoglycaemic agents. We extracted all prescriptions during the study period for the cohort. We categorised treatment as; "Metformin Only" if the patient received only metformin for the whole study period, "Combined Oral" if the patient received any other oral hypoglycaemic either without or in addition to metformin for the whole study period and did not receive insulin; "Insulin" if the patient received insulin for the whole study period; "Metformin Only to Combined Oral" if the patient changed from

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3 Metformin to Combined Oral over the study period; “Any to Insulin” if the patient  
4 changed from Metformin only, or Combined Oral over the study period. We did not  
5 include patients without any prescriptions in a given year as we were unable to  
6 ascertain whether they had in fact left the practice.  
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10 The sample was drawn from all individuals recorded as having type 2 diabetes at the  
11 start of the observation period in the 101 general practices, aged 37 to 71 years in  
12 2007, who had uncontrolled diabetes (HbA1c >7.5%) in 2007 and who also had  
13 HbA1c recorded in 2008 and 2009. Patients were excluded if treatment was missing  
14 during one or more years or treatment did not fit in any of the cohort treatment  
15 categories described. The lower age limit excluded misclassified type 1 diabetes and  
16 older ages were excluded because intensive treatment may be clinically  
17 inappropriate (19, 20).  
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21 Typically the ‘Combined Oral’ treatment will consist of either sulphonylurea alone, or  
22 one of the newer oral agents - thiazolidinediones, insulin secretagogues,  
23 dipeptidylpeptidase-4 inhibitors - alone, or in combination with the  
24 sulphonylurea. We considered five sub- categories for “Combined Oral”:  
25 “Sulphonylurea alone” if the patient received only sulphonylurea for the whole study  
26 period, “New agent alone” if the patient received only new agents for the whole study  
27 period, “Sulphonylurea and new agent” if the patient received sulphonylurea and new  
28 agents for the whole study period, “One to both” if the patient begun on either  
29 sulphonylurea or new agents and their treatment was intensified to both treatments  
30 during the study; and “Other” otherwise.  
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34 Diabetes duration at baseline was categorised as “0-2 years” if the patient received  
35 their first diabetes diagnosis code between 2005 and 2007, and “>2 years” if they  
36 received their first code prior to 2005. Exploratory analysis indicated that these  
37 codes were unreliable to estimate time-with-diabetes prior to 2004.  
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41 Two outcome measures were used to assess treatment effectiveness; change from  
42 baseline HbA1c (CfB) and HbA1c control. HbA1c values in 2007 were taken as the  
43 baseline covariate values. Thus a patient’s CfB HbA1c for 2008 was their 2008 value  
44 minus their 2007 value; CfB HbA1c 2009 was their 2009 value minus their 2007  
45 HbA1c value. A patient was considered to achieve HbA1c control in 2008 if their  
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2008 HbA1c value was 7.5% or less and in 2009 if their 2009 HbA1c value was 7.5% or less.

### Statistical Analysis

Analysis was performed using Stata 12.0 ([www.stata.com](http://www.stata.com)). Demographic statistics for each ethnic group were calculated. Data were structured with variation at four levels; the lowest level was year, level 2 was person, level 3 was practice, level 4 was Primary Care Trust (PCT). A linear multilevel model was used to estimate the CfB HbA1c in 2008 and 2009 (21). A logistic multilevel model was used to estimate the probability of achieving HbA1c control in 2008 and 2009. These models incorporated the structure of the data by including random effects for person, practice and year. The models were adjusted for baseline HbA1c (2007 HbA1c value), age, sex, year, BMI, serum cholesterol, cohort treatment, diabetes duration, Townsend category and ethnic group as these variables were considered likely to influence HbA1c improvement.. Patients with 'Other' ethnic groups recorded were not included in the model construction as they consisted of many different ethnic groups and were small in number.

An ethnicity\*treatment interaction was added to each model to assess whether ethnicity was a factor in HbA1c reduction and HbA1c control for each treatment. An ethnicity\*year interaction were added to the models to assess if the difference in HbA1c reduction and achievement of HbA1c control between ethnic groups changed between 1 and 2 years. An ethnicity\* diabetes duration interaction was added to the models to assess whether the difference between ethnic groups in HbA1c reduction and achievement of HbA1c control varied between the two duration categories. Significance was set at the 5% level.

Exploratory analysis was conducted on the 'Combined Oral' sub categories.

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## Results

In August 2010 data was collected from 100 of the 101 practices in Tower Hamlets and Newham. One practice declined participation. Over the three years of the study, a total of 28,041 people in the study age range were identified as having Type 2 diabetes in 2007 and 17,670 (63%) had an HbA1c recording in 2007. Of these 17,670 people, 8,864 (50%) had uncontrolled diabetes (HbA1c > 7.5%) of whom 42% were white, 50% were black African/Caribbean and 53% were south Asian. Among the 8864 uncontrolled patients, 6,464 (73%) also had HbA1c values in 2008 and 2009. Of those excluded because of missing HbA1c records, 30% were white, 25% south Asian and 27% black African/Caribbean people; 27-28% were in each social deprivation group. Finally 207 (3%) people were excluded because they had missing treatment information in one or more years and 153 (2%) did not fit into any of the cohort treatment categories described in the methods.

The final sample therefore consisted of 6,104 (68.9%) out of the 8,864 people with uncontrolled diabetes HbA1c >7.5%. Of these, 6,017 (99%) had ethnicity recorded, 6087 (>99%) people had Townsend score recorded. Age and sex was recorded in everyone and serum cholesterol in 95% and BMI in 94%. In total there were 1,101 (18%) white, 3785 (63%) south Asian, 993 (16%) black African/Caribbean and 160 (3%) other ethnic groups in the sample. Only 2% of people fell in the two least deprived quintiles, so the least three quintiles were combined and categorized as 'Least' deprived (N=1,204, 20%), 'High' deprivation if they were in the most deprived quintile (N=1,858, 31%) and 'Medium' (N=3025, 50%) otherwise.

Table 1A describes the variable mean or percentage in each category for each demographic group. Table 1B describes the HbA1c mean and proportion of HbA1c control for each demographic group. Baseline HbA1c and the diabetes duration distribution was similar between ethnic groups. After 1 and 2 years mean HbA1c decreased in each ethnic group but the mean reduction in HbA1c from baseline was less in south Asian patients than other ethnic groups and these patients had the least chance of achieving HbA1c controlled to 7.5% or less. A similar proportion of each ethnic group fell into each deprivation category.

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3 Altogether, 7% of patients remained on 'Metformin Only' for the whole study, 46% on  
4 'Combined Oral' and 33% on 'Insulin'. Treatment intensity increased in 15% of  
5 patients during the study. Despite similar baseline HbA1c, treatment categories  
6 between ethnic groups differed significantly ( $p<0.001$ ); there were a greater  
7 proportion of south Asian people on 'Combined Oral treatment' 50% than white 35%  
8 or black African Caribbean 44% and a greater proportion of south Asian 80% and  
9 black African/Caribbean people 79% started and remained on more intensive  
10 treatment (either Combined oral or insulin) than white 75%.

11  
12 Fewer south Asian people, 36% started or changed to insulin compared to black  
13 African/Caribbean 42% and white people 49%. A sub-analysis indicated white  
14 people were significantly more likely to increase their treatment intensity 30%, than  
15 south Asian 19% and black people 22% ( $p<0.001$ ).

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17 Tables 2a and 2b describe the statistical models to estimate CfB HbA1c and HbA1c  
18 control. Person, practice, and PCT were all significant ( $p<0.001$ ) and were included  
19 in the final models. Baseline HbA1c, age, serum cholesterol, ethnicity, sex and  
20 cohort treatment had a significant effect on CfB HbA1c and HbA1c control.  
21 Townsend category and BMI were not significant but were retained in the models as  
22 variables of interest. The ethnicity\*treatment and ethnicity\*year interactions were not  
23 significant and were not included in either model.

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25 In people with uncontrolled HbA1c at baseline, after one and two years on treatment;  
26 south Asian people had 0.15% less reduction in mean HbA1c than white people  
27 ( $p=0.005$ ) and white people were 1.6 times ( $p<0.001$ ) as likely to achieve HbA1c  
28 control relative to south Asian people. White and black African/Caribbean people had  
29 no significant difference in CfB HbA1c ( $p=0.705$ ) or HbA1c control achievement  
30 ( $p=0.460$ ). There was no evidence that social deprivation affected HbA1c reduction  
31 or HbA1c control achievement.

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33 The ethnicity\*treatment interaction was not significant, indicating that in each of the  
34 different treatment groups, south Asian people had the smallest reduction in HbA1c  
35 and the lowest probability of achieving HbA1c control after 1 and 2 years. This also  
36 indicates white and black African/Caribbean people have a similar response to each  
37 treatment. The ethnicity\* diabetes duration interaction was not significant, indicating  
38 that south Asian people have the smallest reduction in HbA1c and probability of  
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3 achieving HbA1c control when their duration of diabetes is between 0-2 years and  
4 more than two years.  
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7 Figure 1 illustrates that for an individual with HbA1c 9% at baseline on 'Metformin  
8 Only' and 'Insulin' treatments, that south Asian people had the least reduction in  
9 HbA1c for each treatment.  
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13 There was little variation in the distribution of sub-categories in the 'Combined Oral'  
14 treatment between ethnic groups (Table 3). Most noticeably, white people were the  
15 most likely to intensify 20%, followed by black African/Caribbean people 18% and  
16 South Asian people 17%.  
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## Discussion

This observational study is the first to assess whether HbA1c responds equally to different types of diabetes treatment in different ethnic and social groups. We found HbA1c improved in all ethnic groups over a two year period, but HbA1c improved less in south Asian people for each treatment relative to other ethnic groups. We found no association between social deprivation and HbA1c improvement after adjustment for other variables.

The interpretation of the model coefficients in Tables 2a/b can be illustrated by considering two patients similar for all variables except treatment. One patient is on 'Metformin Only' and the other on 'Insulin'. In 2008 the patient on 'Insulin' will have their HbA1c reduced by 1.11 less than the patient on 'Metformin Only' treatment. The same comparison in Table 2b indicates a patient on 'Insulin' treatment has an odds ratio of 0.06 meaning that a patient on Metformin is 16.67 (1/0.06) times as likely to achieve HbA1c control than a patient on Insulin. However this does not indicate that Metformin is more effective at controlling HbA1c than Insulin. This study is unable to compare the effectiveness of these treatments as HbA1c levels in patients on insulin are more difficult to control as they are likely to have increased duration of diabetes and other diabetes drugs have failed to control their HbA1c levels.

Higher HbA1c in south Asians has been confirmed in most studies which also confirm their higher intensity of oral treatment and lower use of insulin (15, 22-24). Poor HbA1c control in African Americans has also been reported in the USA, though our study found no such disparity in black African/Caribbean people (14, 16, 25, 26).

Our study is unable to differentiate the reasons why south Asian patients respond less favourably to treatment. It could be lack of treatment efficacy in these patients. Alternatively it could be due to duration of diabetes where HbA1c control has been shown to deteriorate despite treatment in all categories over time (27). South Asian people have earlier onset of diabetes as reflected in our study by the younger mean age; 56 years in south Asians compared to 60 years in white and 58 years in black African/Caribbean people. At the start of the study more black African/Caribbean 79% and south Asian patients 80% were already on higher intensity treatment (either Combined oral or insulin) than white patients 75%. During the study period a significantly higher proportion of white people ( $p < 0.001$ ) increased

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3 their intensity of treatment than black African/Caribbean or south Asian people and  
4 this may also have contributed to less reduction in HbA1c in the latter who were  
5 already on more intensive treatment.  
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9 Our study is large and included almost all those diagnosed with type 2 diabetes in  
10 the age range in a large contiguous geographical area. It has high numbers of  
11 people in each ethnic group allowing for precise comparisons between ethnic groups  
12 and the extent and quality of ethnic group and social deprivation recording was high.  
13 For all adjustment variables used, less than 10% of data was missing. All patients  
14 had longitudinal HbA1c values allowing us to examine the change in HbA1c over  
15 time.  
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21 The different ethnic groups had similar mean baseline HbA1c suggesting diabetes  
22 severity was similar across ethnic groups. HbA1c increases with duration of diabetes  
23 but information was limited as exploratory analysis indicated that durations  
24 exceeding two years could not be further categorised reliably. The inclusion of age  
25 and treatment in the statistical models explains some but not all of the effect of  
26 diabetes duration on HbA1c. Longer diabetes duration could therefore be an  
27 explanation for the observed ethnic group differences.  
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34 A limitation of the study was the exclusion of 31% of those with uncontrolled diabetes  
35 because of missing treatment or HbA1c records which may have introduced bias.  
36 However, fewer south Asians were excluded for this reason which suggests that as a  
37 group, they were more likely to be more concordant with care. Selection bias was an  
38 unlikely cause of the smaller reduction of HbA1c in south Asian people in this study.  
39 Finally, there is no evidence to suggest that south Asian people are less likely to  
40 respond to change in lifestyle factors such as diet or physical activity as compared to  
41 other ethnic groups.  
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## 50 **Conclusion**

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53 This study provides evidence that south Asian people with poorly controlled type 2  
54 diabetes are on higher intensity treatment than white or black African/Caribbean  
55 people. Despite this, south Asians tended to achieve less HbA1c reduction over  
56 time than other ethnic groups from all types of diabetes treatment whether this was  
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3 metformin alone, combined oral treatment or insulin alone or in combination. While  
4 the reasons for this remain uncertain, this finding is relevant to clinicians seeking to  
5 achieve HbA1c control below 7.5%, particularly in areas with large south Asian  
6 populations.  
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10 **Ethics:** Ethical committee consent was not required for review of non-identifiable  
11 routinely collected data.  
12

13  
14 **Declaration of Competing Interests:** Nothing to declare.  
15

16  
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20  
21 **Contributors:** G. James designed the analysis and undertook data extraction,  
22 analysis and interpretation, P. Baker undertook the literature review. All authors  
23 contributed to the drafting of the paper and development of core ideas. J. Robson  
24 and S. Hull were principal investigators who initiated and supervised the study.  
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32 general practitioners for access to data.  
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37 **Data sharing statement:** No additional data available  
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## Tables

Table 1: Patient Characteristics

Table 1A: Demographic and clinical characteristics by ethnic group

Variable	Category	white	S Asian	black	All
<b>N</b>	-	1,101	3,785	971	6,104
<b>%</b>	-	18	63	16	-
<b>Mean age at baseline (years)</b>	-	60	56	58	57
<b>Serum cholesterol mmol/l</b>	-	4.3	4.1	4.4	4.2
<b>BMI</b>	-	34	28	31	29
<b>Sex (%)</b>	Male	59	52	47	53
<b>Townsend group (%)</b>	Least	19	19	20	20
	Medium	52	48	54	50
	High	29	33	26	31
<b>Treatment group (%)</b>	Metformin Only	7	7	7	7
	Combined Oral	35	50	44	46
	Insulin	40	30	35	33
	Metformin to Combined Oral	10	7	7	8
	Any to Insulin	9	6	7	7
<b>Diabetes duration</b>	0-2 years	21	18	19	19
	> 2 years	79	82	81	81

Cohort v15 GJ 27 7 12

Table 1b: Changes in HbA1c over time

Variable	Category	Baseline HbA1c	2008 CfB HbA1c	2009 CfB HbA1c	Baseline HbA1c control	2008 HbA1c control	2009 HbA1c control
<b>Sex (%)</b>	Male	9.2	-0.3	-0.3	0	29	29
	Female	9.1	-0.3	-0.3	0	32	32
<b>Ethnicity</b>	White	9.2	-0.7	-0.6	0	33	34
	S Asian	9.1	-0.5	-0.4	0	29	29
	Black	9.3	-0.8	-0.7	0	33	33
<b>Townsend group (%)</b>	Least	9.2	-0.4	-0.3	0	36	33
	Medium	9.2	-0.3	-0.3	0	31	32
	High	9.0	-0.3	-0.3	0	26	26
<b>Treatment group (%)</b>	Metformin Only	8.5	-1.0	-0.9	0	62	64
	Combined Oral	8.9	-0.6	-0.4	0	36	34
	Insulin	9.5	-0.5	-0.4	0	18	18
	Metformin to Combined Oral	9.0	-0.8	-0.8	0	35	39
	Any to Insulin	9.8	-0.5	-0.5	0	17	19
<b>Diabetes duration</b>	0-2 years	9.1	-1.0	-0.9	0	42	42
	> 2 years	9.1	-0.5	-0.4	0	28	27
<b>All</b>	-	9.2	-0.6	-0.5	0	30	30

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Table 2: Statistical Model Parameter Estimates

a: Linear multilevel regression model to estimate Change from baseline HbA1c (%)

Variable	Category	Effect on CFB HbA1c %	95% CI	Category p-value	Variable p-value
<b>Baseline HbA1c</b>	-	-0.53	(-0.55, -0.51)	<0.001	<0.001
<b>Age</b>	-	-0.01	(-0.02, -0.01)	<0.001	<0.001
<b>Serum cholesterol</b>	-	0.10	(0.07, 0.13)	<0.001	<0.001
<b>BMI</b>	-	0.00	(-0.01, 0.01)	0.747	0.747
<b>Year</b> (2008= Ref)	2009	0.11	(0.07, 0.15)	<0.001	<0.001
<b>Sex</b> (Female = Ref)	Male	0.15	(0.08, 0.22)	<0.001	<0.001
<b>Ethnicity</b> (white = Ref)	S Asian	0.14	(0.04, 0.24)	0.005	<0.001
	black	-0.02	(-0.14, 0.09)	0.705	
<b>Townsend</b> (Least = Ref)	Medium	0.07	(-0.03, 0.16)	0.158	0.3013
	High	0.08	(-0.03, 0.19)	0.161	
<b>Treatment</b> (Metformin Only = Ref)	Combined Oral	0.54	(0.40, 0.68)	<0.001	<0.001
	Insulin	0.98	(0.83, 1.13)	<0.001	
	Metformin to Combined Oral	0.36	(0.19, 0.54)	<0.001	
	Any to Insulin	1.11	(0.92, 1.30)	<0.001	
<b>Diabetes duration</b> (0-2 years = Ref)	>2 years	0.30	(0.21, 0.40)	<0.001	<0.001

Cohort v15 GJ 27 7 12

*b: Logistic multilevel regression model to estimate HbA1c Control*

Variable	Category	OR	95% CI OR	Category p-value	Variable p-value
<b>Baseline HbA1c</b>	-	0.55	(0.51, 0.59)	<0.001	<0.001
<b>Age</b>	-	1.03	(1.02, 1.04)	<0.001	<0.001
<b>Serum cholesterol</b>	-	0.87	(0.81, 0.94)	0.001	0.001
<b>BMI</b>	-	1.01	(1, 1.03)	0.132	0.132
<b>Year</b> (2008= Ref)	2009	0.95	(0.85, 1.06)	0.395	0.395
<b>Sex</b> (Female = Ref)	Male	0.81	(0.69, 0.96)	0.014	<0.001
<b>Ethnicity</b> (white = Ref)	S Asian	0.64	(0.50, 0.81)	<0.001	<0.001
	black	0.90	(0.68, 1.19)	0.460	
<b>Townsend</b> (Least = Ref)	Medium	0.94	(0.76, 1.16)	0.535	0.207
	High	0.81	(0.62, 1.05)	0.118	
<b>Cohort Treatment</b> (Metformin Only = Ref)	Combined Oral	0.21	(0.15, 0.28)	<0.001	
	Insulin	0.06	(0.04, 0.08)	<0.001	
	Metformin to Combined Oral	0.24	(0.16, 0.35)	<0.001	<0.001
	Any to Insulin	0.07	(0.04, 0.11)	<0.001	
<b>Diabetes duration</b> (0-2 years = Ref)	>2 years	0.54	(0.44, 0.68)	<0.001	<0.001

Table 3: Combined Oral treatment sub-categories

Treatment	white	S Asian	black	All
Sulphonylurea	158 (41%)	740 (39%)	167 (39%)	1,065 (41%)
New agent*	42 (11%)	188 (10%)	41 (10%)	271 (11%)
Sulphonylurea and new agent*	61 (16%)	365 (19%)	82 (19%)	508 (16%)
Escalate	78 (20%)	326 (17%)	76 (18%)	480 (20%)
Other	45 (12%)	260 (14%)	57 (13%)	362 (12%)

\*New agent refers to Glinide/Glitazone/Gliptin



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7 **Type 2 diabetes: a cohort study of treatment, ethnic and social group influences on**  
8 **glycated haemoglobin.**  
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10 **Authors**

11  
12  
13 Gareth James      Research Associate / Statistician  
14 Peter Baker        Foundation Year 2 Clinician  
15 Ellena Badrick     Research fellow  
16 Rohini Mathur     Research fellow  
17 Sally Hull         Reader  
18 John Robson        Reader  
19  
20  
21

22 **Address**

23 Centre for Primary Care and Public Health,  
24 St Barts and the London School of Medicine and Dentistry,  
25 Queen Mary University of London,  
26 Yvonne Carter Building,  
27 58 Turner Street,  
28 London E1 2AB  
29  
30  
31

32  
33  
34 Corresponding author: John Robson

35 Email address: [j.robson@qmul.ac.uk](mailto:j.robson@qmul.ac.uk)

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46 Type 2 diabetes; ethnic group; deprivation; HbA1c; diabetes treatment  
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## 7 **Article summary**

### 8 **Article focus**

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- 11 • Variation in HbA1c improvement by ethnic and social group, in people with poorly
- 12 controlled type 2 diabetes (HbA1c > 7.5%).
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- 15 • HbA1c improvement with different types of diabetes treatment by ethnic group.
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### 17 **Key messages**

- 18
- 19 • South Asian people have less improvement in HbA1c than white or black
- 20 African/Caribbeans.
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- 23 • This is true in all treatment categories whether on metformin alone, combined oral or
- 24 insulin.
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### 26 **Strengths and limitations**

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- 29 • ~~This closed cohort is less subject to bias that may occur in cross-sectional studies or~~
- 30 ~~open cohorts where new individuals with diabetes may join or subjects may leave.~~
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- 33 • It is representative of people routinely cared for by general practitioners in community
- 34 settings.
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- 36 • Duration of diabetes is an important influence on HbA1c and treatment response with
- 37 longer duration in South Asians. We were unable to reliably ascertain duration of
- 38 diabetes and cannot confirm whether duration is the cause of our findings.
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Cohort v15 GJ 27 7 12

## Abstract

### Objectives

To assess whether in people with poorly controlled type 2 diabetes (HbA1c > 7.5%) improvement in HbA1c varies by ethnic and social group.

### Design

Prospective two year cohort of type 2 diabetes treated in general practice

### Setting and participants

All patients with type 2 diabetes in 100 out of the 101 general practices in two London boroughs. The sample consisted of an ethnically diverse group with uncontrolled type 2 diabetes aged 37 to 71 years in 2007 and with HbA1c recording in 2008-9.

### Outcome measure

Change from baseline HbA1c in 2007 and achievement of HbA1c control in 2008 and 2009 were estimated for each ethnic, social and treatment group using multilevel modelling.

### Results

The sample consisted of 6,104 people; 18% were white, 63% south Asian, 16% black African/Caribbean and 3% other ethnic groups. HbA1c was lower after one and two years in all ethnic groups but south Asian people received significantly less benefit from each diabetes treatment. After adjustment, south Asian people were found to have 0.154% less reduction in HbA1c compared to white people (95% CI: 0.054%, 0.254%) and white people were 1.6 (95% CI: 1.32, 2.0) times more likely to achieve HbA1c controlled to 7.5% or less relative to south Asian people. HbA1c reduction and control in black African/Caribbean and white people did not differ significantly. There was no evidence that social deprivation influenced HbA1c reduction or control [in this cohort](#).

### Conclusion:

In all treatment groups, south Asian people with poorly controlled diabetes are less likely to achieve controlled HbA1c, with less reduction in mean HbA1c than white or black African/Caribbean people.

Cohort v15 GJ 27 7 12

## Introduction

An estimated two million (4%) people in the UK have Type 2 diabetes. It is a leading cause of cardiovascular and related morbidity and reduces life expectancy by 10 years(1, 2). Higher HbA1c values are associated with greater mortality and morbidity (3, 4).

Ethnic and social differences in diabetes prevalence are substantial and increasing particularly among south Asian people in whom onset is a decade earlier, with higher levels of HbA1c and increased morbidity in comparison to white people (1, 5). In 2004, initiatives to improve care targeted the most socially disadvantaged 'Spearhead' Primary Care Trusts (PCT). In addition national guidance was supported by a national Quality and Outcomes Framework (QoF) with financial incentives to general practitioners who achieved HbA1c levels controlled to 7.5% or less (6, 7). From 2004 to 2010 more intensive drug treatment was associated with improved HbA1c control in all ethnic groups, but differences between ethnic groups persisted (8-13). The 2009 national UK diabetes audit recorded 70% of white people with controlled HbA1c levels, compared to 58% of south Asian people (1).

There have been no trials to evaluate whether diabetes treatments to control HbA1c levels are variably effective by ethnic and social group (14-16). We aimed to assess, if improvement in HbA1c in people with poorly controlled type 2 diabetes (HbA1c > 7.5%) varies by ethnic and social group- using primary care data in an ethnically diverse population, we assessed whether HbA1c is equally responsive to different categories of diabetes treatment in different ethnic and social groups in people with poorly controlled type 2 diabetes.

Comment [GDRJ1]: Reviewer 2 Comment 1

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## Methods

This study is based on the electronic medical records of all 101 general practices in Newham and Tower Hamlets Primary Care Trusts (PCT) which serve 440,000 people. The same computer system and pre-specified codes for recording data are used by all practitioners. The data was accessed via EMIS web ([www.emis-online.com](http://www.emis-online.com)) in August 2010.

Individual self-reported ethnicity was recorded by general practices using the groups identified in the 2001 UK census and collapsed into four categories; white (British, Irish, other white), south Asian (Bangladeshi, Indian, Pakistani, other Asian, mixed Asian), black African/Caribbean (African, Caribbean, black British, mixed black), and other (any other recorded ethnic group). This enabled comparison with existing studies in the UK. Social deprivation was measured using the Townsend score, which is routinely available in these electronic medical records. This score is derived from Census data on unemployment, car and home ownership and overcrowding at lower superoutput area level (approximately 400 households) linked to individual patient postcode (17, 18). The score indicates the spectrum of deprivation within small geographical areas where the most deprived are likely to be unemployed, without a car and living in rented, overcrowded accommodation.

Body Mass index (BMI) and serum cholesterol were estimated using the latest recording in 2007. The latest HbA1c value and all diabetes prescriptions within each annual 12 month period were recorded. Variables were marked as missing if values lay outside specified limits.

Broadly speaking there are four clinical stages of treatment to reduce HbA1c levels in patients with diabetes; diet only, metformin, other oral hypoglycaemic medication with or without metformin and insulin alone or in combination with oral hypoglycaemic agents. We extracted all prescriptions during the study period for the cohort. We categorised treatment as; "Metformin Only" if the patient received only metformin for the whole study period, "Combined Oral" if the patient received any other oral hypoglycaemic either without or in addition to metformin for the whole study period and did not receive insulin; "Insulin" if the patient received insulin for the whole study period; "Metformin Only to Combined Oral" if the patient changed from

Comment [GDRJ2]: Reviewer 1 Minor 2

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Metformin to Combined Oral over the study period; “Any to Insulin” if the patient changed from Metformin only, or Combined Oral over the study period. We did not include patients without any prescriptions in a given year as we were unable to ascertain whether they had in fact left the practice.

The sample was drawn from all people/individuals recorded as having type 2 diabetes at the start of the observation period diagnosed with type 2 diabetes in the 101 general practices, aged 37 to 71 years in 2007, who had uncontrolled diabetes (HbA1c >7.5%) in 2007 and who also had HbA1c recorded in 2008 and 2009. Patients were excluded if treatment was missing during one or more years or treatment did not fit in any of the cohort treatment categories described. The lower age limit excluded misclassified type 1 diabetes and older ages were excluded because intensive treatment may be clinically inappropriate (19, 20).

Typically the ‘Combined Oral’ treatment will consist of either sulphonylurea alone, or one of the newer oral agents - thiazolidinediones, insulin secretagogues, dipeptidylpeptidase-4 inhibitors - alone, or in combination with the sulphonylurea. We considered five sub- categories for “Combined Oral”: “Sulphonylurea alone” if the patient received only sulphonylurea for the whole study period, “New agent alone” if the patient received only new agents for the whole study period, “Sulphonylurea and new agent” if the patient received sulphonylurea and new agents for the whole study period, “One to both” if the patient begun on either sulphonylurea or new agents and their treatment was intensified to both treatments during the study; and “Other” otherwise.

Diabetes duration at baseline was categorised as “0-2 years” if the patient received their first diabetes diagnosis code between 2005 and 2007, and “>2 years” if they received their first code prior to 2005. Exploratory analysis indicated that these codes were unreliable to estimate time-with-diabetes prior to 2004.

Two outcome measures were used to assess treatment effectiveness; change from baseline HbA1c (CfB) and HbA1c control. HbA1c values in 2007 were taken as the baseline covariate values. Thus a patient’s CfB HbA1c for 2008 was their 2008 value minus their 2007 value; CfB HbA1c 2009 was their 2009 value minus their 2007 HbA1c value. A patient was considered to achieve HbA1c control in 2008 if their

**Comment [GDRJ4]:** Reviewer 1 Minor comment 1

Reviewer 2 comment 2

**Comment [GDRJ5]:** Reviewer 1 Major 1

Reviewer 2 Comment 6

**Comment [GDRJ6]:** DIABETES DURATION

Reviewer 1 major 2, Reviewer 2 comment 7

**Comment [GDRJ7]:** Should this be here? Also put similar in discussion.

Cohort v15 GJ 27 7 12

2008 HbA1c value was 7.5% or less and in 2009 if their 2009 HbA1c value was 7.5% or less.

## Statistical Analysis

Analysis was performed using Stata 12.0 ([www.stata.com](http://www.stata.com)). Demographic statistics for each ethnic group were calculated. Data were structured with variation at four levels; the lowest level was year, level 2 was person, level 3 was practice, level 4 was Primary Care Trust (PCT). A linear multilevel model was used to estimate the CfB HbA1c in 2008 and 2009 ~~and confidence intervals~~ (21). A logistic multilevel model was used to estimate the probability of achieving HbA1c control in 2008 and 2009. These models incorporated the structure of the data by including random effects for person, practice and year. The models were adjusted for baseline HbA1c (2007 HbA1c value), age, sex, year, BMI, serum cholesterol, cohort treatment, diabetes duration, Townsend category and ethnic group as these variables were considered likely to influence HbA1c improvement. ~~Duration of diabetes was not available in this study.~~ Patients with 'Other' ethnic groups recorded were not included in the model construction as they consisted of many different ethnic groups and were small in number.

An ethnicity\*treatment interaction was added to each model to assess whether ethnicity was a factor in HbA1c reduction and HbA1c control for each treatment. An ethnicity\*year interaction were added to the models to assess if the difference in HbA1c reduction and achievement of HbA1c control between ethnic groups changed between 1 and 2 years. An ethnicity\* diabetes duration interaction was added to the models to assess whether the difference between ethnic groups in HbA1c reduction and achievement of HbA1c control varied between the two duration categories. Significance was set at the 5% level.

Exploratory analysis was conducted on the 'Combined Oral' sub categories.

**Comment [GDRJ8]:** Reviewer 2 Comment 8

**Comment [GDRJ9]:** DIABETES DURATION  
Reviewer 1 comment 2, Reviewer 2 comment 7

**Comment [GDRJ10]:**

JOHN this new interaction is quite important. The fact that it was not significant is useful.

i.e. consider a white and s Asian person with similar characteristics who has had diabetes for 0-2 years.

The white person will have a greater HbA1c reduction and a greater chance of achieving HbA1c control.

The same can be said for white and S Asian patients with 3+ years!

**Comment [GDRJ11]:** Reviewer 1 Major 1  
Reviewer 2 Comment 6

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## Results

In August 2010 data was collected from 100 of the 101 practices in Tower Hamlets and Newham. One practice declined participation. Over the three years of the study, a total of 28,041 people in the study age range were identified as having diagnosed with Type 2 diabetes in 2007 and 17,670 (63%) had an HbA1c recording in 2007. Of these 17,670 people, 8,864 (50%) had uncontrolled diabetes (HbA1c > 7.5%) of whom 42% were white, 50% were black African/Caribbean and 53% were south Asian. Among the 8864 uncontrolled patients, 6,464 (73%) also had HbA1c values in 2008 and 2009. Of those excluded because of missing HbA1c records, 30% were white, 25% south Asian and 27% black African/Caribbean people; 27-28% were in each social deprivation group. Finally 207 (3%) people were excluded because they had missing treatment information in one or more years and 153 (2%) did not fit into any of the cohort treatment categories described in the methods.

The final sample therefore consisted of 6,104 (68.9%) out of the 8,864 people with uncontrolled diabetes HbA1c >7.5%. Of these, 6,017 (99%) had ethnicity recorded, 6087 (>99%) people had Townsend score recorded. Age and sex was recorded in everyone and serum cholesterol in 95% and BMI in 94%. In total there were 1,101 (18%) white, 3785 (63%) south Asian, 993 (16%) black African/Caribbean and 160 (3%) other ethnic groups in the sample. Only 2% of people fell in the two least deprived quintiles, so the least three quintiles were combined and categorized as 'Least' deprived (N=1,204, 20%), 'High' deprivation if they were in the most deprived quintile (N=1,858, 31%) and 'Medium' (N=3025, 50%) otherwise.

Table 1A describes the variable mean or percentage in each category for each demographic group. Table 1B describes the HbA1c mean and proportion of HbA1c control for each demographic group. Baseline HbA1c and the diabetes duration distribution was similar between ethnic groups. After 1 and 2 years mean HbA1c decreased in each ethnic group but the mean reduction in HbA1c from baseline was less in south Asian patients than other ethnic groups and these patients had the least chance of achieving HbA1c controlled to 7.5% or less. A similar proportion of each ethnic group fell into each deprivation category.

Comment [GDRJ12]: Reviewer 2 comment 3

Comment [GDRJ13]: Reviewer 2 Comment 10

Comment [GDRJ14]: DIABETES DURATION  
Reviewer 1 comment 2, Reviewer 2 major 7



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Altogether, 7% of patients remained on 'Metformin Only' for the whole study, 46% on 'Combined Oral' and 33% on 'Insulin'. Treatment intensity increased in 15% of patients during the study. Despite similar baseline HbA1c, treatment categories between ethnic groups differed significantly ( $p < 0.001$ ); there were a greater proportion of south Asian people on 'Combined Oral treatment' 50% than white 35% or black African Caribbean 44% and a greater proportion of south Asian 80% and black African/Caribbean people 79% started and remained on more intensive treatment (either Combined oral or insulin) than white 75%.

Fewer south Asian people, 36% started or changed to insulin compared to black African/Caribbean 42% and white people 49%. A sub-analysis indicated white people were significantly more likely to increase their treatment intensity 30%, than south Asian 19% and black people 22% ( $p < 0.001$ ).

Tables 2a and 2b describe the statistical models to estimate CfB HbA1c and HbA1c control. Person, practice, and PCT were all significant ( $p < 0.001$ ) and were included in the final models. Baseline HbA1c, age, serum cholesterol, ethnicity, sex and cohort treatment had a significant effect on CfB HbA1c and HbA1c control.

Townsend category and BMI were not significant but were retained in the models as variables of interest. The ethnicity\*treatment and ethnicity\*year interactions were not significant and were not included in either model.

The interpretation of the model coefficients in Tables 2a/b can be illustrated by considering two patients similar for all variables except treatment. One patient is on 'Metformin Only' and the other on 'Insulin'. In 2008 the patient on 'Insulin' will have their HbA1c reduced by 1.14 less than the patient on 'Metformin Only' treatment. The same comparison in Table 2b indicates a patient on 'Insulin' treatment has an odds ratio of 0.04 meaning that a patient on Metformin is 25 (1/0.04) times as likely to achieve HbA1c control than a patient on Insulin.

In people with uncontrolled HbA1c at baseline, after one and two years on treatment; south Asian people had 0.15% less reduction in mean HbA1c than white people ( $p = 0.0045$ ) and white people were 1.6 times ( $p < 0.001$ ) as likely to achieve HbA1c control relative to south Asian people. White and black African/Caribbean people had no significant difference in CfB HbA1c ( $p = 0.7805$ ) or HbA1c control achievement

Comment [GDRJ15]: Reviewer 1 major 3 (moved to conclusion)

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7 (p=0.355460). There was no evidence that social deprivation affected HbA1c  
8 reduction or HbA1c control achievement.  
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10 The ethnicity\*treatment interaction was not significant, indicating that in each of the  
11 different treatment groups, south Asian people had the smallest reduction in HbA1c  
12 and the lowest probability of achieving HbA1c control after 1 and 2 years. This also  
13 indicates white and black African/Caribbean people have a similar response to each  
14 treatment. [The ethnicity\\* diabetes duration interaction was not significant, indicating  
15 that south Asian people have the smallest reduction in HbA1c and probability of  
16 achieving HbA1c control when their duration of diabetes is between 0-2 years and  
17 more than two years.](#)  
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22 Figure 1 illustrates that for an individual with HbA1c 9% at baseline on 'Metformin  
23 Only' and 'Insulin' treatments, that south Asian people had the least reduction in  
24 HbA1c for each treatment.  
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27 [There was little variation in the distribution of sub-categories in the 'Combined Oral'  
28 treatment between ethnic groups \(Table 3\). Most noticeably, white people were the  
29 most likely to intensify 20%, followed by black African/Caribbean people 18% and  
30 South Asian people 17%.](#)  
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Comment [GDRJ16]: Reviewer 1 Major 1  
Reviewer 2 Comment 6

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### Discussion

This observational study is the first to assess whether HbA1c responds equally to different types of diabetes treatment in different ethnic and social groups. We found HbA1c improved in all ethnic groups over a two year period, but HbA1c improved less in south Asian people for each treatment relative to other ethnic groups. We found no association between social deprivation and HbA1c improvement after adjustment for other variables.

The interpretation of the model coefficients in Tables 2a/b can be illustrated by considering two patients similar for all variables except treatment. One patient is on 'Metformin Only' and the other on 'Insulin'. In 2008 the patient on 'Insulin' will have their HbA1c reduced by 1.11 less than the patient on 'Metformin Only' treatment. The same comparison in Table 2b indicates a patient on 'Insulin' treatment has an odds ratio of 0.06 meaning that a patient on Metformin is 16.67 (1/0.06) times as likely to achieve HbA1c control than a patient on Insulin. However this does not indicate that Metformin is more effective at controlling HbA1c then Insulin. This study is unable to compare the effectiveness of these treatments as HbA1c levels in patients on insulin are more difficult to control as they are likely to have increased duration of diabetes and other diabetes drugs have failed to control their HbA1c levels.

Comment [GDRJ17]: Reviewer 1: Major 3.

Comment [GDRJ18]: Reviewer 1: Major 3.

Higher HbA1c in south Asians has been confirmed in most studies which also confirm their higher intensity of oral treatment and lower use of insulin (15, 22-24). Poor HbA1c control in African Americans has also been reported in the USA, though our study found no such disparity in black African/Caribbean people (14, 16, 25, 26).

Our study is unable to differentiate the reasons why south Asian patients respond less favourably to treatment. It could be could be lack of treatment efficacy in these patients. Alternatively it could be due to duration of diabetes where HbA1c control has been shown to deteriorate despite treatment in all categories over time (27). South Asian people have earlier onset of diabetes as reflected in our study by the younger mean age; 56 years in south Asians compared to 60 years in white and 58 years in black African/Caribbean people. At the start of the study more black African/Caribbean 79% and south Asian patients 80% were already on higher intensity treatment (either Combined oral or insulin) than white patients 75%. During

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6 the study period a significantly higher proportion of white people ( $p < 0.001$ ) increased  
7 their intensity of treatment than black African/Caribbean or south Asian people and  
8 this may also have contributed to less reduction in HbA1c in the latter who were  
9 already on more intensive treatment.  
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13 Our study is large and included almost all those diagnosed with type 2 diabetes in  
14 the age range in a large contiguous geographical area. It has high numbers of  
15 people in each ethnic group allowing for precise comparisons between ethnic groups  
16 and the extent and quality of ethnic group and social deprivation recording was high.  
17 For all adjustment variables used, less than 10% of data was missing. All patients  
18 had longitudinal HbA1c values allowing us to examine the change in HbA1c over  
19 time.  
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24 ~~Our study is a closed cohort and meets some of the concerns regarding potential~~  
25 ~~bias from using open cohorts of general practice populations that include people who~~  
26 ~~leave the cohort or who join through registration with the general practitioner or as~~  
27 ~~new diagnoses(13).~~  
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30 The different ethnic groups had similar mean baseline HbA1c suggesting diabetes  
31 severity was similar across ethnic groups. HbA1c increases with duration of diabetes  
32 but information was unavailable limited as exploratory analysis indicated that  
33 durations exceeding two years could not be further categorised reliably. The  
34 inclusion of age and treatment in the statistical models explains some but not all of  
35 the effect of diabetes duration on HbA1c. Longer diabetes duration could therefore  
36 be an explanation for the observed ethnic group differences.  
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41 A limitation of the study was the exclusion of 31% of those with uncontrolled diabetes  
42 because of missing treatment or HbA1c records which may have introduced bias.  
43 However, fewer south Asians were excluded for this reason which suggests that as a  
44 group, they were more likely to be more concordant with care. Selection bias was an  
45 unlikely cause of the smaller reduction of HbA1c in south Asian people in this study.  
46 Finally, there is no evidence to suggest that south Asian people are less likely to  
47 respond to change in lifestyle factors such as diet or physical activity as compared to  
48 other ethnic groups.  
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**Comment [GDRJ19]:** Added to account for some info on duration now.

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## Conclusion

This study provides evidence that south Asian people with poorly controlled type 2 diabetes are on higher intensity treatment than white or black African/Caribbean people. Despite this, sSouth Asians tended to achieve less HbA1c reduction over time than other ethnic groups from all types of diabetes treatment whether this was metformin alone, combined oral treatment or insulin alone or in combination. While the reasons for this remain uncertain, this finding is relevant to clinicians seeking to achieve HbA1c control below 7.5%, particularly in areas with large south Asian populations.

**Ethics:** Ethical committee consent was not required for review of non-identifiable routinely collected data.

**Declaration of Competing Interests:** Nothing to declare.

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**Contributors:** G. James designed the analysis and undertook data extraction, analysis and interpretation, P. Baker undertook the literature review. All authors contributed to the drafting of the paper and development of core ideas. J. Robson and S. Hull were principal investigators who initiated and supervised the study.

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**Data sharing statement:** No additional data available

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## Tables

Table 1: [Patient Characteristics](#)[Table 1A: Demographic and clinical characteristics by ethnic group](#)

Variable	Category	white	S Asian	black	All
<b>N</b>	-	1,101	3,785	971	6,104
<b>%</b>	-	18	63	16	-
<b>Baseline HbA1c%</b>	-	<u>9.2</u>	<u>9.1</u>	<u>9.3</u>	<u>9.2</u>
<b>CfB HbA1c% after 1 year</b>	-	<u>-0.7</u>	<u>-0.5</u>	<u>-0.8</u>	<u>-0.6</u>
<b>CfB HbA1c% after 2 years</b>	-	<u>-0.6</u>	<u>-0.4</u>	<u>-0.7</u>	<u>-0.5</u>
<b>HbA1c control after 1 year (%)</b>	HbA1c Controlled	33	29	33	30
<b>HbA1c control after 2 years (%)</b>	HbA1c Controlled	34	29	33	30
<b>Mean age at baseline (years)</b>	-	60	56	58	57
<b>Serum cholesterol mmol/l</b>	-	4.3	4.1	4.4	4.2
<b>BMI</b>	-	34	28	31	29
<b>Sex (%)</b>	Male	59	52	47	53
<b>Townsend group (%)</b>	Least	19	19	20	20
	Medium	52	48	54	50
	High	29	33	26	31
<b>Treatment group (%)</b>	Metformin Only	7	7	7	7
	Combined Oral	35	50	44	46
	Insulin	40	30	35	33
	Metformin to Combined Oral	10	7	7	8
	Any to Insulin	9	6	7	7
<b>Diabetes duration</b>	<u>0-2 years</u>	<u>21</u>	<u>18</u>	<u>19</u>	<u>19</u>
	<u>&gt; 2 years</u>	<u>79</u>	<u>82</u>	<u>81</u>	<u>81</u>

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Table 1b: Changes in HbA1c over time

Comment [GDRJ20]: Reviewer 2 Comment 10.

<u>Variable</u>	<u>Category</u>	<u>Baseline HbA1c</u>	<u>2008 CfB HbA1c</u>	<u>2009 CfB HbA1c</u>	<u>Baseline HbA1c control</u>	<u>2008 HbA1c control</u>	<u>2009 HbA1c control</u>
<u>Sex (%)</u>	<u>Male</u>	<u>9.2</u>	<u>-0.3</u>	<u>-0.3</u>	<u>0</u>	<u>29</u>	<u>29</u>
	<u>Female</u>	<u>9.1</u>	<u>-0.3</u>	<u>-0.3</u>	<u>0</u>	<u>32</u>	<u>32</u>
<u>Ethnicity</u>	<u>White</u>	<u>9.2</u>	<u>-0.7</u>	<u>-0.6</u>	<u>0</u>	<u>33</u>	<u>34</u>
	<u>S Asian</u>	<u>9.1</u>	<u>-0.5</u>	<u>-0.4</u>	<u>0</u>	<u>29</u>	<u>29</u>
	<u>Black</u>	<u>9.3</u>	<u>-0.8</u>	<u>-0.7</u>	<u>0</u>	<u>33</u>	<u>33</u>
<u>Townsend group (%)</u>	<u>Least</u>	<u>9.2</u>	<u>-0.4</u>	<u>-0.3</u>	<u>0</u>	<u>36</u>	<u>33</u>
	<u>Medium</u>	<u>9.2</u>	<u>-0.3</u>	<u>-0.3</u>	<u>0</u>	<u>31</u>	<u>32</u>
	<u>High</u>	<u>9.0</u>	<u>-0.3</u>	<u>-0.3</u>	<u>0</u>	<u>26</u>	<u>26</u>
<u>Treatment group (%)</u>	<u>Metformin Only</u>	<u>8.5</u>	<u>-1.0</u>	<u>-0.9</u>	<u>0</u>	<u>62</u>	<u>64</u>
	<u>Combined Oral</u>	<u>8.9</u>	<u>-0.6</u>	<u>-0.4</u>	<u>0</u>	<u>36</u>	<u>34</u>
	<u>Insulin</u>	<u>9.5</u>	<u>-0.5</u>	<u>-0.4</u>	<u>0</u>	<u>18</u>	<u>18</u>
	<u>Metformin to Combined Oral</u>	<u>9.0</u>	<u>-0.8</u>	<u>-0.8</u>	<u>0</u>	<u>35</u>	<u>39</u>
	<u>Any to Insulin</u>	<u>9.8</u>	<u>-0.5</u>	<u>-0.5</u>	<u>0</u>	<u>17</u>	<u>19</u>
<u>Diabetes duration</u>	<u>0-2 years</u>	<u>9.1</u>	<u>-1.0</u>	<u>-0.9</u>	<u>0</u>	<u>42</u>	<u>42</u>
	<u>&gt; 2 years</u>	<u>9.1</u>	<u>-0.5</u>	<u>-0.4</u>	<u>0</u>	<u>28</u>	<u>27</u>
<u>All</u>	<u>-</u>	<u>9.2</u>	<u>-0.6</u>	<u>-0.5</u>	<u>0</u>	<u>30</u>	<u>30</u>

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Table 2: Statistical Model Parameter Estimates  
 a: Linear multilevel regression model to estimate Change from baseline HbA1c (%)

<u>Variable</u>	<u>Category</u>	<u>Effect on CfB HbA1c %</u>	<u>95% CI</u>	<u>Category p- value</u>	<u>Variable p-value</u>
<b>Baseline HbA1c</b>	:	<u>-0.53</u>	<u>(-0.55, -0.51)</u>	<u>&lt;0.001</u>	<u>&lt;0.001</u>
<b>Age</b>	:	<u>-0.01</u>	<u>(-0.02, -0.01)</u>	<u>&lt;0.001</u>	<u>&lt;0.001</u>
<b>Serum cholesterol</b>	:	<u>0.10</u>	<u>(0.07, 0.13)</u>	<u>&lt;0.001</u>	<u>&lt;0.001</u>
<b>BMI</b>	:	<u>0.00</u>	<u>(-0.01, 0.01)</u>	<u>0.747</u>	<u>0.747</u>
<b>Year (2008= Ref)</b>	<u>2009</u>	<u>0.11</u>	<u>(0.07, 0.15)</u>	<u>&lt;0.001</u>	<u>&lt;0.001</u>
<b>Sex (Female = Ref)</b>	<u>Male</u>	<u>0.15</u>	<u>(0.08, 0.22)</u>	<u>&lt;0.001</u>	<u>&lt;0.001</u>
<b>Ethnicity (white = Ref)</b>	<u>S Asian</u>	<u>0.14</u>	<u>(0.04, 0.24)</u>	<u>0.005</u>	<u>&lt;0.001</u>
	<u>black</u>	<u>-0.02</u>	<u>(-0.14, 0.09)</u>	<u>0.705</u>	
<b>Townsend (Least = Ref)</b>	<u>Medium</u>	<u>0.07</u>	<u>(-0.03, 0.16)</u>	<u>0.158</u>	<u>0.3013</u>
	<u>High</u>	<u>0.08</u>	<u>(-0.03, 0.19)</u>	<u>0.161</u>	
<b>Treatment (Metformin Only = Ref)</b>	<u>Combined Oral</u>	<u>0.54</u>	<u>(0.40, 0.68)</u>	<u>&lt;0.001</u>	<u>&lt;0.001</u>
	<u>Insulin</u>	<u>0.98</u>	<u>(0.83, 1.13)</u>	<u>&lt;0.001</u>	
	<u>Metformin to Combined Oral</u>	<u>0.36</u>	<u>(0.19, 0.54)</u>	<u>&lt;0.001</u>	
	<u>Any to Insulin</u>	<u>1.11</u>	<u>(0.92, 1.30)</u>	<u>&lt;0.001</u>	
<b>Diabetes duration (0-2 years = Ref)</b>	<u>&gt;2 years</u>	<u>0.30</u>	<u>(0.21, 0.40)</u>	<u>&lt;0.001</u>	<u>&lt;0.001</u>

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b: Logistic multilevel regression model to estimate HbA1c Control

Variable	Category	OR	95% CI OR	Category p-value	Variable p-value
<b>Baseline HbA1c</b>	:	0.55	(0.51, 0.59)	<0.001	<0.001
<b>Age</b>	:	1.03	(1.02, 1.04)	<0.001	<0.001
<b>Serum cholesterol</b>	:	0.87	(0.81, 0.94)	0.001	0.001
<b>BMI</b>	:	1.01	(1, 1.03)	0.132	0.132
<b>Year</b> (2008= Ref)	2009	0.95	(0.85, 1.06)	0.395	0.395
<b>Sex</b> (Female = Ref)	Male	0.81	(0.69, 0.96)	0.014	<0.001
<b>Ethnicity</b> (white = Ref)	S Asian	0.64	(0.50, 0.81)	<0.001	<0.001
	black	0.90	(0.68, 1.19)	0.460	
<b>Townsend</b> (Least = Ref)	Medium	0.94	(0.76, 1.16)	0.535	0.207
	High	0.81	(0.62, 1.05)	0.118	
<b>Cohort Treatment</b> (Metformin Only = Ref)	Combined Oral	0.21	(0.15, 0.28)	<0.001	
	Insulin	0.06	(0.04, 0.08)	<0.001	<0.001
	Metformin to Combined Oral	0.24	(0.16, 0.35)	<0.001	<0.001
	Any to Insulin	0.07	(0.04, 0.11)	<0.001	<0.001
<b>Diabetes duration</b> (0-2 years = Ref)	>2 years	0.54	(0.44, 0.68)	<0.001	<0.001

Table 3: Combined Oral treatment sub-categories

Treatment	white	S Asian	black	All
Sulphonylurea	158 (41%)	740 (39%)	167 (39%)	1,065 (41%)
New agent*	42 (11%)	188 (10%)	41 (10%)	271 (11%)
Sulphonylurea and new agent*	61 (16%)	365 (19%)	82 (19%)	508 (16%)
Escalate	78 (20%)	326 (17%)	76 (18%)	480 (20%)
Other	45 (12%)	260 (14%)	57 (13%)	362 (12%)

\*New agent refers to Glinide/Glitazone/Gliptin

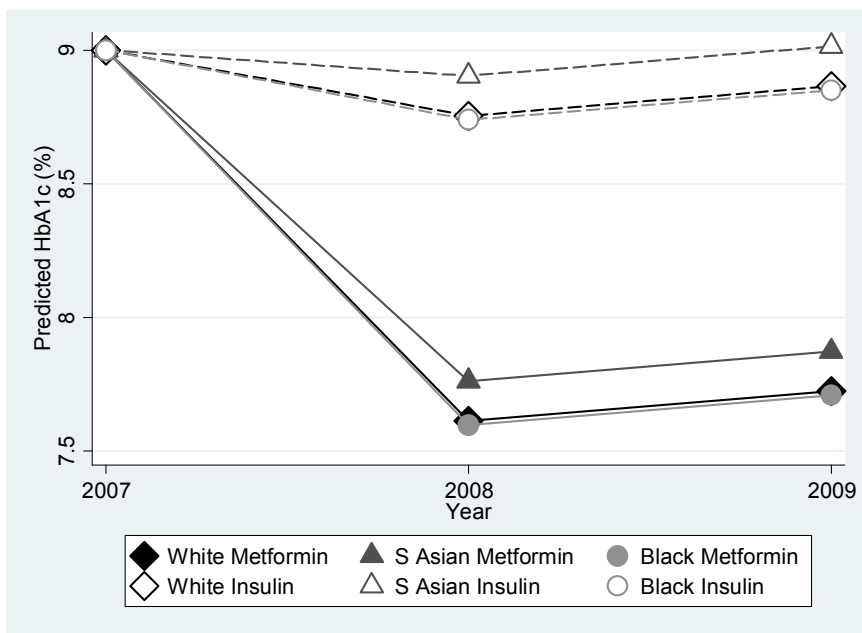
Figures

Comment [GDRJ21]: Reviewer 1 Major 1  
Reviewer 2 Comment 6

Cohort v15 GJ 27 7 12

Figure 1: Expected HbA1c for each ethnic group on 'Metformin Only' and 'Insulin' treatment

**Comment [GDRJ22]:** Note that I have updated and replaced the graph, although there was very little change



review only