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Diet and glycosylated haemoglobin in the 1946 British birth cohort

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Abstract

Objectives: Raised glycosylated haemoglobin (HbA_{1c}) concentration is a recognised risk factor for diabetes the incidence of which is rising world-wide. The intake of certain foods has been related to HbA_{1c} concentration. The aim of this study was to investigate whether nutrient intake, sourced by these foods, was predictive of raised glycosylated haemoglobin (HbA_{1c}) concentration in a British cohort.

Subjects/methods: The subjects were 495 men and 570 women who were members of the Medical Research Council National Survey of Health and Development, 1946 birth cohort. Diet was assessed from 5-day records in 1982, 1989 and 1999. HbA_{1c} was measured in blood samples collected in 1999. Individuals in whom concentration of HbA_{1c} was ≥ 6.3% were identified as being “at risk” and their nutrient intake was compared to those whose concentration of HbA_{1c} was within the normal range (< 6.2%).

Results: Lower intakes of protein, carbohydrate, non-starch polysaccharide, iron, folate, vitamin B₁₂ and a higher percentage energy from fat in 1989 were significantly predictive of high HbA_{1c} status in 1999. In 1999 there were no nutrient intakes that were predictive of HbA_{1c} status. Global tests of whether the intakes of energy, carbohydrate, sodium, iron, riboflavin and vitamin B₁₂ at all three time-points were related to HbA_{1c} status in 1999, were significant.

Conclusion: An increased intake of energy, carbohydrate, sodium, iron, riboflavin and vitamin B₁₂ over 10 years was predictive of raised HbA_{1c} status. Increased energy intake may have resulted in the increase in body weight that is a risk factor for diabetes.

Keywords

Diet; Nutrients; Glycosylated haemoglobin; NSHD

Introduction

Elevated glycosylated haemoglobin (HbA_{1c}) in the blood is an indicator of chronically raised blood glucose concentrations that is used as a method of identifying people at risk of developing diabetes or as a marker of poor control in diagnosed diabetics. The incidence of diabetes in the UK is rising; between 1996 and 2007 the number of diagnosed diabetics has

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risen from 1.4 million to 2.3 million (Diabetes UK 2007). Incidence is projected to reach 3 million by 2010; around 85% being type 2 diabetes (Medical Research Council 2002). Type 2 diabetes is usually associated with obesity and is considered to be a result of inappropriate diet and lifestyle over a long period (Mann 2002; Montonen *et al.* 2005; Schulze *et al.* 2005). Similarly, elevated HbA_{1c} in older people may be attributed to unhealthy dietary and other behaviours (Boeing *et al.* 2000). Raised HbA_{1c} is also a risk factor for cardiovascular disease particularly when combined with high blood pressure and raised cholesterol (Adler 2008)

The UK Prospective Diabetes Study (UKPDS) group reported the normal range of HbA_{1c} to be 4.5-6.2 % and values above may indicate individuals at risk of diabetes (UKPDS 1994; Stratton *et al.* 2000). Khaw *et al.* reported that the concentration of HbA_{1c} in the men of the EPIC (Norfolk) cohort not only explained most of the excess mortality risk of diabetes but was also continuously related to all-cause mortality through the whole population distribution even below the threshold, HbA_{1c} 7%, for undiagnosed diabetes (Khaw *et al.* 2001).

The relationship between HbA_{1c} and components of the diet, such as fish, alcohol, fruit and vegetables and fats diet has been examined in several studies of the EPIC (Norfolk) cohort. (Harding *et al.* 2001; Sargeant *et al.* 2001; Harding *et al.* 2002; Harding *et al.* 2004). These results showed that total fat intake was positively associated with HbA_{1c} concentration (Harding *et al.* 2001) but there was an inverse relationship with fruit and vegetable consumption (Sargeant *et al.* 2001). Other studies have also reported that consumption of green vegetables and fruits (Sargeant *et al.* 2000; Montonen *et al.* 2005; Bazzano *et al.* 2008; Harding *et al.* 2008) has been found to predict a reduced rate of type 2 diabetes. In a sample of British adults aged over 64 years Bates *et al.* reported that subjects with HbA_{1c} above 6.3% had lower intakes of fruit and vegetables and lower intakes of vitamin C than those with HbA_{1c} concentrations within the normal range (Bates *et al.* 2004). Meta-analyses that examined the relationship between HbA_{1c} status and dietary glycaemic properties have shown that diets with a lower glycaemic index (GI) reduced HbA_{1c} concentration as did a greater intake of unavailable carbohydrate (Livesey *et al.* 2008).

Most of these studies were cross-sectional so diet prior to the assessment of HbA_{1c} status could not be assessed. The MRC National Survey of Health and Development, (NSHD) (1946 Birth Cohort) has provided a unique opportunity to investigate whether the diet over a period of nearly 20 years can be related to HbA_{1c} concentration measured at the last assessment of the subjects in this time period. Analysis of the dietary data collected at three time-points over 17 years may provide evidence of association between HbA_{1c} status and both current and previous diet.

Subjects and methods

The MRC National Survey of Health and Development (NSHD), the 1946 British Birth Cohort, is a social class stratified random sample of 5,362 singleton legitimate births in England, Scotland or Wales during the first week of March 1946. The members of the cohort were interviewed and dietary data were collected at age 36, 43 and 53 years (in 1982, 1989 and 1999 respectively). Of the 3035 cohort members who were contacted in 1999, there were 1065 subjects who provided blood samples and for whom there were also diet records collected in 1982 and 1989. None of these subjects had been diagnosed as having diabetes (type 1 or type 2).

The subjects were interviewed at each time-point when height and weight were measured from which body mass index (BMI) was calculated (kg m^{-2}). A non-fasting blood sample

was collected and HbA_{1c} was measured by ion exchange chromatographic separation using HPLC on a Tosoh A1c-2.2 Analyser.

Dietary Assessment

Details of the dietary assessment have been reported earlier (Prynne *et al.* 2005). Subjects were given a diary in which to record details of all food and drink consumed at home and away over a 5-day period. This method of dietary assessment has been validated by Bingham *et al.* (Bingham *et al.* 1995). Food and nutrient intakes for all three time points were calculated using the in-house suite of programs based on McCance and Widdowson's *The Composition of Foods*, 4th edition (Paul and Southgate 1978) for 1982 and supplements (Holland *et al.* 1988; Holland *et al.* 1989) for 1989 and 6th edition (Food Standards Agency 2002) for 1999. Vitamin K₁ values were added from the database provided by Bolton-Smith and Shearer (Bolton-Smith *et al.* 2000) and unpublished data.

Analysis

For the analysis the subjects were grouped according to their HbA_{1c} status measured in 1999. Those individuals in whom concentration of HbA_{1c} was $\geq 6.3\%$ were identified as being "at risk" (UKPDS 1994). These subjects were compared to those whose HbA_{1c} was within the normal range ($< 6.2\%$). The particular nutrients investigated were those found in foods of interest; fruits, vegetables, meat and dairy products, the latter two being principal sources of fat in the diet. Logarithmic transformations of all the vitamin intakes were performed prior to analysis to normalise their distributions. Geometric means and confidence intervals are presented for these variables. Logistic regression was used to investigate the relationship between nutrient intake and HbA_{1c} status. For the nutrient explanatory variables, an odds ratio greater than one is interpreted as an increased chance of having a HbA_{1c} above 6.3% corresponding to an increase in the nutrient, similarly an odds ratio less than one is interpreted as a lower chance of HbA_{1c} being above 6.3% for an increase in the nutrient. The adjusted odds ratios (ORs) were calculated controlling for the possible confounders; BMI, socio-economic status and smoking; the latter two were treated as unordered categorical covariates and the former is a continuous variable.

Multiple logistic regression was used to examine the relationship between diet over time and HbA_{1c} status. Nutrient intakes in 1982 and 1989 as well as 1999 were considered as independent predictors in the same model and two global tests were calculated: 1) whether nutrients were related to HbA_{1c} status and 2) whether this relationship varied over time. Both tests were controlled for the confounders above. Stepwise logistic regression was used to identify the years that most predicted HbA_{1c} status. The parsimonious model, that was used to elucidate when the association occurred, included only 1989 and 1999 and the nutrient intake at each time point was adjusted for the other.

All analyses were conducted using SPSS for MS Windows (version 10) and Stata 1 (version 9.1). The nominal significance level was taken as $P = 0.05$.

Results

Table 1 shows characteristics and concentrations of HbA_{1c} of subjects who provided dietary data in 1982, 1989 and 1999. Of the 1065 subjects, 19 (3.8%) men and 27 (4.7%) women had concentrations of HbA_{1c} $\geq 6.3\%$. Compared with those subjects whose HbA_{1c} was within the normal range these individuals had significantly greater BMIs in 1982 ($p=0.003$), 1989 ($p=0.001$) and 1999 ($p=0.001$) and a higher percentage were smokers. All subjects gained weight between 1982 and 1999; there was no significant difference between the two groups in the size of this weight gain.

Table 2 shows the mean daily intake of selected nutrients measured in the same subjects in 1982 and 1989 categorised by HbA_{1c} status measured in 1999; HbA_{1c} < 6.3% and HbA_{1c} ≥ 6.3%. Lower intakes of iron and folate and non-starch polysaccharides (NSP) in 1982 and 1989 were significantly predictive of high HbA_{1c} status in 1999. In addition, in 1989, lower intakes of protein, carbohydrate, and vitamin B₁₂ and a greater percent energy from fat were significantly predictive of high HbA_{1c} status in 1999. Before adjustment for BMI, SES and smoking, lower intakes of vitamins C and K₁ in 1982 and 1989 were predictive of high HbA_{1c} status (results not shown) but after adjustment these intakes were no longer significant.

Table 3 shows the mean daily intake of energy and selected nutrients in 1999 categorised as above. The calculated ORs (adjusted for BMI, SES and smoking) showed that none of the nutrient intakes were predictive of high HbA_{1c} status. Before adjustment for BMI, SES and smoking, lower intakes of K₁ were predictive of high HbA_{1c} status (OR; 0.42 (0.19,0.9) p=0.027) but significance disappeared on adjustment.

Table 4 shows the results of the global tests of association that indicated whether the 1982, 1989 and 1999 intakes of energy, carbohydrate, sodium, iron, riboflavin and vitamin B₁₂ were related to HbA_{1c} status in 1999. ORs are given for nutrient intakes in 1989 and 1999 that were significantly predictive of HbA_{1c} status in 1999 when each year's nutrient intakes were adjusted for the other. For each nutrient the adjusted ORs were all <1 in 1989 but > 1 in 1999. This indicated that a higher intake of energy and these nutrients in 1999, controlling for the level in 1989, i.e. the change over time of the individual nutrients, was associated with high HbA_{1c} status. For example, subjects who increased sodium intake in 1999 by 1 g/day relative to 1989 were 73% more likely to have a high HbA_{1c} status in 1999. Subjects who increased carbohydrate intake in 1999 by 100 g/day relative to 1989 were 95% more likely to have a high HbA_{1c} status in 1999.

Discussion

In this examination of dietary intakes in relation to HbA_{1c} concentration in 1999, there were no nutrient intakes in 1999 that were univariately predictive of concentrations above the “at risk” cut-off point. However, increases in intakes of energy, carbohydrate, sodium, iron, riboflavin and vitamin B₁₂ relative to 1989 were associated with raised HbA_{1c} status. These results suggest that an increase in the intake of some foods containing these nutrients might be related to elevated HbA_{1c}.

Although there were indications of trends over the 3 survey years in intakes of vitamin C, folate and vitamin K₁ in relation to HbA_{1c} concentrations, due to the small numbers of subjects classified as being “at risk” there were few significant relationships. A weakness of the study is that the number of subjects who completed diaries at all 3 time points and gave blood samples in 1999 was small. These may be the most motivated members of the cohort, with dietary characteristics that may have been different from those who did not complete diaries. The majority of these subjects were from non-manual occupational social classes (Wadsworth 2003) who tend to have a greater degree of literacy and are more health-aware. The fact that none of the subjects who had been diagnosed with diabetes completed diaries in 1999 would also indicate a bias in the sample.

Several studies have shown a relationship between dietary fat and hyperglycaemia although it is not clear whether this is due to its association with obesity and the ensuing insulin resistance. Data on 9772 non-diabetic adults from the Health Survey for England 1994 showed that higher HbA_{1c} was associated with the frequent consumption of fat containing foods (Gulliford and Ukoumunne 2001). In the present study there was a significant

relationship between percent energy from fat in 1989 and HbA_{1c} status although there was no relationship with actual fat intake. In 1989 energy and carbohydrate intakes were lower in the “at risk” subjects but in 1999, although fat intakes had fallen and carbohydrate intakes had risen in all subjects, the percent energy from fat was still greater in those with elevated HbA_{1c}.

Kirk *et al.* showed in a meta-regression analysis that HbA_{1c} status improved in patients with type 2 diabetes given lower carbohydrate diets (Kirk *et al.* 2008) but Livesey *et al.* published evidence that the effect of carbohydrate intake would depend on the GI of the diet (Livesey *et al.* 2008). In the present study we have shown that an increase in carbohydrate intake over 10 years was predictive of elevated HbA_{1c} and, at all three time points, intake of NSP, a factor contributing to GI, was lower in those with elevated HbA_{1c}.

Several studies have examined the intake of fruits and vegetables in relation to HbA_{1c} concentrations or the incidence of type 2 diabetes (Williams *et al.* 1999; Sargeant *et al.* 2000; Montonen *et al.* 2005; Bazzano *et al.* 2008). Participants in the EPIC- Norfolk study who reported never or seldom consuming both fruit and green leafy vegetables had higher mean HbA_{1c} concentrations while mean plasma vitamin C concentrations were significantly higher in subjects with HbA_{1c} concentrations < 7% (Sargeant *et al.* 2000). Extrapolating from these results would seem to indicate that the intake of the anti-oxidant vitamins, vitamin C and beta carotene as well as folate and vitamin K₁, also found in vegetables, may have a role in regulating blood glucose and HbA_{1c} concentrations. Yoshida *et al.* measured vitamin K₁ intake of 2719 men and women of the Framingham Offspring Cohort and found a decreased hazard of HbA_{1c} 6.5% with increasing intakes of vitamin K₁, although this trend was not significant (Yoshida *et al.* 2008). Our study showed no significant association between HbA_{1c} and vitamins C and K₁ or carotene intake in 1999. When intakes of these vitamins at all 3 time points were examined, there was a trend for mean intakes to be lower in subjects with elevated HbA_{1c} but the range in this latter group was very wide. This, together with the small sample size, made it difficult to achieve a significant difference compared to those subjects in the normal range of HbA_{1c}.

All the subjects gained weight between 1982 and 1999 but those with raised HbA_{1c} in 1999 had a significantly higher BMI at all time-points, despite having a lower energy intake in 1989. Thus, by 1999, the mean BMI of this group was within the over-weight range. In the majority of subjects, those with HbA_{1c} within the normal range, energy intakes fell between 1989 and 1999 indicating, perhaps, that physical activity had declined with increasing age. But in those subjects with raised HbA_{1c}, who were already heavier in 1989, energy intake increased between 1989 and 1999. Assuming that these subjects had not increased their physical activity, the increased energy intake would have contributed to the weight gain. A longitudinal study in the US over 10 years showed that for every kilogram of increase in weight the diabetes risk increased by 4.5% (Ford *et al.* 1997). In the present study the weight gain could be the primary cause of the raised HbA_{1c} in these subjects.

It could be argued that it is the energy intake that is driving the associations between HbA_{1c} and the increased intakes of carbohydrate, sodium, iron, riboflavin and vitamin B₁₂. However, it is still relevant to examine the principal sources of some of these nutrients; namely milk, meat and meat products. In this study, the increase in milk consumption over 10 years, between 1989 and 1999, was found to be associated with elevated HbA_{1c} (results not shown). While cows' milk has been cited as a contributory factor in the development of type 1 diabetes (Virtanen and Knip 2003) its involvement with type 2 diabetes is less clear. Dairy consumption was inversely associated with the incidence of insulin resistance components in young adults aged 18 to 30 years in the US but the findings from the British Women's Heart and Health study found that, in these older subjects aged 60-70, avoiding

milk was associated with a reduced risk of insulin resistance (Lawlor *et al.* 2005). The ATTICA study, with subjects aged between 18 and 89 years, also reported a strong positive association between whole milk consumption and blood glucose (Papakonstantinou *et al.* 2005). The present study found that lower intakes of nutrients found in milk at age 43, but higher intakes at age 53, were associated with raised HbA_{1c} at age 53 and it was the change in intakes of those nutrients between 43 years and 53 years that was significant. Although liquid milk consumption in the general population has fallen (Department for Environment Food and Rural Affairs 2001), in this cohort it had risen between 1989 and 1999 (Prynne *et al.* 2005).

Consumption of meat, particularly red meat and processed meat, has been implicated as a risk factor for type 2 diabetes (van Dam *et al.* 2002; Fung *et al.* 2004; Papakonstantinou *et al.* 2005; Schulze *et al.* 2005). The consumption of red and processed meat overall in the NSHD cohort has declined from 1989 to 1999 (Prynne *et al.* 2007). However, McNaughton *et al.* showed that in the NSHD cohort a dietary pattern that was characterised by a high consumption of meat, potatoes and sweet foods was significantly positively associated with elevated HbA_{1c} (McNaughton *et al.* 2007). This agrees with our finding that those with elevated HbA_{1c} had increased their carbohydrate intake between 1989 and 1999. The possible causal factor common to both meat and milk is their content of saturated fat which has been positively associated with HbA_{1c} (Harding *et al.* 2001) but in the present study we cannot show whether there is a direct link or whether it is the consumption of these foods contributing to the increase in body weight that is of greater importance.

None of the 1065 members of 1946 birth cohort who were included in this study had been diagnosed as diabetic although 4.3% had elevated concentrations of HbA_{1c} in 1999. Within the latter group there was a non-significant trend showing a lower intake of nutrients provided by fruits and vegetables and significant associations with increases in the intake of energy, carbohydrate and certain micronutrients provided by milk and meat. In general, the diets of members of the 1946 cohort who have been examined at all three time points have shown a general improvement which concurs with current dietary guidelines (Prynne *et al.* 2005) and is characteristic of older people who are more health-aware. However there are still some subjects whose elevated HbA_{1c} and higher energy intake combined with a lower intake of certain micronutrients and a higher intake of others may place them at risk of developing type 2 diabetes some time in the future.

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Table 1Characteristics of subjects divided by concentration of HbA_{1c} measured in 1999

n= 1065	HbA _{1c} <6.3%	HbA _{1c} 6.3%	P
Men, n 495	476 (96.2%)	19 (3.8%)	
Women, n 570	543 (95.3%)	27 (4.7%)	
1982 BMI (wt ht ⁻²)	23.1 (23.0,23.3)	24.5 (23.4,25.5)	0.003
1989 BMI (wt ht ⁻²)	24.3 (24.1,24.5)	26.1 (24.8,7.4)	<0.001
1999 BMI (wt ht ⁻²)	26.5 (26.2,26.7)	28.6 (27.0,30.3)	0.001
Weight change (kg) 1982-99	8.6	10.4	NS
Mean HbA _{1c} %	5.52	6.60	
Range of HbA _{1c} %	4 – 6.2	6.3 – 12.8	
Smokers	16%	26%	0.068*
Manual social class	28%	31%	NS*

BMI = Body mass index

* Pearson Chi square

Table 2

Daily intake of selected nutrients; mean or geometric mean (95% confidence intervals) in 1982 and 1989 of subjects classified by concentration of HbA_{1c} measured in 1999

n= 1065	HbA _{1c} <6.3%	HbA _{1c} 6.3%	Adjusted ¹ OR (95%CI)	P
1982 Energy, MJ	8.8 (8.6,9.0)	8.1 (7.5,8.8)	0.92 (0.82,1.0)	NS
1989 Energy, MJ	9.2 (9.1,9.4)	8.3 (7.6,9.0)	0.88 (0.77,1.0)	0.053
1982 Protein, g	74.3 (73.1,75.5)	70.1 (64.6,75.6)	0.91 (0.77,1.1)	NS
1989 Protein, g	79.5 (78.1,80.7)	71.7 (66.4,77.0)	0.83 (0.70,0.98)	0.031
1982 Fat, g	91.9(90.1,93.7)	86.6 (78.4,94.7)	0.94 (0.85,1.04)	NS
1982 Fat % energy	39.3 (39,36.6)	40.0 (38.6,41.5)	1.04 (0.98,1.1)	NS
1989 Fat, g	95.8 (93.9,97.8)	89.8 (81.2,98.5)	0.94 (0.85,1.04)	NS
1989 Fat % energy	38.9 (38.5,39.2)	40.7 (39.0,42.3)	1.13 (1.06,1.2)	0.023
1982 Carbohydrate, g	234 (229,238)	216 (196,234)	0.81 (0.54,1.2)	NS
1989 Carbohydrate, g	246 (241,250)	216 (195,237)	0.62 (0.39,0.99)	0.043
1982 Non-starch polysaccharide, g	12.4 (12.1,12.7)	10.4 (9.4,11.4)	0.89 (0.82,0.98)	0.012
1989 Non-starch polysaccharide, g	13.5 (13.2,13.9)	11.3 (9.9,12.6)	0.90 (0.84,0.98)	0.012
1982 Sodium, mg	2690 (2636,2744)	2520 (2298,2742)	0.83 (0.57,1.2)	NS
1989 Sodium, mg	2965 (2905,3025)	2661 (2419,2903)	0.73 (0.51,1.1)	0.09
1982 Calcium, mg	877 (859,895)	882 (769,995)	1.05 (0.4,2.78)	NS
1989 Calcium, mg	950 (932,968)	868 (780,956)	0.37 (0.13,1.08)	NS
1982 Iron, mg	12.0 (11.7,12.3)	10.3 (9.4,11.2)	0.90 (0.81,0.99)	0.030
1989 Iron, mg	13.0 (12.7,13.3)	11.2 (10.1,12.4)	0.91 (0.83,0.99)	0.033
1982 Beta carotene, µg ²	1569 (1503,1638)	1257 (1001,1577)	0.70 (0.45,1.09)	NS
1989 Beta carotene, µg ²	2056 (1971,2145)	1871 (1433,2444)	0.87 (0.56,1.33)	NS
1982 Riboflavin, mg ²	1.69 (1.65,1.73)	1.50(1.33,1.73)	0.70 (0.31,1.6)	NS
1989 Riboflavin, mg ²	1.73 (1.69,1.76)	1.49 (1.33,1.68)	0.43 (0.17,1.07)	0.07
1982 Folate, ug ²	205 (200,209)	175 (158,193)	0.39 (0.16,0.94)	0.016
1989 Folate, ug ²	267 (262,272)	226 (203,252)	0.27 (0.10,0.69)	0.006
1982 Vitamin B ₁₂ , ug ²	4.9 (4.6,5.1)	3.9 (3.3,4.7)	0.95 (0.89,1.01)	NS
1989 Vitamin B ₁₂ , ug ²	5.2 (5.0,5.4)	4.0 (3.5,4.7)	0.85 (0.74,0.97)	0.015
1982 Vitamin C, mg ²	61 (59,63)	52 (45,60)	0.61 (0.32,1.16)	NS
1989 Vitamin C, mg ²	63 (61,65)	52 (44,62)	0.57 (0.32,1.02)	0.057
1982 Vitamin K ₁ , ug ²	68 (65,70)	58 (50,66)	0.69 (0.39,1.27)	NS
1989 Vitamin K ₁ , ug ²	74 (71,76)	61 (51,73)	0.60 (0.35,1.03)	0.062

¹ Adjusted for body mass index, smoking and socio-economic status in 1999

² Indicates geometric mean, back transformed from natural log

Table 3

Daily intake of selected nutrients; mean or geometric mean (95% confidence intervals) in 1999 of subjects classified by concentration of HbA_{1c} measured in 1999

n = 1065	HbA _{1c} <6.3%	HbA _{1c} 6.3%	Adjusted ¹ OR (95%CI)	P
1999 Energy, MJ	8.5(8.4,8.6)	8.6 (8.0,9.2)	1.05 (0.91,1.21)	NS
1999 Protein, g	78 (77,79)	80 (75,86)	1.01 (0.99,1.02)	NS
1999 Fat, g	78 (76,79)	82 (76,89)	1.01 (0.99,1.02)	NS
1999 Fat %energy	34.3 (33.9,34.7)	36.1 (34.7,37.4)	1.13 (1.06,1.2)	NS
1999 Carbohydrate, g	239 (235,243)	241 (221,261)	1.00 (0.99,1.00)	NS
1999 Non-starch polysaccharide, g	14.6 (14.4,14.9)	13.3 (12.0,14.6)	0.94 (0.87,1.01)	NS
1999 Sodium, mg	2728 (2679,2777)	2941 (2691,3192)	1.35 (0.95,1.92)	NS
1999 Calcium, mg	985 (966,1003)	997 (912,1082)	1.59 (0.6,4.2)	NS
1999 Iron, mg	11.7 (11.5,11.9)	11.9 (10.9,12.9)	1.05 (0.96,1.14)	NS
1999 Beta carotene, µg ²	2348 (2238,2464)	2053 (1661,2538)	0.81 (0.55,1.2)	NS
1999 Riboflavin, mg ²	1.87 (1.83,1.91)	1.94 (1.75,2.160)	1.98 (0.78,5.0)	NS
1999 Folate, µg ²	286 (280,291)	270 (249,292)	0.70 (0.26,1.89)	NS
1999 Vitamin B ₁₂ , µg ²	5.6 (5.4,5.7)	6.1 (5.1,7.4)	1.67 (0.95,2.92)	NS
1999 Vitamin C, mg ²	87 (84,90)	78 (66,92)	0.93 (0.55,1.58)	NS
1999 Vitamin E, mg ²	10.0 (9.8,10.3)	9.9 (8.8,11.1)	0.96 (0.45,2.0)	NS
1999 Vitamin K ₁ , µg ²	83 (80,85)	69 (60,79)	0.52 (0.27,0.99)	NS

¹Adjusted for body mass index, smoking and socio-economic status in 1999

²Indicates geometric mean, back transformed from natural log

Table 4Odds ratios (95% confidence intervals) for high HbA_{1c} status for selected nutrient intakes in 1989 and 1999¹

Nutrient	1989 Adjusted ² OR (95%CI)	1999 Adjusted ² OR (95%CI)	<i>P</i> for global test of association
Energy, MJ ³	0.80 (0.68,0.95)	1.22 (1.02,1.46)	0.049
Carbohydrate, 100g ³	0.44 (0.25,0.78)	1.95 (1.1,3.47)	0.023
Sodium, 1g ³	0.60 (0.41,0.90)	1.73 (1.17,2.56)	0.016
Iron, 1mg ³	0.87 (0.79,0.96)	1.10 (1.00,1.21)	0.013
Riboflavin, 1mg ³	0.43 (0.23,0.80)	1.78 (1.14,2.78)	0.019
Vitamin B ₁₂ , 1µg ³	0.84 (0.73,0.96)	1.06 (1.01,1.10)	0.012

¹Odds ratios were obtained from the parsimonious model and *p*-values were from the model with all three years' nutrient intakes.

²Adjusted for body mass index, smoking and socio-economic status in 1999

³The units given are those used to calculate the odds ratios