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Association between an anti-inflammatory and anti-oxidant dietary pattern and diabetes in British adults: Results from the National Diet and Nutrition Survey rolling programme Years 1-4

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Abstract

This study investigated the cross-sectional association between an anti-inflammatory and anti-oxidant dietary pattern and diabetes in the National Diet and Nutrition Survey rolling programme Years 1-4. A total of 1531 survey members provided dietary data. Reduced Rank Regression was used to derive an anti-inflammatory and anti-oxidant dietary pattern. Serum C-reactive protein and plasma carotenoids were selected as response variables and markers of inflammation and antioxidant status, respectively. Overall, 52 survey members had diabetes. The derived anti-inflammatory and anti-oxidant dietary pattern was inversely related to C-reactive protein and positively to carotenoids. It was associated with lower odds of diabetes (multivariate adjusted OR for highest compared with lowest quintile: 0.17; 95%CI: 0.04-0.73; *P* for linear trend=0.013). In conclusion, an anti-inflammatory and anti-oxidant dietary pattern is inversely related to diabetes. Further research is required to understand the overall framework within which foods and nutrients interact to affect metabolic pathways related to diabetes risk.

Keywords: Glycosylated Haemoglobin; C-reactive protein; carotenoids; dietary patterns; National Diet and Nutrition Survey; Diet; Nutritional epidemiology

Abbreviations: National Diet and Nutrition Survey NDNS; Reduced Rank Regression RRR; C-reactive protein CRP; Odds Ratio OR; Lower reference nutrient intake LRNI; Diet In Nutrients Out (DINO); Glycosylated haemoglobin Hb_{A1c}; Computer Assisted Personal Interview CAPI; National Statistics Socio-economic Classification NSSEC

INTRODUCTION

Inflammation and oxidative stress play a central role in the pathophysiology of type 2 diabetes (Rosen et al. 2001;Spranger et al. 2003). However, to date, little is known of how various dietary components interact to influence this inflammatory and anti-oxidant process and subsequently the development of type 2 diabetes. Most current research has focused on assessing individual nutrients or foods in relation to diabetes risk. Such research ignores the complexity of eating behaviour and diet providing an oversimplified view of the role of nutrition in chronic disease prevention (Sievenpiper and Dworatzek 2013). Although globally the role of diet as a whole is increasingly recognised in the nutritional management of diabetes, the same is not true for prevention (Sievenpiper and Dworatzek 2013). Of the few studies that have investigated the relationships between dietary patterns and diabetes, most assessed diet using food frequency questionnaires, a method that captures data on usual intake and remains useful in assessing dietary intake in large cohorts, but which also suffers from systematic bias due to errors in estimating portion size and limitations concerning the food groups included in the questionnaires (Schulze et al. 2005;Nettleton et al. 2007;Nettleton et al. 2008). Because foods are consumed in combination, it is imperative for observational studies to utilise more advanced methods of analysis to investigate diet-disease relationships. Reduced rank regression (RRR) is more effective than the widely-used principal component analysis, since it permits the use of prior knowledge to identify dietary patterns that explain as much variation as possible in a set of response variables presumed to be related to disease risk (Hoffmann et al. 2004;Hoffmann et al. 2005;Michels and Schulze 2005;Schulze and Hoffmann 2006;DiBello et al. 2008). The resulting dietary patterns thus provide information on potential biological pathways that link diet to disease (Michels and Schulze 2005). To our knowledge, only two studies have so far utilised this method to identify dietary patterns related to biomarkers linked to diabetes (Heidemann et al.

2005;Schulze et al. 2005). Of these studies, none has been conducted in the UK or utilised more robust methods of dietary assessment such as food diaries.

The National Diet and Nutrition Survey (NDNS) rolling programme is a cross-sectional survey of a nationally representative sample of the UK population (Whitton et al. 2011). It utilises food diaries to collect data on food consumption, nutrient intakes and nutritional status. This method of dietary assessment is known to correlate more highly with biomarker data [11] and to be less prone to measurement error than food frequency questionnaires (Heidemann et al. 2005;Stephen 2007). The NDNS rolling programme also contains up to date information on lifestyle and blood biomarkers in people aged 1.5 years and above living in England, Wales, Scotland and Northern Ireland, thereby providing a unique opportunity for studying the association between diet and diabetes in a nationally representative sample.

The present study investigated the association between an anti-inflammatory and anti-oxidant dietary pattern derived using reduced rank regression (Hoffmann et al. 2004;Hoffmann et al. 2005;Schulze and Hoffmann 2006) and diabetes status in the National Diet and Nutrition Survey (NDNS) rolling programme Years 1-4.

METHODS

Study population

The survey design and sampling methods of NDNS have been described extensively in previous studies (Bates et al. 2014). The NDNS rolling programme is a nationally-representative survey of food consumption, nutrient intakes and nutritional status in people aged 1.5 years and above living in England, Wales, Scotland and Northern Ireland (Bates et al. 2014). The survey is implemented by a consortium of three organisations: the National Centre for Social Research (NatCen), MRC Human Nutrition Research, and the Department of Epidemiology and Public Health at the University College London Medical School. Fieldwork for the NDNS rolling programme began in 2007 and is on-going.

The overall response rate for fully productive individuals (i.e. those completing three or four dietary recording days) was 56% in Year 1, 57% in Year 2, 53% in Year 3 and 55% in Year 4, giving a sample size of 3,450 fully-productive adults aged 19 years and over (Bates et al. 2014). All individuals who completed three or four days of dietary recording were eligible for a nurse visit. Of these, 1531 adult survey members (19-65 years) went on to have a nurse visit

This survey was conducted according to the guidelines set in the Declaration of Helsinki. All procedures involving human volunteers were approved by the Oxfordshire Research Ethics Committee and all participants gave informed consent for each phase of the study.

Dietary assessment

Details of dietary assessment have been provided elsewhere (Riley 2010;Department of Health 2011;Whitton et al. 2011). Diet was assessed using 4 day estimated food diaries. In Year 1, the recording period started on a Thursday, Friday or Saturday and included both weekend days. This led to an over-representation of weekend days while Wednesdays were never represented. From Year 2 onwards, the food diary recording period was changed to allow all days of the week to be equally represented. Participants were asked to report all foods and drinks consumed both at home and away from home. Portion sizes were estimated using household measures, weights on labels or by comparison with life-size photographs of spoons and glasses. To improve compliance and recording, food diaries were reviewed by trained interviewers on the second day of recording and participants were asked to clarify any uncertainties (Bates et al. 2014). When completed, diaries were checked by interviewers with respondents and missing details added to improve completeness. Diet diaries were coded and edited using DINO (Diet In Nutrients Out) and nutrient intakes calculated using the NDNS nutrient databank (Whitton et al. 2011).

Definition of diabetes and biomarkers of glycaemic control

Fasting blood samples were collected for measurements of glycosylated haemoglobin (Hb_{A1c}) at four stages of recruitment between February 2008 to March 2009, April 2009 to May 2010, April 2010 to August 2011, and April 2011 to August 2012 (Bates et al. 2014). For Hb_{A1c} analysis, samples were sent by nurses overnight to Addenbrooke's Hospital in Cambridge. Consistency of measurements was checked by running three controls on each run. Optimal concentration of Hb_{A1c} was defined as Hb_{A1c} < 6.5%, while survey members with Hb_{A1c} values ≥ 6.5% were deemed to have diabetes. Two categories of diabetes status were defined: no diabetes, and self-reported or undiagnosed diabetes. This categorisation was based on self-reported diabetes status and Hb_{A1c} concentrations. Survey members were deemed to have no diabetes if they did not report having diabetes and if Hb_{A1c} was normal. Survey members who reported having diabetes but had normal or high Hb_{A1c} were deemed to have self-reported diabetes. Survey members who did not report having diabetes but had high Hb_{A1c} were considered to have undiagnosed diabetes. Self-reported diabetes was assessed by asking participants the following questions: Do you have any long-standing illness, disability or infirmity? By long-standing I mean anything that has troubled you over a period of time, or that is likely to affect you over a period of time? The variables for longstanding illness had 42 codes. Participants who were assigned the code "diabetes including hyperglycaemia" were deemed to have self-reported diabetes.

Additional measures and covariates

Height and weight were measured using a portable stadiometer and weighing scales. BMI (weight (kg)/ height (m^2)) was classified according to the criteria set by the World Health Organisation and National Institute for Health and Clinical Excellence. A Computer Assisted Personal Interview (CAPI) was also conducted during the initial visit by trained interviewers to obtain information on respondent's health status; smoking and drinking habits; socio-economic characteristics; medication use and some usual dietary behaviours. Socio-economic status was defined based on the National Statistics Socio-economic Classification (NS-SEC) as: 1) higher occupations, 2) intermediate occupations, 3) lower occupations, and 4) never worked or long-term unemployed.

Statistical methods

Data were weighed to correct for unequal sample selection, non-response for household and individual interview and non-response to nurse visit (Food Standards Agency. 2010). This weighing factor adjusts for differences in socio-demographic variables, such as age, sex, ethnicity and region, between participants and non-participants to the nurse visit to ensure survey sample is representative of the UK population (Food Standards Agency. 2010).

Differences between survey members with or without diabetes were assessed using independent sample t-tests for continuous variables or χ^2 tests for categorical variables. Trends in energy and macronutrient intake across quintiles of dietary pattern scores were assessed using a non-parametric trend test ("**nptrend**" in Stata), an extension of the Wilcoxon rank-sum test for trend across ordered groups. Bivariate associations were evaluated using chi-square tests for categorical variables.

Reduced Rank Regression

To derive dietary patterns, reduced rank regression (RRR) was used on 49 pre-defined food groups. Serum C-reactive protein (CRP) a marker of inflammation, and plasma total carotenoids, a marker of anti-oxidant status, were selected as response variables. These markers were selected on the basis of their relation to diabetes and influence by diet (Ford et al. 2003;Higuchi et al. 2015;Sluijs et al. 2015) . Inflammation is known to reduce cellular anti-oxidant capacity (Khansari et al. 2009), and has been shown to be inversely related to serum carotenoids through the acute phase response (Schweigert 2001). Likewise, serum carotenoids have been shown to correlate negatively with CRP and other markers of inflammation (Kritchevsky et al. 2000). Both response variables were skewed and were log-transformed prior to inclusion in RRR. Details of quality control procedures and assays used to measure C-reactive protein and plasma total carotenoids have been published elsewhere (Public Health England and Food Standards Agency 2014). Briefly, CRP was assayed using a Dade Behring Dimension RXL Clinical Chemistry Analyser. The assay method is based on a high sensitivity particle enhanced turbidimetric immunoassay (PETIA) technique, with a detection range ≥1.0mg/L. Carotenoids were measured by HPLC coupled with a photodiode array detector using a method derived from Thurnham et al (Thurnham et al. 1988).

RRR was run using a STATA module that implements the SAS partial least squares procedure. The module was installed using the command "ssc install plssas" (2007). Z-scores were assigned to each survey member indicating how closely their dietary intake reflects the obtained dietary pattern. Analysis were repeated using food groups adjusted for energy intake. The resulting factor loadings did not differ from the values obtained using the absolute food group intake. Consequently, only data from model including absolute food group intake are presented.

Logistic Regression

Odds ratios (ORs) and associated 95% confidence intervals (CIs) for quintiles of dietary pattern Z-scores in relation to diabetes status were estimated using multivariable logistic regression models. Model 1 adjusted for age, sex and ethnicity. Model 2 additionally adjusted for energy intake. Model 3 included all covariates in Model 2 as well as BMI. Finally, Model 4 included all of the above covariates in addition to adjusting for waist circumference. These covariates were selected on the basis of their relationship with diet and influence on diabetes status (Wang et al. 2005;Shai et al. 2006). BMI and waist circumference data were missing in 8% and 28% of the productive adult sample, respectively. These values were assumed to be missing at random and consequently imputed as continuous variables by using multiple imputation. Thirty imputed data sets were created and fitted by using the "ice" and "mim" packages in Stata (StataCorp LP). Sensitivity analysis were conducted comparing findings from imputed data and complete case analysis. Additional sensitivity analysis including social class, smoking status and physical activity as covariates were conducted. These covariates were subsequently dropped from the final model as they did not add to the predictive power of the model. Tests for linear trend of the association between quintiles of dietary patterns and diabetes status were assessed by assigning the median value of each quintile and modelling the variable as a continuous variable.

All statistical analyses were carried out by using Stata Statistical Software version 13. The *P*-values reported were 2-tailed, and a *P*-value <0.05 was considered statistically significant.

RESULTS

Characteristics of the study population are provided in Table 1, while intakes of food groups are provided in Table 2. Of the 1531 individuals included in the RRR analysis, 52 had diabetes. Survey members with diabetes were older (P<0.001), and had higher BMI (P<0.001) and waist circumference (P<0.001) compared to survey members without diabetes. There were no differences in total energy intake over the day between survey members with or without diabetes.

Two dietary patterns were derived using RRR. Dietary pattern 1 explained the maximum variation in response variables (13%) and was inversely related to serum CRP and positively to plasma carotenoids. Correlation coefficients ranged from -0.42 for CRP to 0.90 for plasma carotenoids. This anti-inflammatory and anti-oxidant dietary pattern was characterised by high intake of vegetables and fruit and low intake of chips, sugar and white bread (Figure 1). Dietary pattern 2 explained a smaller variation in food intake and was positively associated with serum CRP and plasma carotenoids. As a result, only Dietary pattern 1 was deemed of interest to the current study.

There were significant associations between the anti-inflammatory and anti-oxidant dietary pattern and sex and ethnicity, with a higher proportion of women and non-white survey members being in the highest quintile of Dietary pattern 1 (Table 3). Energy and macronutrient intake varied across quintiles of Dietary pattern 1. In particular, there was a trend towards increased energy intake, protein (expressed as percentage of energy intake), n-3 polyunsaturated fatty acids (expressed as percentage of energy intake), fibre, intrinsic milk sugars and starch across increasing quintiles of Dietary pattern 1. By contrast, there was a trend towards lower carbohydrate intake (expressed as percentage of energy intake), particularly non-milk extrinsic sugars, across quintiles of Dietary pattern 1. There was also a marginally significant trend towards reduced BMI and waist circumference across quintiles of Dietary pattern 1 (Table 3).

In the logistic regression analysis, the highest quintiles of dietary pattern 1 were associated with lower ORs of diabetes (OR for highest compared with lowest quintile: 0.17;

95% CI: 0.04-0.73; *P* for linear trend = 0.013; based on adjustment for age, sex, ethnicity and energy intake) (Table 4). After adjustment for BMI and waist circumference, the association weakened slightly but remained significant (OR for highest compared with lowest quintile: 0.22; 95% CI: 0.05-0.96; *P* for linear trend= 0.047).

DISCUSSION

Interpretation of main findings

The current study identified a dietary pattern that was inversely associated with biomarkers of inflammation and positively with biomarkers of anti-oxidant status. This anti-inflammatory anti-oxidant dietary pattern, characterised by high intake of vegetables and fruit and low intake of chips, sugar and white bread, was associated with lower prevalence of type 2 diabetes.

Our findings are consistent with previous research on the association between dietary patterns and type 2 diabetes risk. In particular, the dietary pattern identified in our study is comparable to the dietary pattern identified in the Nurses' Health Study (Schulze et al. 2005). In the latter study, the dietary pattern was associated with markers of inflammation and endothelial dysfunction, and was characterised by low intake of vegetables and high intake of sugary beverages. This pattern strongly predicted risk of type 2 diabetes independent of BMI and other diabetes risk factors. In contrast in the current study, the association between the derived dietary pattern and diabetes prevalence was reduced slightly following adjustment for BMI and waist circumference. This may suggest that the relationship between the anti-inflammatory anti-oxidant dietary pattern and diabetes is mediated by BMI and body fat distribution. The latter is in line with previous studies demonstrating that the association between diet and type 2 diabetes risk could be affected by BMI and body fat distribution For instance, in the EPIC-InterAct study, the association between total protein as well as animal protein and type 2 diabetes risk was attenuated in men after adjustment for body composition (van Nielen et al. 2014). In the latter study, obesity - in particular, abdominal obesity - was an independent risk factor for type 2 diabetes that strongly correlated with protein intake (van Nielen et al. 2014). In our study, waist circumference was found to decrease across quintiles of the anti-inflammatory anti-oxidant dietary pattern. This may imply that the observed dietary pattern reflects an anti-inflammatory and anti-oxidant dietary pattern related to abdominal obesity, although this would need to be explored further.

The role of individual foods and nutrients in relation to inflammation and anti-oxidant status is well recognised (Ahluwalia et al. 2013;Barbaresko et al. 2013;Uusitupa and Schwab 2013). This knowledge provides us with a basic understanding as to how various dietary constituents exert anti-inflammatory anti-oxidant effects. In the current study, the observed dietary pattern was characterised by increasing intake of vegetables, fruit, nut and fish, and decreasing intake of chips, sugar and white bread. This, in turn, was reflected in the nutrient composition of the dietary pattern; high intake of protein, omega-3 fatty acids, starch and fibre across the quintiles, and low intake of carbohydrate, non-milk intrinsic sugars and extrinsic milk sugars. These findings are noteworthy as they provide us with insight into specific combinations of food and nutrients that might be relevant to reducing inflammation and improving anti-oxidant status. To date, our knowledge of how foods and nutrients interact together and how these need to be combined to achieve a desired health outcome remains limited. What remains clear, however, is that dietary approaches that take into consideration complex interactions between various dietary components have proved to be more effective compared to dietary interventions focusing on a single food or nutrient (Franco et al. 2004;Shirani et al. 2013). One such example is the DASH diet, which has been shown consistently to improve cardiovascular disease risk factors (Siervo et al. 2014) and improve insulin sensitivity (Shirani et al. 2013). Such evidence implies the need to improve our understanding as to how foods interact to prevent chronic diseases such as type 2 diabetes. In this respect, novel methods such as RRR provide a framework for investigating diet-disease relationships taking into account existing knowledge of disease pathways. Nonetheless, there is a need for developing models that will assist nutrition researchers in interpreting dietary patterns further in order to devise dietary recommendations that could assist in preventing chronic diseases.

Two interesting findings of the current study are the relative change in the proportion of energy obtained from protein versus carbohydrates across quintiles of the dietary pattern, and the variation in fat composition across the quintiles. These findings warrant further investigation in other observational studies on dietary patterns and type 2 diabetes. Most current dietary guidelines focus on adjusting the percentage energy intake from carbohydrates and fat, while maintaining energy intake from protein at 15%. In relation to clinical practice, there has been a gradual shift in the nutritional recommendations for patients with diabetes, with most current diabetes societies recommending up to 20% of energy intake from protein (Sievenpiper and Dworatzek 2013). However, the debate concerning varying energy intake from protein in relation to diabetes risk remains controversial (Afshin et al. 2014). In the European Prospective Investigation into Cancer and Nutrition (EPIC)-NL Study, consuming 5% energy from total or animal protein at the expense of 5% energy from carbohydrates or fat was associated with an increased diabetes risk (Sluijs et al. 2010). Similarly, in the EPIC-InterAct Case-Cohort Study, high total and animal protein intake was associated with a modest elevated risk of type 2 diabetes (van Nielen et al. 2014). This is in contrast to findings from short-term intervention studies demonstrating a beneficial effect of high-protein diets on weight loss and glycaemic control (Ajala et al. 2013). These discrepancies in findings could be attributed to various factors, including the use of food frequency questionnaires to assess food and nutrient intake. A reductionist approach to nutrition research could also be a key factor, as research that does not take into consideration the context within which nutrients are consumed, often ignores the complexity of diet and the potential additive and synergetic effects of multiple foods and dietary components (Sievenpiper and Dworatzek 2013). Nutrients are known to interact differently when present as foods, and as such there is a pressing need to combine dietary patterns approaches and nutrient approaches in order to gain a stronger understanding of the role of diet in health and disease.

Strengths and Weakness of the Study

One of the main weaknesses of the current study compared to previous studies is the cross-sectional design of the study which limits any causal inferences. Moreover, given that only a fraction of the productive sample went on to have nurse visits and that the total number of diabetes cases is relatively small, the extent to which the findings can be generalised is limited, although data were weighed to overcome this limitation and to account for the sampling method and non-responsiveness. The small number of cases also hindered further assessment of differences in dietary pattern between survey members with self-reported and undiagnosed diabetes, which is an important weakness of the current study compared to previous studies. The latter investigation could be of interest as it provides insight into changes in food choices following diagnosis of type 2 diabetes. Despite these weaknesses, it is important to acknowledge that the NDNS rolling programme is the only cross-sectional survey in the UK that utilises robust methods of dietary assessment and which is run on a rolling basis. As such, the NDNS rolling programme provides a unique opportunity to generate hypothesis and investigate diet-disease relationships. Undoubtedly, this points towards the importance of continuing to measure biomarkers of diabetes risk in this survey, as the pseudo-longitudinal design of this study might allow us in the future to improve our understanding of the association between diet and disease, thereby providing the basis for further research and policy development.

CONCLUSION AND IMPLICATIONS

The present study identified an anti-inflammatory anti-oxidant dietary pattern which was related to lower prevalence of diabetes. This dietary pattern was characterised by high intake of vegetables and fruit and low intake of chips, sugar and white bread. This research points towards the importance of improving our understanding of the relation between diet as a whole and chronic disease outcomes such as type 2 diabetes, as opposed to focusing on single food or nutrients. Further research is required to understand the overall framework within which various foods interact to affect metabolic pathways related to diabetes risk. Moreover, evidence from observational studies need to be supported by further intervention studies that can examine the effect of an anti-inflammatory anti-oxidant dietary pattern on biomarkers of glucose metabolism. Finally, more research is required to understand the effect of varying energy intake from the various macronutrients whilst taking into account macronutrient sources and the overall diet. Such research will undoubtedly form the basis for developing public health policies that take into consideration the complex nature of diet, shifting the paradigm towards a more holistic view of nutrition.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORSHIP

LM was responsible for analysing and interpreting data, drafting the article and revising and approving the final draft. CRM supervised the project, assisted with data interpretation, revised, edited and approved the final draft of the manuscript. SA conceptualised the study, assisted in the analyses and data interpretation, supervised the research, wrote and revised the manuscript.

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Table 1 Characteristics of study population (n=1531). Data are presented as means and SDs for continuous variables or as counts and percentages for categorical variables.

	Diabetes Status						
	No			Yes			P-value*
	Unweighted N	Mean (or count)	SD (or %)	Unweighted N	Mean (or count)	SD (or %)	
Dietary pattern z-score	1479	0.04	1.05	52	-0.16	1.21	0.195
Age (years)	1479	42	12	52	51	11	<0.001
BMI (kg/m^2)	1369	27.7	5.5	46	31.6	5.7	<0.001
Waist circumference (cm)	1054	93.1	14.6	42	105.2	16.2	<0.001
Total daily energy (kcal)	1479	1828	584	52	1716	633	0.175
Sex (% female)		842	56.9		28	53.9	0.659
Ethnicity (% non-white)		148	10.0		8	15.4	0.208
Smoking							
% ex-regular smoker		293	19.8		16	30.8	0.103
% current smoker		387	26.2		9	17.3	

* P-value from 2-sided test for difference by diabetes status.

Table 2 Intake of food groups (grams) and percentage consumers of study population.

Food group	N	Consumers (%)	Mean	SD
Bacon and ham	1531	(59)	15	20
Beer, lager, cider and perry	1531	(33.6)	199	491
Biscuits	1531	(60.9)	13	18
Brown granary and wheat germ bread	1531	(34.2)	14	27
Buns, cakes, pastries and fruit pies	1531	(48.7)	17	27
Burgers and kebabs	1531	(13.1)	6	19
Butter	1531	(30.4)	3	7
Cheese	1531	(61.4)	29	37
Chicken and turkey dishes	1531	(66.5)	58	75
Chips, fried/roast potatoes and potatoes	1531	(64.3)	41	46
Coated chicken	1531	(14.4)	6	18
confectionery	1531	(48.1)	10	19
Crisps and savoury snacks	1531	(49.3)	7	11
Dry weight beverages	1531	(14.5)	2	10
Eggs and egg dishes	1531	(49.2)	20	36
Fruit	1531	(76.9)	91	104
Fruit juice	1531	(37.6)	52	114
High-fibre breakfast cereals	1531	(42.7)	19	43
Ice-cream	1531	(18.2)	5	13
Low fat milk	1531	(80.5)	117	125
Low fat spread not polyunsaturated	1531	(5.3)	0.44	2
Reduced fat spread not polyunsaturated	1531	(46.7)	4.65	7
Low fat spreads and polyunsaturated fatty acids spreads	1531	(33.8)	3	6
Meat pies and pastries	1531	(23.3)	11	27
Nuts and seeds	1531	76(18)	2	8
Oily fish and other fish	1531	(46.7)	28	50
Other breakfast cereals	1531	(29.3)	6	12
Other meats and meat products	1531	(17.3)	7	24

Other milk and cream	1531	(19.3)	9	34
Other potatoes, potato salad dishes	1531	(65.2)	45	50
Pasta, rice and other cereals	1531	(76.6)	78	84
Pork and dishes	1531	(19.9)	10	30
Puddings	1531	(22.1)	11	27
Red meat and dishes	1531	(58.3)	61	82
sausages	1531	(32.6)	14	31
Savoury sauces, pickles gravies, condiments	1531	(81.1)	24	28
Soft drinks low calorie	1531	(35.9)	108	235
Soft drinks not low calorie	1531	(49.3)	123	224
Soup homemade and retail	1531	(27.8)	32	66
Spirits and liqueurs	1531	(12.5)	5	25
Sugars preserves and sweet Spreads	1531	(64.4)	11	16
Tea, coffee and water	1531	(98.3)	1104	627
Vegetables	1531	(96.5)	133	103
White bread	1531	(79.4)	50	49
White fish, coated or fried	1531	(21.6)	8	18
Wholemeal bread and other bread	1531	(41.5)	20	35
Whole milk	1531	(18.9)	23	73
Wine	1531	(33.9)	65	137
Yogurt, fromage frais and dairy desserts	1531	(37.5)	28	49

Figure 1 Factor loading for the anti-inflammatory and anti-oxidant dietary pattern.

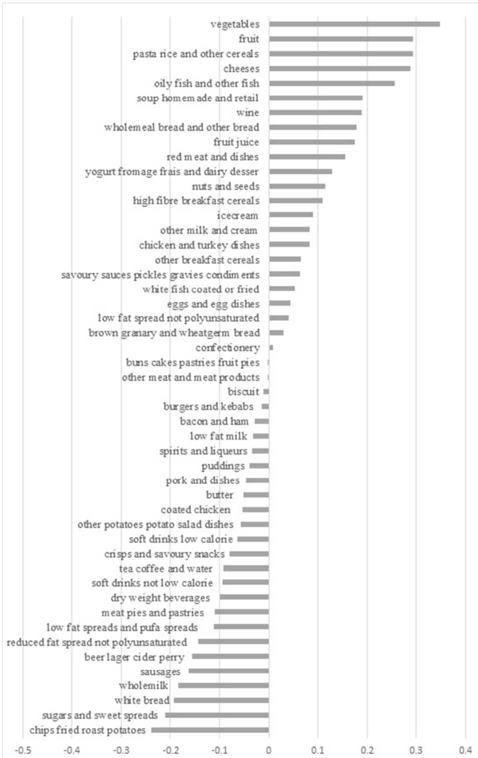
Table 3 Survey member characteristics and macronutrient intake according to quintiles of the anti-inflammatory and anti-oxidant dietary pattern.

	Quintile of dietary pattern (1=lowest quintile, 5=highest)										P-Value
	1		2		3		4		5		
	Mean (n=307)	SD	Mean (n=306)	SD	Mean (n=306)	SD	Mean (n=306)	SD	Mean (n=306)	SD	
Ethnicity (% non-white)	2.6		5.6		10.8		12.4		19.6		<0.001
Sex (% female)	47.2		55.9		64.4		62.4		54.2		<0.001
Age (yrs)	41.8	12.7	41.7	12.7	43.1	12.9	42.0	12.1	43.6	12.1	0.107
Waist circumference (cm)	67.9	45.4	69.7	45.1	64.9	44.2	66.3	43.2	64.6	44.4	0.025
BMI (kg/m^2)	26.0	9.5	26.2	9.5	25.4	9.4	26.0	8.6	24.8	9.5	0.050
Energy (kcal)	1855.6	685.3	1714.6	492.8	1780.5	504.0	1882.6	505.5	2036.4	545.0	<0.001
Food energy (kcal)	1730.2	579.4	1620.5	440.6	1691.4	454.0	1778.6	494.5	1924.9	516.4	<0.001
Protein (% Energy)	15.0	4.0	16.3	3.4	16.9	3.7	16.8	3.5	17.2	4.2	<0.001
Fat (% Energy)	32.8	6.7	33.5	6.2	33.0	5.8	32.5	6.4	32.8	6.8	0.345
Saturated fatty acids (% Energy)	12.1	3.5	12.5	3.4	12.1	3.1	11.9	3.3	11.8	3.4	0.093
Cis-monounsaturated fatty acids (% Energy)	12.1	2.8	12.1	2.6	11.9	2.6	11.8	2.7	11.8	3.1	0.053
Cis-n6 fatty acids (% Energy)	4.7	1.5	4.8	1.4	4.9	1.4	4.7	1.4	4.9	1.8	0.663
Cis-n3 fatty acids (% Energy)	0.9	0.4	1.0	0.4	0.9	0.3	1.0	0.4	1.0	0.5	0.008
Transfattyacids (% Energy)	0.6	0.4	0.6	0.3	0.6	0.3	0.6	0.3	0.6	0.3	0.353
Carbohydrate (% Energy)	46.4	7.6	45.4	7.8	45.6	7.2	45.6	7.9	44.7	7.7	0.008
Starch (g)	127.5	47.4	120.9	35.7	120.1	39.7	130.3	41.2	140.1	43.1	<0.001
Total sugars (g)	104.6	53.2	87.4	44.1	94.8	40.4	96.8	44.3	98.1	37.5	0.297
Nonmilkextrinsicsugars (g)	74.6	48.9	55.1	40.2	55.2	34.6	56.8	37.1	52.2	30.8	<0.001
Intrinsicandmilksugars (g)	30.0	17.1	32.3	15.1	39.6	16.4	40.0	17.9	45.9	19.6	<0.001
Fibre (g)	11.6	4.4	12.3	4.0	13.6	3.7	14.8	4.7	17.3	5.0	<0.001

Table 4 Associations between quintiles of the anti-inflammatory and anti-oxidant dietary pattern and OR (95% CI) of diabetes*.

	Quintile of dietary pattern (1=lowest quintile, 5=highest) †					
	1	2	3	4	5	P-value for linear trend
Model 1‡	1.0 (Ref)	0.66 (0.21, 2.08)	0.55 (0.16, 1.93)	0.5 (0.18, 1.4)	0.16 (0.04, 0.69)	0.008
Model 2	1.0 (Ref)	0.66 (0.21, 2.06)	0.56 (0.16, 1.94)	0.52 (0.19, 1.48)	0.17 (0.04, 0.76)	0.014
Model 3	1.0(Ref)	0.74(0.23,2.36)	0.69(0.2,2.41)	0.64 (0.22,1.87)	0.21 (0.05,0.92)	0.033
Model 4	1.0 (Ref)	0.69 (0.22, 2.12)	0.69 (0.19, 2.48)	0.69 (0.24, 1.98)	0.22 (0.05, 0.96)	0.047

* Data presented from the multiple imputation model.
† Cutoff values for quintiles of dietary pattern scores were: Q1: -5.4 to -0.8 (n=307), Q2: -0.79 to -0.25 (n=306), Q3: -0.24 to 0.24 (n=306), Q4: 0.25 to 0.83 (n=306), Q5: 0.84 to 5.96 (n=306).
‡ Model 1 adjusted for age (continuous), sex (male vs. female) and ethnicity (white vs. non-white). Model 2 additionally adjusted for energy intake (continuous). Model 3 included all covariates in Model 2 as well as BMI (continuous). Finally, Model 4 included all of the above covariates in addition to adjusting for waist circumference (continuous).



Factor loading for the anti-inflammatory and anti-oxidant dietary pattern.
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