Dietary changes and associations with metabolic improvements in adults with Type 2 diabetes during a patient-centred dietary intervention: a secondary analysis

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-004953
Article Type:	Research
Date Submitted by the Author:	28-Jan-2014
Complete List of Authors:	England, Clare; University of Bristol, Centre for Exercise, Nutrition and Health Sciences Thompson, Janice; The University of Birmingham, School of Sport & Exercise Sciences Jago, Russ; University of Bristol, Centre for Exercise, Nutrition and Health Sciences Cooper, Ashley; University of Bristol, Centre for Exercise, Nutrition and Health Sciences Andrews, Robert; University of Bristol, Henry Wellcome Laboratories for Integrative
Primary Subject Heading:	Diabetes and endocrinology
Secondary Subject Heading:	Nutrition and metabolism
Keywords:	Type 2 diabetes, Dietary analysis, Dietary change

Dietary changes and associations with metabolic improvements in adults with Type 2 diabetes during a patient-centred dietary intervention: a secondary analysis

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Running title: Dietary change in adults with Type 2 diabetes

Keywords: Type 2 diabetes, dietary analysis, dietary change

Bath Research Ethics Committee (05/Q2001/5)

<u>Word count</u>

Abstract: 299

Main text: 3758

Number of tables: 3

Abstract

Objectives: Examine dietary changes reported during a non-prescriptive dietary intervention and explore whether these changes had a role in observed improvements in HbA1c, weight, lipids and blood pressure.

Design: Secondary analysis of data from the Early ACTivity in Diabetes randomised controlled trial.

Participants 262 patients with newly diagnosed Type 2 diabetes randomised to the dietary intervention.

Outcomes and analysis: Changes in energy intake, macronutrients, fibre and alcohol and in weight, waist circumference, lipids, HbA1c and blood pressure at baseline and 6 months. Multivariate models were used to examine associations between dietary changes and metabolic variables.

Results: Men reported reducing mean energy intake from 1903 ± 462kcal to 1685kcal ± 439kcal ($p<0.001$), increasing carbohydrate intake from 42.4 ± 6.6% to 43.8 ± 6.6% ($p=0.002$) and reducing alcohol intake from 18 ± 20g to 11 ± 14g ($p<0.001$). Women reported reducing mean energy intake from 1582 ± 379kcal to 1409 ± 326kcal ($p<0.001$) with no change to macronutrient distribution and no reduction in alcohol. Fibre intake was maintained. In men (n=148) weak and clinically insignificant associations were found between increased carbohydrates and reduction in HbA1c (β= -0.003 [-0.006, -0.001]; p=0.009), increased fibre and reduction in total cholesterol (β= -0.023 [-0.044, -0.002]; p=0.033), decreased total fat and reduction in LDL-cholesterol (β= 0.024 [0.006, 0.001]; p=0.011), and decreased alcohol and reduction in diastolic blood pressure (β= 0.276 [0.055, 0.497]; p=0.015). In women (n=75) associations were found between a decrease in trans-fats and reductions in waist circumference (β= -0.029 [0.006, 0.052]; p=0.015), total cholesterol (β= 0.399 [0.028, 0.770]; p=0.036) and LDL cholesterol (β= 0.365 [0.042, 0.668]; p=0.028).

Conclusion: Clinically significant metabolic improvements observed in a patient-centred dietary intervention are not explained by changes in percentage intake of macronutrients. However, a non-prescriptive approach may promote a reduction in total energy intake whilst maintaining fibre consumption.

Article summary

Strengths and limitations

- Describes the dietary intake of people soon after diagnosis of Type 2 DM living in the UK, the dietary changes made during a dietary intervention and examines associations between dietary changes and changes in metabolic outcomes. This intervention was based on the dietary advice that is given in routine clinical practice in the UK.

- Only 53% of the participants provided food diary data at the end of the trial and these people showed greater improvements in metabolic outcomes than those who did not return food diaries. It is probable that they were more motivated than a typical patient group and this limits the generalizability of the findings.

Introduction

Dietary management is recognised as highly important in the treatment of Type 2 diabetes (Type 2 DM). Based upon meta-analyses of exercise and diet studies, the American Diabetes Association (ADA) and European Association for the Study of Diabetes (EASD) recommend that lifestyle interventions should be initiated as the first step in treating new-onset Type 2 DM [1]. Over the last 3 years, The Look Ahead research group, the Lifestyle Over and Above Drugs in Diabetes (LOADD) and Early Activity in Diabetes (Early ACTID) randomised controlled trials (RCTs) have shown that dietary interventions which target weight reduction are beneficial and improve glycaemic control [2-4]. These trials achieved reductions in HbA1c comparable to reductions demonstrated in patients starting metformin or a gliptin as monotherapies [5] and, although the Look Ahead trial showed no reduction in cardiovascular events after 9.6 years, participants in the intervention arm were less likely to be treated with insulin [6].

The effect of specific dietary changes on metabolic outcomes is still, unclear and no single 'diet for diabetes' has been identified [7]. In recognition of this both the 2012 ADA and EASD joint guidelines and 2011 Diabetes UK nutritional guidelines emphasise the importance of an individualised, patient-centred approach to diet rather than a prescriptive approach [1 8]. Few studies have looked at what changes are made in response to this type of dietary advice and how these impact on metabolic control.

The Early ACTID trial included a non-prescriptive, patient-centred dietary intervention. The trial aimed to assess whether adding physical activity to a dietary intervention produced greater benefit than diet alone or usual care in individuals newly diagnosed with Type 2 DM [4]. Participants who received the lifestyle interventions had better HbA1c, lower body weight, less insulin resistance, and were on less medication than the control group at 6 and 12 months.

The aim of this paper is to describe baseline energy and macronutrient intakes and the reported changes made by men and women newly diagnosed with Type 2 DM who were enrolled into the dietary intervention in the Early ACTID study. The associations between changes to energy, macronutrients and metabolic outcomes were explored to determine the effect of dietary changes on the metabolic variables.

There is evidence that men and women living in the UK have differing dietary patterns [9]. Men have been reported to drink more alcohol and consume more meat but less fruit and diet soft drinks than women [10]. Based on this evidence, we hypothesised that men and women with Type 2 DM would make different dietary changes in response to the dietary intervention and so gender differences were also examined.

Subjects and methods

Subjects

This paper is a secondary analysis of data from the Early ACTID randomised controlled trial. Early ACTID was a diet and physical activity trial involving patients living in the South West of England who were recruited within 5 to 8 months of a diagnosis of Type 2 DM from December 2005 to September 2008. Full trial procedures with the CONSORT diagram and results are described elsewhere [4 11 12].

Overview of the dietary intervention

Patients in the diet alone and the diet and physical activity groups received the same dietary intervention. For the first 6 months the intervention aimed to promote dietary change. At randomisation patients attended a one-hour appointment with a study dietitian followed by 2 further visits of 30 minutes. These visits were supported by 6 additional visits with a research nurse, where 15 minutes were used to discuss dietary matters for both groups, reinforcing dietary goals, and 15 minutes to discuss physical activity or other matters pertinent to the patient, depending upon intervention group. Maintenance was the primary goal of the second 6 months and consisted of 2 more 30 minute dietitian visits and 4 additional visits with the research nurses.

The dietary intervention was based upon the 2003 Diabetes UK healthy eating guidelines [13] and employed goal oriented motivational interviewing [14]. Patients were encouraged to discuss their reasons for change, any ambivalence about change and to set their own dietary goals and identify their own strategies for achieving these goals. Prescriptive daily requirements for energy or macronutrients were not calculated unless requested by the patient and prescriptive meal plans or food lists were not used. Instead patients received study specific written dietary information at each visit (available here: http://jcrubristol.org.uk/EA/ACTID%20patients%20Handbook/Forms/AllItems.aspx) and were encouraged to use this to evaluate their own eating habits. The materials included information on maintaining a regular meal pattern and including starchy carbohydrates as a part of each meal, reducing total, saturated and *trans* fat intake, limiting non-milk extrinsic sugars, aiming for 5 portions a day of fruit and vegetables and gave guidance on portion control. The benefit of aiming for a 5 to 10% weight loss by reducing overall energy intake was discussed with everyone. Goals were reviewed at each appointment and successes, difficulties and new strategies discussed. Patients were encouraged to self-monitor their weight and diet.

Measurements

Measures were taken at baseline (prior to randomisation) and repeated 6 and 12 months later. Baseline and 6 month data were used in the current analysis, since outcomes at 6 months were defined as the primary endpoint of the study. Measurements used in this analysis were weight, height (to calculate body mass index (BMI)), waist circumference, blood pressure, HbA1c, fasting lipids and minutes of moderate to vigorous physical activity (MVPA) measured using accelerometry and defined as activity expending greater than 3kcal/kg/hour . As previously described, blood measurements and anthropometric measures were carried out using standardised procedures [11]. Smoking habits and use of dietary supplements were assessed by a research nurse. The UK Index of Multiple Deprivation (IMD) 2007 was calculated from home postcode and used as an indicator of socio-economic position [15].

Dietary assessment and analysis

Patients in the intervention arms were asked to complete 4-day food diaries prior to each dietitian appointment, recording all foods and drinks consumed during those 4 days. Portion sizes were estimated using household measures and package weights and brands indicated where appropriate. The diaries were discussed during the appointments and used to identify potential areas for change, difficulties in making change, and for patients to observe change in their diets over time. Patients were asked to return all the diaries at the final visit for further analysis. Those who did not return diaries at the visit were reminded by telephone and e-mail to post outstanding diaries to the research team after the visit.

Baseline and 6-month food diaries were coded by one coder and checked for accuracy and agreement by a second coder, using the dietary coding programme Diet in Data Out (DIDO), developed at the Medical Research Council Human Nutrition Unit in Cambridge, UK [16]. Diaries were analysed with the nutrient analysis programme Bristol General Analysis of Dietary Experiments (BRIGADE) [17]. The nutrient database is based on *McCance and Widdowson's Composition of Foods, 5th edition* [18], updated with the supplements to that edition, new data from the 6th edition and manufacturers' data. Additional nutrient data from the INTERMAP nutrient database for the UK were also used [19]. If no portion size information was given, age-appropriate portion sizes were assigned [20]. The mean daily consumption of each nutrient was calculated for each participant.

Statistical analysis

As the dietary intervention was designed to be identical for both intervention groups and there were no difference in outcomes between the diet and diet and physical activity groups, the data were analysed as a cohort. Patients in the usual care group were excluded from the analysis since they did not receive the dietary intervention and were not asked to complete a diary at 6 months. Descriptive statistics were used for patient characteristics and for intakes of macronutrients at baseline and 6 months. Variables were checked for normal distribution; non-normal variables were log transformed prior to analysis. For ease of interpretation, arithmetic means and back transformed variables are presented. Independent *t*-tests were used to explore differences in continuous variables between men and women at baseline and between those who did and did not return food diaries, and chi-squared tests were used to explore differences in dichotomous variables. Paired sample *t*-tests were used to describe differences in energy and macronutrient intake between baseline and 6 months. McNemar tests were used to explore differences in numbers of people meeting recommendations at baseline and 6 months. As alcohol variables could not be transformed, the Mann Whitney U and paired sample Wilcoxon signed rank test were used to describe differences. Cases with missing data were excluded listwise.

Multivariate regression models were used to investigate associations between changes in energy and macronutrient intake and the metabolic variables at 6 months in those who provided valid physical activity data. Change in energy intake was explored using a standard multivariate model. Each macronutrient was explored independently using a multivariate nutrient density model to adjust for change in energy intake. Change in percentage energy from each macronutrient was calculated and entered into the model with change in total energy included as a covariate. Change in fibre intake was explored using a standard multivariate model and entered as an absolute intake (in grams) with change to total energy intake as a covariate [21]. Models were adjusted for age, BMI, time since diagnosis, minutes of moderate to vigorous physical activity (MVPA) and dichotomous yes/no variables for smoking status, relevant lipid lowering, blood pressure and diabetes medication and dietary supplement use.

Due to the number of different analyses that were conducted the results are interpreted in terms of strength of evidence of associations [22]. This is an exploratory analysis and as such has not been adjusted for multiple comparisons, consequently p values of <0.05 are interpreted as some evidence of association, p<0.01 as increasing evidence and p<0.001 as strong evidence.

Results

Study participants

A total of 593 patients were recruited into the Early ACTID study, with 494 being assigned to one of the intervention groups. 396 (80%) patients were recorded as completing food diaries at both baseline and 6 months but only 262 (53%) patients returned them, and 223 of these had valid accelerometry data at both time points. At 6 months 491 (99%) patients assigned to one of the intervention arms remained in the study, with 434 (88%) attending all scheduled visits up to that point and a further 37 (8%) attending all except one.

Mean age was 62.4 (9.0) years, 97% of patients were white, 83% were married or with a long term partner and 41% were in the lowest IMD quartile. 40% of participants were on oral hypoglycaemic medication, 65% on lipid lowering medication and 66% on blood pressure medication. Only 6% of patients were current smokers at baseline. Men and women had similar characteristics, although there was some evidence that men were more likely to be on lipid lowering medication than women (69% vs. 56%, p=0.041).

Compared to the patients who did not return food diaries, those who did were older (62 years vs 57 years, p<0.001), with a lower mean weight (88.2 kg vs 93.3 kg, p=0.001), lower mean BMI (30.7 vs 32.5, p=0.001) and lower mean waist circumference (105 cm vs 108 cm, p=0.025), but there was no difference in glycaemic control, lipids and blood pressure.

Metabolic outcomes

Table 1 shows the metabolic outcomes at baseline and 6 months for those who returned food diaries. There was no difference in glycaemic control or blood pressure between men and women, but women had higher total ($p<0001$), LDL ($p<0.001$) and HDL ($p=0.015$) cholesterol levels.

Weight, waist circumference and BMI improved at 6 months for both men and women ($p<0.001$). Men and women improved their HbA1c (men: $p=0.006$; women: $p<0.001$). Men improved their fasting blood glucose ($p=0.006$) and there is some evidence that women increased their HDL cholesterol ($p=0.033$).

At 6 months those who returned food diaries had lost more weight (2.4 kg vs 1.3 kg, $p=0.001$), reduced waist circumference more (2.7 cm vs 1.3 cm, $p=0.022$) and reduced HbA1c (0.18% (2 mmol/l) vs 0% (0 mmol/l), $p=0.02$).

Nutrient analysis

Table 2 shows the mean reported energy and nutrient intakes at baseline and 6 months and their mean reported changes.

At baseline participants reported generally good dietary habits. 61% of women and 59% of men reported the recommended total fat intake (less than 35% of energy from total fat) and 55% of women and 66% of men reported a low to moderate carbohydrate intake (<45% of energy). Men were more likely to drink alcohol and more likely to drink to excess than women with 49% of women and 28% of men recording no alcohol during the 4 days and 8% of women and 19% of men reporting more than 30g of alcohol per day ($p=0.022$).

At 6 months mean daily reported energy intake was reduced by 187 kcal ($p<0.001$). Men reduced their energy intake more than women (218 ± 332 vs. 123 ± 270 kcal/day, $p=0.022$). This was achieved by small reductions in all macronutrients, whilst maintaining fibre intake. The mean percentage energy from macronutrients was unchanged for women whilst men reported a small mean increase of $1.4 \pm 5.9\%$ ($p<0.001$) of energy from carbohydrates. Men reported reducing mean alcohol intake ($p<0.001$), with 40% reporting no alcohol during the 4 days and 15% reporting more than 30g per day. There was no reported mean change in alcohol intake for women. Despite no mean change to energy from saturated fat, more men met recommendations at 6 months (35% men at baseline vs. 49% at 6 months reporting less than 10% energy from saturated fat, p=0.007). There was no change in the number of women meeting recommendations (40% baseline vs 44% at 6 months, p=0.71).

Table 3 shows the regression coefficients and confidence intervals for changes in energy and macronutrients that show evidence for associations with specific metabolic variables. In men a 1% reduction in energy from alcohol was associated with a 0.276 mmHg reduction in diastolic blood pressure (95% CI= 0.055 to 0.497). In women a 1% reduction in energy from trans-fat was associated with a decrease in cholesterol of 0.399 mmol/l (95% CI= 0.028 to 0.770). In men a 1% increase in energy from carbohydrate was associated with a decrease in HbA1c of 0.003% (95% CI= -0.006 to -0.001). There were no associations between change in energy intake and the metabolic variables.

Discussion

Main findings

The main findings from this analysis are that patients who were randomised to the intervention arms in the Early ACTID study and returned food diaries reported a good diet at baseline but still achieved small dietary changes. They reported a mean decrease in energy intake of around 200 kcal per day, during the first 6 months. Men reported a reduced alcohol intake that produced a greater reduction in energy and reported a small increase in the percentage energy from carbohydrate. Women reported modest reductions to all macronutrients but made no changes to alcohol, their energy reduction was less and the macronutrient ratio of their diets did not change. Both sexes maintained fibre intake. Although changes in percentage intake of macronutrients were associated with metabolic outcomes, these effect sizes were too small to be of clinical significance. These results suggest that current recommendations that dietary advice is personalised, flexible and focuses on realistic, achievable, and sustainable reductions in intake may promote dietary change in people with T2 DM.

Comparison with other studies

The Early ACTID dietary intervention was a pragmatic, 'real world' intervention, in which participants discussed dietary advice with dietitians and nurses to decide on their own dietary changes. The approach contrasts with dietary studies where participants are asked to make specific, prescribed changes to the macronutrient composition, by lowering carbohydrate and increasing protein [23-25] or to lower the glycaemic index [26 27]. The LOADD trial [3] based a successful dietary intervention in patients with poor glycaemic control on very similar recommendations to those used in the Early ACTID intervention, but total energy intake and macronutrient ratios for each participant were calculated and diets were prescribed according to these calculations. The Early ACTID intervention did not compare a prescriptive with a non-prescriptive approach so cannot be used to demonstrate that this is superior but reductions in weight, waist circumference and HbA1c were achieved that are comparable to those achieved during these interventions. Withdrawal rates for prescriptive dietary interventions range from 10% to 30% and these higher withdrawal rates may suggest that in routine clinical care a more flexible approach can be advantageous in promoting retention. Of those participants in Early ACTID who either did not attend all appointments or withdrew completely, only one person stated that they did not see the benefit of the trial. The majority could not schedule all 9 dietitian and nurse visits because of other commitments, 5 cited other health issues, 3 moved too far away, 1 said they 'did not want to diet,' 1 wanted to take orlistat from baseline and 3 gave no reasons. What is common to intervention trials in diabetes is that patients receive individual support and attend multiple appointments with a dietitian or a health practitioner who is expert in promoting dietary change. It is important to emphasise that this model is not routinely replicated in primary care for patients with Type 2 DM.

The associations between specific dietary changes and metabolic outcomes have not, as far as we are aware, previously been examined in patients with Type 2 DM. Effect sizes were small and not clinically significant but they are consistent with existing nutritional data on the benefits of a reduction in trans fats on lipids and waist circumference [28], an increase in fibre on LDL cholesterol [29] and a reduction in alcohol and blood pressure [30]. It is of interest that this analysis found that there was no benefit in carbohydrate reduction in men with good glycaemic control who are already consuming a low to moderate carbohydrate diet. It is not possible to determine whether there is an optimum macronutrient distribution for T2 DM from this analysis, particularly in those with poor glycaemic control, but there is no unequivocal evidence that low carbohydrate diets produce better blood glucose control or weight loss than higher carbohydrate diets [31]. A meta-analysis of low carbohydrate diets versus low fat diets conducted in 2012 [32] concluded that there was evidence of a small but beneficial effect on lipid profiles of a low (defined as <45% energy from carbohydrate) or very low carbohydrate (<60g carbohydrate) diet but no difference in improvements to weight or glycaemic control.

Strengths and weaknesses

To our knowledge this is the first study to describe the dietary intake of people soon after diagnosis with Type 2 DM living in the UK, the dietary changes made during an intervention based on patient-centred, non-prescriptive dietary advice and that examines associations between dietary change and metabolic variables. The demographics of the Early ACTID participants included in this analysis suggest that these findings are only representative of the white population; however the sample is socio-economically diverse with 40% of participants living in areas of high economic deprivation.

The study has important weaknesses. Only 53% of the participants returned baseline and 6 month food diaries at the end of the trial and these people had a lower BMI and waist circumference at baseline and achieved greater metabolic improvements. The participants who did not return diaries reported mislaying them which may indicate less motivation and less engagement with the trial. Participants who did return diaries could have been more motivated to make dietary changes than a typical patient population, and, given that their diets were good at baseline, may already have made dietary changes prior to entry into the Early ACTID study. The relative lack of dietary data limits our ability to generalise these findings to broader patient groups.

The use of any self-reported measure of diet, including 4-day food diaries, is a recognised limitation in dietary studies. Under-reporting of food intake and selective under-reporting or under-eating of foods perceived to be 'bad' are commonly documented, especially in people who are obese [33 34]. Methods exist to estimate under-reporting, using calculated basal metabolic rate and estimates of physical activity [35 36] but these methods assume that an individual's weight is stable and are consequently inappropriate for use during a weight loss trial. It should be noted that other dietary interventions in patients with Type 2 DM have reported similar energy intakes [23 26] and an energy reduction of around 200kcal/day is plausible assuming a dynamic model of energy balance [37] and given the modest weight reduction observed. It is also important to note that this is a secondary analysis so cause and effect cannot be assumed.

Conclusion

The Early ACTID trial indicates that a flexible, non-prescriptive approach to dietary advice based on standard healthy eating guidelines in Type 2 DM given soon after diagnosis may be effective in promoting small dietary change, even in patients with good glycaemic control. This supports current clinical practice and guidelines. The current analysis suggests that changes in percentage intake of macronutrients did not have any clinically significant effect on metabolic outcomes during the trial but this needs confirmation in a larger cohort, with less good glycaemic control. Further research is needed on whether dietary changes made using a non-prescriptive approach are sustainable and beneficial in the longer term in a more typical patient population.

Acknowledgements

We would like to acknowledge the participants in the Early ACTID trial, members of the Early ACTID team and steering committee, Dr Pauline Emmett for advice on dietary analysis, Dr Rosemary Greenwood for advice on statistical analysis and Professor Debbie Sharp for assistance in manuscript preparation.

Funding

The Early ACTID trial was supported by Diabetes UK, the UK Department of Health and Western Comprehensive Local Research Network. Pilot dietary analysis was supported by the Above and Beyond Foundation. C.Y. England is supported by NIHR Clinical Doctoral Research Fellowship 10-017.

Authors' contributions

This work forms part of the PhD of CYE which is supervised by RCA, JLT and RJ. RCA led the Early ACTID study and advised on clinical application of this work. CYE participated in data collection, data entry and was responsible for data analysis with guidance from JLT and RJ. ARC was responsible for the design of the ACTID physical activity intervention and for processing and analysis of the physical activity data. The first draft of the manuscript was prepared by CYE with critical input and revisions by all other authors. All authors approved the final manuscript.

Conflicts of interests

The authors declare that they have no conflict of interest

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Table 1: Metabolic characteristics at baseline and 6 months

Metabolic characteristics	Baseline			6 months			Change (6 months - baseline)		
	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)
Weight, kg	88.2 (16.1)	83.1 (17.9)	90.7 (14.5)[c]	85.9 (16.3)	80.7 (17.7)	88.5 (15.0)	- 2.3 (3.3)[z]	- 2.5 (3.3)[z]	- 2.3 (3.3)[z]
Body mass index, kg/m^2	30.7 (5.3)	31.9 (6.9)	30.2 (4.7)[a]	29.9 (5.4)	30.9 (6.2)	29.4 (4.9)	- 0.8 (1.2)[z]	- 1 (1.0)[z]	- 0.8 (1.1)[z]
Waist circumference, cm	105 (12)	102 (13)[1]	107 (11)[b]	103 (12)	100 (13)	104 (12)	- 3 (4)[z]	- 3 (4)[z]	- 3 (4)[z]
HbA1c, % (mmol/l)	6.66 (0.94) (49.0 (10.3))	6.67 (0.91) (49.0 (9.9))	6.65 (0.95) (49.0 (10.4))	6.47 (0.89) (47.0 (9.7))	6.41 (0.63) (47.0 (6.9))	6.51 (0.99)[1] (48.0 (10.8))	- 0.18 (0.72)[z] (- 2.0 (7.9))	- 0.27 (0.63)[z] (- 3.0 (6.9))	- 0.14 (0.75)[x] (- 1.5 (8.2))
Total cholesterol, mmol/l	4.33 (0.90)	4.66 (0.89)[1]	4.16 (0.86)[1c]	4.29 (0.93)	4.66 (0.98)	4.11 (0.84)	- 0.03 (0.69)	0.01 (0.79)	- 0.06 (0.63)
LDL-cholesterol, mmol/l	2.30 (0.78)	2.55 (0.81)[3]	2.18 (0.74)[2c]	2.27 (0.81)	2.51 (0.88)[3]	2.15 (0.75)[1]	- 0.03 (0.67)	- 0.03 (0.76)	- 0.03 (0.62)
HDL-cholesterol, mmol/l	1.29 (0.33)	1.37 (0.39)[1]	1.25 (0.29)[1a]	1.34 (0.37)	1.45 (0.47)	1.28 (0.30)	0.05 (0.27)[y]	0.09 (0.37)[x]	0.03 (0.21)
Systolic blood pressure, mmHg	134 (16)	133 (16)	134 (15)	134 (15)	135 (16)	134 (14)	1 (12)	2 (13)	0 (12)
Diastolic blood pressure, mmHg	79 (8)	78 (8)	79 (8)	78 (8)	78 (8)	78 (8)	0 (7)	0 (8)	0 (7)
Physical activity	(n=223)	(n=75)	(n=148)	(n=223)	(n=75)	(n=148)	(n=223)	(n=75)	(n=148)
Minutes of moderate to vigorous physical activity / day (MVPA)	26 (21)	21 (18)	29 (22)	33 (25)	21 (19)	38 (26)	7 (21)	1 (12)	10 (24)

a = p<0.05; b = p<0.005; c = p<0.001 women vs. men at baseline
x = p<0.05; y = p<0.005; z = p<0.001 baseline vs. 6 month
Numerical superscripts indicate number of participants with missing data for the variable of interest.

Table 2: Nutrient intake at baseline and 6 months

Mean daily intake nutrients	Baseline			6 months			Change (6 months - baseline)		
	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)
Energy (kcal)	1796 (461)	1582 (379)	1903 (462)[c]	1610 (418)	1459 (326)	1685 (439)[c]	-187 (315)[z]	- 123 (270)[z]	- 218 (332)[a z]
Protein (g)	80 (19)	73 (16)	83 (20)[c]	74 (19)	68 (13)	77 (20)[c]	- 6 (17)[z]	- 5 (15)[y]	- 6 (19)[z]
Total carbohydrates (g)	202 (55)	186 (48)	211 (57)[b]	186 (53)	170 (39)	194 (58)[b]	- 17 (41)[z]	- 15 (33)[z]	- 17 (45)[z]
Total sugar (g)	81 (32)	77 (28)	83 (34)	75 (31)	71 (23)	77 (34)	- 6 (26)[z]	- 6 (21)[x]	- 6 (28)[y]
Starch (g)	119 (36)	105 (30)	126 (37)[c]	109 (31)	97 (26)	115 (32)[c]	-10 (28)[z]	- 9 (24)[y]	- 11 (30)[z]
Non-starch polysaccharide (g)	17 (5)	16 (5)	17 (5)	16 (5)	15 (4)	17 (5)[a]	- 1 (5)	- 1 (4)	0 (5)
Total fat (g)	69 (22)	61 (20)	73 (220)[c]	61 (20)	56 (19)	64 (20)[b]	- 8 (18)[z]	- 5 (17)[x]	- 9 (18)[z]
Saturated fat (g)	23 (9)	21 (8)	24 (9)[b]	20 (9)	19 (9)	21 (9)	- 3 (8)[z]	- 2 (7)[x]	- 3 (8)[z]
Trans fat (g)	2.3 (1.1)	2.0 (1)	2.4 (1.1)[b]	2.1 (1.1)	1.9 (1.1)	2.2 (1.1)[a]	- 0.2 (1.1)[y]	- 0.1 (1.1)	- 0.3 (1.2)[y]
Monounsaturated fat (g)	24 (8)	21 (8)	26 (8)[c]	22 (8)	20 (7)	23 (8)[b]	- 2 (7)[z]	- 1 (8)[x]	- 3 (7)[z]
Polyunsaturated fat (g)	13 (6)	12 (6)	14 (6)[a]	12 (4)	11 (4)	13 (5)[a]	- 1 (5)[z]	-1 (6)	- 1 (5)[y]
Alcohol (g)	14 (18)	7 (11)	18 (20)[a]	10 (13)	7 (9)	11 (14)[b]	- 5 (14)[z]	0 (10)	- 7 (15)[c z]
% Energy from protein	18.3 (3.6)	19.0 (3.7)	18.0 (3.5)[a]	18.8 (3.5)	19.0 (3.3)	18.7 (3.6)	0.5 (3.7)[z]	0.0 (3.6)	0.7 (3.8)[y]
% Energy from total carbohydrates	43.2 (6.6)	44.8 (6.4)	42.4 (6.6)[a]	44.1 (6.5)	44.7 (6.2)	43.8 (6.6)	0.9 (6.0)[z]	- 0.1 (6.2)	1.4 (5.9)[y]
% Energy from total fat	33.5 (5.6)	33.4 (5.8)	33.6 (5.5)	33.3 (5.8)	33.3 (6.4)	33.3 (5.4)	-0.2 (5.9)	- 0.1 (6.3)	- 0.3 (5.7)
% Energy from saturated fat	11.2 (3.1)	11.4 (3.4)	11.2 (3.1)	11.0 (3.4)	11.1 (3.6)	10.9 (3.2)	- 0.3 (3.3)	- 0.3 (3.1)	- 0.3 (3.5)
% Energy from trans fat	1.1 (0.4)	1.1 (0.43)	1.1 (0.5)	1.1 (0.5)	1.1 (0.4)	1.1 (0.5)	0.0 (0.5)	0.0 (0.5)	0.0 (0.5)
% Energy from monounsaturated fat	11.7 (2.5)	11.5 (2.6)	11.9 (2.5)	11.9 (2.5)	11.7 (2.7)	12.0 (2.5)	- 0.2 (2.8)	0.2 (3.2)	0.1 (2.6)
% Energy from polyunsaturated fat	6.5 (2.2)	6.7 (2.4)	6.4 (2.1)	6.6 (1.9)	6.6 (1.9)	6.6 (1.9)	0.1 (2.4)	0.0 (2.6)	0.2 (2.3)
% Energy from total sugar	17.2 (5.7)	18.7 (5.5)	16.5 (5.6)[b]	17.7 (5.7)	18.8 (5.4)	17.2 (5.8)[a]	0.5 (5.0)	0.2 (5.2)	0.7 (4.9)
% Energy from alcohol	5.0 (6.1)	2.9 (4.3)	6.1 (6.6)[c]	3.9 (4.9)	3.0 (3.9)	4.3 (5.3)[a]	- 1.2 (4.7)[z]	0.2 (4.0)	- 1.8 (5.0)[c z]

a = p<0.05; b = p<0.005; c = p<0.001 women vs. men
y = p<0.005; z = p<0.001 baseline vs. 6 months

Table 3: Associations between macronutrients and metabolic outcomes in men (n=148) and women (n=75) who provided physical activity data.

Macronutrient		Metabolic outcomes	Regression coefficient, β (95% Confidence interval)	p value
Change to % energy from total carbohydrates	Men	HbA1c	-0.003 (-0.006, -0.001)	0.009
Change to fibre (nsp) intake (g)	All	Total cholesterol	-0.023 (-0.044, -0.002)	0.033
	Men	Total cholesterol	-0.025 (-0.047, -0.003)	0.023
Change to % energy from total fat	All	LDL cholesterol	0.018 (0.003, 0.032)	0.016
	Men	LDL cholesterol	0.024 (0.006, 0.042)	0.011
Change to % energy from trans fat	All	Waist circumference	0.014 (0.003, 0.024)	0.011
	Women	Waist circumference	0.029 (0.006, 0.052)	0.015
		Total cholesterol	0.399 (0.028, 0.770)	0.036
		LDL cholesterol	0.365 (0.042, 0.688)	0.028
Change to % energy from monounsaturated fats	All	LDL cholesterol	0.036 (0.006, 0.065)	0.018
Change to % energy from alcohol	All	Diastolic blood pressure	0.217 (0.020, 0.414)	0.031
	Men	Diastolic blood pressure	0.276 (0.055, 0.497)	0.015

All models are adjusted for change in energy intake, outcome at baseline, age, BMI, time since diagnosis, medication, dietary supplements, mean daily minutes of moderate to vigorous physical activity.
For each macronutrient listed a 1% (1g for fibre) increase is associated with the change in outcome listed

BMJ Open

Dietary changes and associations with metabolic improvements in adults with Type 2 diabetes during a patient-centred dietary intervention: an exploratory analysis

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-004953.R1
Article Type:	Research
Date Submitted by the Author:	13-May-2014

Complete List of Authors:	England, Clare; University of Bristol, Centre for Exercise, Nutrition and Health Sciences Thompson, Janice; The University of Birmingham, School of Sport & Exercise Sciences Jago, Russ; University of Bristol, Centre for Exercise, Nutrition and Health Sciences Cooper, Ashley; University of Bristol, Centre for Exercise, Nutrition and Health Sciences Andrews, Robert; University of Bristol, Henry Wellcome Laboratories for Integrative

Primary Subject Heading:	Diabetes and endocrinology
Secondary Subject Heading:	Nutrition and metabolism
Keywords:	Type 2 diabetes, Dietary analysis, Dietary change

Dietary changes and associations with metabolic improvements in adults with Type 2 diabetes during a patient-centred dietary intervention: an exploratory analysis

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Running title: Dietary change in adults with Type 2 diabetes

Keywords: Type 2 diabetes, dietary analysis, dietary change

Bath Research Ethics Committee (05/Q2001/5)

<u>Word count</u>

Abstract: 299

Main text: 3758

Number of tables: 3

Abstract

Objectives: Describe dietary intake of participants enrolled in a non-prescriptive dietary intervention and dietary changes at 6 months and explore whether these changes had a role in observed improvements in HbA1c, weight, lipids and blood pressure.

Design: Secondary analysis of data from the Early ACTivity in Diabetes randomised controlled trial.

Participants 262 patients with newly diagnosed Type 2 diabetes randomised to the dietary intervention.

Outcomes and analysis: Changes in energy intake, macronutrients, fibre and alcohol and in weight, waist circumference, lipids, HbA1c and blood pressure at baseline and 6 months. Multivariate models were used to examine associations between dietary changes and metabolic variables.

Results: Men reported reducing mean energy intake from 1903 ± 462kcal to 1685kcal ± 439kcal ($p<0.001$), increasing carbohydrate intake from 42.4 ± 6.6% to 43.8 ± 6.6% ($p=0.002$) and reducing median alcohol intake from 13 (0-27)g to 5 (0-18)g ($p<0.001$). Women reported reducing mean energy intake from 1582 ± 379kcal to 1459 ± 326kcal ($p<0.001$) with no change to macronutrient distribution and alcohol. Fibre intake was maintained. In men (n=148) weak and clinically insignificant associations were found between increased carbohydrates and reduction in HbA1c (β= -0.003 [-0.006, -0.001]; $p=0.009$), increased fibre and reduction in total cholesterol (β= -0.023 [-0.044, -0.002]; $p=0.033$), decreased total fat and reduction in LDL-cholesterol (β= 0.024 [0.006, 0.001]; $p=0.011$), and decreased alcohol and reduction in diastolic blood pressure (β= 0.276 [0.055, 0.497]; $p=0.015$). In women (n=75) associations were found between a decrease in trans-fats and reductions in waist circumference (β= -0.029 [0.006, 0.052]; $p=0.015$), total cholesterol (β= 0.399 [0.028, 0.770]; $p=0.036$) and LDL cholesterol (β= 0.365 [0.042, 0.668]; $p=0.028$).

Conclusion: Clinically important metabolic improvements observed in a patient-centred dietary intervention were not explained by changes in macronutrients. However, a non-prescriptive approach may promote a reduction in total energy intake whilst maintaining fibre consumption.

Article summary

Strengths and limitations

- Describes the dietary intake of people soon after diagnosis of Type 2 DM living in the UK, the dietary changes made during a dietary intervention and explores associations between dietary changes and changes in metabolic outcomes. This intervention was based on the dietary advice that is given in routine clinical practice in the UK.

- Only 53% of the participants provided food diary data at the end of the trial and these people showed greater improvements in metabolic outcomes than those who did not return food diaries. It is probable that they were more motivated than a typical patient group and this limits the generalizability of the findings.

Introduction

Dietary management is recognised as highly important in the treatment of Type 2 diabetes (Type 2 DM). Based upon meta-analyses of exercise and diet studies, the American Diabetes Association (ADA) and European Association for the Study of Diabetes (EASD) recommend that lifestyle interventions should be initiated as the first step in treating new-onset Type 2 DM [1]. Over the last 3 years, The Look Ahead research group, the Lifestyle Over and Above Drugs in Diabetes (LOADD) and Early Activity in Diabetes (Early ACTID) randomised controlled trials (RCTs) have shown that dietary interventions which target weight reduction are beneficial and improve glycaemic control [2-4]. These trials achieved reductions in HbA1c comparable to reductions demonstrated in patients starting metformin or a gliptin as monotherapies [5] and, although the Look Ahead trial showed no reduction in cardiovascular events after 9.6 years, participants in the intervention arm were less likely to be treated with insulin [6].

It has been reported that changes to the macronutrient composition of the diet may impact upon glycaemic control, blood lipids and weight [7], but the effect of specific dietary changes on these metabolic outcomes are still unclear and no single 'diet for diabetes' has been identified [8]. In recognition of this, both the 2012 ADA and EASD joint guidelines and 2011 Diabetes UK nutritional guidelines emphasise the importance of an individualised, patient-centred approach to diet rather than a prescriptive approach [1 ,9]. This approach recognises that different people have individual dietary habits and may find certain dietary changes more straightforward than others. There is evidence that men and women living in the UK have differing dietary patterns [10]. Men have been reported to drink more alcohol and consume more meat but less fruit and diet soft drinks than women [11]Few studies have looked at what changes are made to macronutrients in response to non-prescriptive dietary advice, whether men and women make different changes and whether these changes impact on metabolic control.

The Early ACTID trial included a non-prescriptive, patient-centred dietary intervention. The trial aimed to assess whether adding physical activity to a dietary intervention produced greater benefit than diet alone or usual care in individuals newly diagnosed with Type 2 DM [4]. Participants who received the lifestyle interventions had better HbA1c, lower body weight, less insulin resistance, and were on less medication than the control group at 6 and 12 months. During the intervention participants in this cohort reported small changes to higher calorie, low fibre foods. Examination of the specific changes to foods and food groups reported by participants has been previously published [12] and this current paper focuses on macronutrients.

The aim of this paper is to describe baseline energy and macronutrient intakes of men and women who were enrolled into the dietary intervention in the Early ACTID study and to examine reported dietary changes made after 6 months.

We conducted exploratory analysis to examine the following hypotheses:

- Men and women with Type 2 DM make different dietary changes in response to a dietary intervention.
- The changes to energy intake and macronutrients are associated with beneficial changes to glycaemic control, weight, waist circumference, blood pressure and lipids.

Subjects and methods

Subjects

This paper is an exploratory analysis of data from the Early ACTID randomised controlled trial. Early ACTID was a diet and physical activity trial involving patients living in the South West of England who were recruited within 5 to 8 months of a diagnosis of Type 2 DM from December 2005 to September 2008. Full trial procedures with the CONSORT diagram and results are described elsewhere [4 ,13 ,14]. The analysis is limited to participants in the intervention arms who returned valid food diary data.

Overview of the dietary intervention

Patients in the diet alone and the diet and physical activity groups received the same dietary intervention. For the first 6 months the intervention aimed to promote dietary change. At randomisation patients attended a one-hour appointment with a study dietitian followed by 2 further visits of 30 minutes. These visits were supported by 6 additional visits with a research nurse, where 15 minutes were used to discuss dietary matters for both groups, reinforcing dietary goals, and 15 minutes to discuss either physical activity or other matters pertinent to the patient, depending upon intervention group allocated to. Maintenance was the primary goal of the second 6 months and consisted of 2 more 30 minute dietitian visits and 4 additional visits with the research nurses.

The dietary intervention was based upon the 2003 Diabetes UK healthy eating guidelines [15] and employed goal oriented motivational interviewing [16]. Patients were encouraged to discuss their reasons for change, any ambivalence about change and to set their own dietary goals and identify their own strategies for achieving these goals. Prescriptive daily requirements for energy or macronutrients were not calculated unless requested by the patient and prescriptive meal plans or food lists were not used. Instead patients received study specific written dietary information at each visit (available here: http://jcrubristol.org.uk/EA/ACTID%20patients%20Handbook/Forms/AllItems.aspx) and were encouraged to use this to evaluate their own eating habits. The materials included information on maintaining a regular meal pattern and including starchy carbohydrates as a part of each meal, reducing total, saturated and *trans* fat intake, limiting non-milk extrinsic sugars, aiming for 5 portions a day of fruit and vegetables and gave guidance on portion control. Specific food choices were discussed and participants were advised on choosing wholegrain and higher fibre foods, reducing fatty and processed meats and high fat dairy products, and increasing oily fish and limiting foods like cakes, biscuits, salty snacks and take-away meals. The benefit of aiming for a 5 to 10% weight loss by reducing overall energy intake was discussed with everyone. Goals were reviewed at each appointment and successes, difficulties and new strategies discussed. Patients were encouraged to self-monitor their weight and diet.

Measurements

Measures were taken at baseline (prior to randomisation) and repeated 6 and 12 months later. Baseline and 6 month data were used in the current analysis, since outcomes at 6 months were defined as the primary endpoint of the study. Measurements used in this analysis were weight, height (to calculate body mass index (BMI)), waist circumference, blood pressure, HbA1c, fasting lipids and minutes of moderate to vigorous physical activity (MVPA) measured using accelerometry and defined as activity expending greater than 3kcal/kg/hour . As previously described, blood measurements and anthropometric measures were carried out using standardised procedures [13]. Smoking habits and use of dietary supplements were assessed by a research nurse. The UK Index of Multiple Deprivation (IMD) 2007 was calculated from home postcode and used as an indicator of socio-economic position [17].

Dietary assessment and analysis

Patients in the intervention arms were asked to complete 4-day food diaries, to include 2 weekdays and 1 weekend day, prior to each dietitian appointment, recording all foods and drinks consumed during those 4 days. Portion sizes were estimated using household measures and package weights and brands indicated where appropriate. The diaries were discussed during the appointments and used to identify potential areas for change, difficulties in making change, and for patients to observe change in their diets over time. Patients were asked to return all the diaries at the final visit for further analysis. Those who did not return diaries at the visit were reminded by telephone and e-mail to post outstanding diaries to the research team after the visit.

Baseline and 6-month food diaries were coded by one coder and checked for accuracy and agreement by a second coder, using the dietary coding programme Diet in Data Out (DIDO), developed at the Medical Research Council Human Nutrition Unit in Cambridge, UK [18]. Diaries were analysed with the nutrient analysis programme Bristol General Analysis of Dietary Experiments (BRIGADE) [19]. The nutrient database is based on *McCance and Widdowson's Composition of Foods, 5th edition* [20], updated with the supplements to that edition, new data from the 6th edition and manufacturers' data. Additional nutrient data from the INTERMAP nutrient database for the UK were also used [21]. If no portion size information was given, age-appropriate portion sizes were assigned [22]. The mean daily consumption of each nutrient was calculated for each participant.

Statistical analysis

As the dietary intervention was designed to be identical for both intervention groups and there were no difference in outcomes between the diet and diet and physical activity groups, the data were analysed as a cohort. Patients in the usual care group were excluded from the analysis since they did not receive the dietary intervention and were not asked to complete a diary at 6 months. Descriptive statistics were used for patient characteristics and for intakes of macronutrients at baseline and 6 months. Variables were checked for normal distribution;

non-normal variables were log transformed prior to analysis. For ease of interpretation, arithmetic means and back transformed variables are presented. Independent *t*-tests were used to explore differences in continuous variables between men and women at baseline and between those who did and did not return food diaries, and chi-squared tests were used to explore differences in dichotomous variables. Paired sample *t*-tests were used to describe differences in energy and macronutrient intake between baseline and 6 months. McNemar tests were used to explore differences in numbers of people meeting recommendations at baseline and 6 months. As alcohol variables could not be transformed, the Mann Whitney U and paired sample Wilcoxon signed rank test were used to describe differences. Cases with missing data were excluded listwise. Data were assumed to be randomly missing and table 1 includes numerical superscripts to indicate the number of participants with missing data for the variable of interest.

Multivariate regression models were used to conduct exploratory analysis to investigate associations between changes in energy and macronutrient intake and the metabolic variables at 6 months in those who provided valid physical activity data. Changes in energy intake were explored using a standard multivariate model. Each macronutrient was explored independently using a multivariate nutrient density model to adjust for change in energy intake. Change in percentage energy from each macronutrient was calculated and entered into the model with change in total energy included as a covariate. Change in fibre intake was explored using a standard multivariate model and entered as an absolute intake (in grams) with change to total energy intake as a covariate [23]. Models were adjusted for age, BMI, time since diagnosis, minutes of moderate to vigorous physical activity (MVPA) and dichotomous yes/no variables for smoking status, relevant lipid lowering, blood pressure and diabetes medication and dietary supplement use at 6 months.

Due to the number of different analyses that were conducted the results are interpreted in terms of strength of evidence of associations [24]. This is an exploratory analysis and as such has not been adjusted for multiple comparisons [25 ,26], consequently p values of <0.05 are interpreted as some evidence of association, $p<0.01$ as increasing evidence and $p<0.001$ as strong evidence.

Results

Study participants

A total of 593 patients were recruited into the Early ACTID study, with 494 being assigned to one of the intervention groups. 396 (80%) patients were recorded as completing food diaries at both baseline and 6 months but only 262 (53%) patients returned them. Metabolic and dietary outcomes at baseline and 6 months are presented for these 262 patients. At 6 months 491 (99%) patients assigned to one of the intervention arms remained in the study, with 434 (88%) attending all scheduled visits up to that point and a further 37 (8%) attending all except one.

Mean age was 62.4 (9.0) years, 97% of patients were white, 83% were married or with a long term partner and 41% were in the lowest IMD quartile. At baseline 104 (40%) of participants were on oral hypoglycaemic medication, 170 (65%) on lipid lowering medication and 174 (66%) on blood pressure medication. Only 6% of patients were current smokers at baseline. Men and women had similar characteristics, although there was some evidence that men were more likely to be on lipid lowering medication than women (69% vs. 56%, p=0.041). At 6 months, 105 (40%) of participants were on oral hypoglycaemic medication, although 12 (5%) participants had increased the dose and 4 (2%) had decreased; 177 (68%) were on lipid lowering medication and 175 (67%) were on blood pressure medication.

Compared to the patients who did not return food diaries, those who did were older (62 years vs 57 years, p<0.001), with a lower mean weight (88.2 kg vs 93.3 kg, p=0.001), lower mean BMI (30.7 vs 32.5, p=0.001) and lower mean waist circumference (105 cm vs 108 cm, p=0.025), but there was no difference in glycaemic control, lipids and blood pressure.

Metabolic outcomes

Table 1 shows the metabolic outcomes at baseline and 6 months for those who returned food diaries. There was no difference in glycaemic control or blood pressure between men and women, but women had higher total (p<0001), LDL (p<0.001) and HDL (p=0.015) cholesterol levels.

Weight, waist circumference and BMI improved at 6 months for both men and women (p<0.001). Men and women improved their HbA1c (men: p=0.006; women: p<0.001). Men improved their fasting blood glucose (p=0.006) and there is some evidence that women increased their HDL cholesterol (p=0.033).

At 6 months those who returned food diaries had lost more weight (2.4 kg vs 1.3 kg, p=0.001), reduced waist circumference more (2.7 cm vs 1.3 cm, p=0.022) and reduced HbA1c (0.18% (2 mmol/l) vs 0% (0 mmol/l), p=0.02).

Nutrient analysis

Table 2 shows the mean reported energy and nutrient intakes at baseline and 6 months and their mean reported changes.

At baseline participants reported generally good dietary habits. 61% of women and 59% of men reported the recommended total fat intake (less than 35% of energy from total fat) and 55% of women and 66% of men reported a low to moderate carbohydrate intake (<45% of energy). Men were more likely to drink alcohol and more likely to drink to excess than women with 49% of women and 28% of men recording no alcohol during the 4 days and 8% of women and 19% of men reporting more than 30g of alcohol per day (p=0.022).

At 6 months mean daily reported energy intake was reduced by 187 kcal (p<0.001). Men reduced their energy intake more than women (218 ± 332 vs. 123 ± 270 kcal/day, p=0.022). This was achieved by small reductions in all macronutrients, whilst maintaining fibre intake. The mean percentage energy from macronutrients was unchanged for women whilst men reported a small mean increase of 1.4 ± 5.9% (p<0.001) of energy from carbohydrates. Men reported reducing median alcohol intake (p<0.001), with 40% reporting no alcohol during the 4 days and 15% reporting more than 30g per day. There was no reported median change in alcohol intake for women. Despite no mean change to energy from saturated fat, more men met recommendations at 6 months (35% men at baseline vs. 49% at 6 months reporting less than 10% energy from saturated fat, p=0.007). There was no change in the number of women meeting recommendations (40% baseline vs 44% at 6 months, p=0.71).

Valid physical activity data and dietary data were provided by 223 (45%) participants. Table 3 shows the regression coefficients and confidence intervals for changes in energy and macronutrients that show evidence for associations with specific metabolic variables. In men a 1% reduction in energy from alcohol was associated with a 0.276 mmHg reduction in diastolic blood pressure (95% CI= 0.055 to 0.497). In women a 1% reduction in energy from trans-fat was associated with a decrease in cholesterol of 0.399 mmol/l (95% CI= 0.028 to 0.770). In men a 1% increase in energy from carbohydrate was associated with a decrease in

HbA1c of 0.003% (95% CI= -0.006 to -0.001). There were no associations between change in energy intake and the metabolic variables.

Discussion

Main findings

The main findings from this exploratory analysis are that patients who were randomised to the intervention arms in the Early ACTID study and returned food diaries reported a good diet at baseline but still achieved small dietary changes. They reported a mean decrease in energy intake of around 200 kcal per day, during the first 6 months. This is a modest reduction in calorie intake but, if sustained, will have an impact on weight and glycaemic control. It has been argued that long-term small changes are more effective for weight management than short-term large changes [27]. Men reported a reduced alcohol intake that produced a greater reduction in energy and reported a small increase in the percentage energy from carbohydrate. Women reported modest reductions to all macronutrients but made no changes to alcohol, their energy reduction was less and the macronutrient ratio of their diets did not change. Both sexes maintained fibre intake. Although changes in percentage intake of macronutrients were associated with metabolic outcomes, these effect sizes were too small to be of clinical significance

Comparison with other studies

The Early ACTID dietary intervention was a pragmatic, 'real world' intervention, in which participants discussed dietary advice with dietitians and nurses to decide on their own dietary changes. The approach contrasts with dietary studies where participants are asked to make specific, prescribed changes to the macronutrient composition, by lowering carbohydrate and increasing protein [28-30] or to lower the glycaemic index [31 ,32]. The LOADD trial [3] based a successful dietary intervention in patients with poor glycaemic control on very similar recommendations to those used in the Early ACTID intervention, but total energy intake and macronutrient ratios for each participant were calculated and diets were prescribed according to these calculations taking into account personal preference, budget and sociocultural factors. The Early ACTID intervention did not compare a prescriptive with a non-prescriptive approach so cannot be used to demonstrate that this is superior but reductions in weight, waist circumference and HbA1c were achieved that are comparable to those achieved during these interventions. Withdrawal rates for prescriptive dietary interventions range from 10% to 30% and these higher withdrawal rates may suggest that in routine clinical care a more flexible approach can be advantageous in promoting retention. Of those participants in Early ACTID who either did not attend all appointments or withdrew completely, only one person stated that they did not see the benefit of the trial. The majority could not schedule all 9 dietitian and nurse visits because of other commitments, 5 cited other health issues, 3 moved too far away, 1 said they 'did not want to diet,' 1 wanted to take orlistat from baseline and 3 gave no reasons. What is common to intervention trials in diabetes is that patients receive individual support and attend multiple appointments with a dietitian or a health practitioner who is expert in promoting dietary change. It is important to emphasise that this model is not routinely replicated in primary care for patients with Type 2 DM.

Exploratory analysis of the associations between specific dietary changes and metabolic outcomes found small effect sizes that are not clinically important, but they are consistent with existing nutritional data on the benefits of a reduction in trans fats on lipids and waist circumference [33], an increase in fibre on LDL cholesterol [34] and a reduction in alcohol and blood pressure [35]. It is of interest that this analysis found that there was no benefit in carbohydrate reduction in men with good glycaemic control who are already consuming a low to moderate carbohydrate diet. It is not possible to determine whether there is an optimum macronutrient distribution for T2 DM from this analysis, particularly in those with poor glycaemic control, but there is no unequivocal evidence that low carbohydrate diets produce better blood glucose control or weight loss than higher carbohydrate diets [36]. A meta-analysis of low carbohydrate diets versus low fat diets conducted in 2012 [37] concluded that there was evidence of a small but beneficial effect on lipid profiles of a low (defined as <45% energy from carbohydrate) or very low carbohydrate (<60g carbohydrate) diet but no difference in improvements to weight or glycaemic control. Larsen et al [29] correlated dietary change with metabolic outcomes and found associations with energy reduction and HbA1c and waist circumference.

Strengths and weaknesses

To our knowledge this is the first study to describe the dietary intake of people soon after diagnosis with Type 2 DM living in the UK, the dietary changes made during an intervention based on patient-centred, non-prescriptive dietary advice and that examines associations between dietary change and metabolic variables. The demographics of the Early ACTID participants included in this analysis suggest that these findings are only representative of the white population; however the sample is socio-economically diverse with 40% of participants living in areas of high economic deprivation. Ethical approval was granted to make no changes to hypoglycaemic, lipid lowering or blood pressure medications during the first 6 months, unless absolutely necessary and this was controlled by a strict protocol. Due to small numbers those participants who made medication changes were included in the analysis without correction.

The study has important weaknesses. Only 53% of the participants returned baseline and 6 month food diaries at the end of the trial and these people had a lower BMI and waist circumference at baseline and achieved greater metabolic improvements. The participants who did not return diaries reported mislaying them which may indicate less motivation and less engagement with the trial. Participants who did return diaries could have been more motivated to make dietary changes than a typical patient population, and, given that their diets were good at baseline, may already have made dietary changes prior to entry into the Early ACTID study. The relative lack of dietary data limits our ability to generalise these findings to broader patient groups. Furthermore this was an exploratory analysis using an existing dataset and as such an estimation of sample size was not conducted in advance. . However, post hoc sample calculations indicate that the study was underpowered to detect small associations between dietary changes and metabolic outcomes, having 15% power for women and 52% for men at an alpha of 0.05.

The use of any self-reported measure of diet, including 4-day food diaries, is a recognised limitation in dietary studies. Under-reporting of food intake and selective under-reporting or under-eating of foods perceived to be 'bad' are commonly documented, especially in people who are obese [38 ,39]. Measurement of alcohol can be problematic due to the episodic nature of consumption, although including at least one weekend day can improve estimates by including alcohol consumption of 'weekend-only' drinkers [40]. Methods exist to estimate under-reporting, using calculated basal metabolic rate and estimates of physical activity [41

,42] but these methods assume that an individual's weight is stable and are consequently inappropriate for use during a weight loss trial. It should be noted that other dietary interventions in patients with Type 2 DM have reported similar energy intakes [28 ,31] and an energy reduction of around 200kcal/day is plausible assuming a dynamic model of energy balance [43] and given the modest weight reduction observed. It is also important to note that this is a secondary analysis so cause and effect cannot be assumed. It was not possible to perform a formal mediation analysis since participants from the control arm were not asked to complete a food diary at 6 months.

Conclusion

The Early ACTID trial indicates that a flexible, non-prescriptive approach to dietary advice based on standard healthy eating guidelines in Type 2 DM given soon after diagnosis may be effective in promoting small dietary change, even in patients with good glycaemic control. This supports current clinical practice and guidelines. The current analysis suggests that changes in percentage intake of macronutrients did not have any clinically significant effect on metabolic outcomes during the trial but this needs confirmation in a larger cohort, with less good glycaemic control. Further research is needed on whether dietary changes made using a non-prescriptive approach are sustainable and beneficial in the longer term in a more typical patient population.

Acknowledgements

We would like to acknowledge the participants in the Early ACTID trial, members of the Early ACTID team and steering committee, Dr Pauline Emmett for advice on dietary analysis, Dr Rosemary Greenwood for advice on statistical analysis and Professor Debbie Sharp for assistance in manuscript preparation.

Funding

The Early ACTID trial was supported by Diabetes UK, the UK Department of Health and Western Comprehensive Local Research Network. Pilot dietary analysis was supported by the Above and Beyond Foundation. C.Y. England is supported by NIHR Clinical Doctoral Research Fellowship 10-017.

Authors' contributions

This work forms part of the PhD of CYE which is supervised by RCA, JLT and RJ. RCA led the Early ACTID study and advised on clinical application of this work. CYE participated in data collection, data entry and was responsible for data analysis with guidance from JLT and RJ. ARC was responsible for the design of the ACTID physical activity intervention and for processing and analysis of the physical activity data. The first draft of the manuscript was prepared by CYE with critical input and revisions by all other authors. All authors approved the final manuscript.

Conflicts of interests

The authors declare that they have no conflict of interest

Data Sharing Statement

No additional data are available

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Table 1: Metabolic characteristics at baseline and 6 months

Metabolic characteristics	Baseline			6 months			Change (6 months - baseline)		
	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)
Weight, kg	88.2 (16.1)	83.1 (17.9)	90.7 (14.5)	85.9 (16.3)	80.7 (17.7)	88.5 (15.0)	- 2.3 (3.3)[z]	- 2.5 (3.3)[z]	- 2.3 (3.3)[z]
Body mass index, kg/m^2	30.7 (5.3)	31.9 (6.9)	30.2 (4.7)[a]	29.9 (5.4)	30.9 (6.2)	29.4 (4.9)	- 0.8 (1.2)[z]	- 1 (1.0)[z]	- 0.8 (1.1)[z]
Waist circumference, cm	105 (12)	102 (13)[1]	107 (11)	103 (12)	100 (13)	104 (12)	- 3 (4)[z]	- 3 (4)[z]	- 3 (4)[z]
HbA1c, % (mmol/l)	6.66 (0.94) (49.0 (10.3))	6.67 (0.91) (49.0 (9.9))	6.65 (0.95) (49.0 (10.4))	6.47 (0.89) (47.0 (9.7))	6.41 (0.63) (47.0 (6.9))	6.51 (0.99)[1] (48.0 (10.8))	- 0.18 (0.72)[z] (- 2.0 (7.9))	- 0.27 (0.63)[z] (- 3.0 (6.9))	- 0.14 (0.75)[x] (- 1.5 (8.2))
Total cholesterol, mmol/l	4.33 (0.90)	4.66 (0.89)[1]	4.16 (0.86)[1c]	4.29 (0.93)	4.66 (0.98)	4.11 (0.84)	- 0.03 (0.69)	0.01 (0.79)	- 0.06 (0.63)
LDL-cholesterol, mmol/l	2.30 (0.78)	2.55 (0.81)[3]	2.18 (0.74)[2c]	2.27 (0.81)	2.51 (0.88)[3]	2.15 (0.75)[1]	- 0.03 (0.67)	- 0.03 (0.76)	- 0.03 (0.62)
HDL-cholesterol, mmol/l	1.29 (0.33)	1.37 (0.39)[1]	1.25 (0.29)[1a]	1.34 (0.37)	1.45 (0.47)	1.28 (0.30)	0.05 (0.27)[y]	0.09 (0.37)[x]	0.03 (0.21)
Systolic blood pressure, mmHg	134 (16)	133 (16)	134 (15)	134 (15)	135 (16)	134 (14)	1 (12)	2 (13)	0 (12)
Diastolic blood pressure, mmHg	79 (8)	78 (8)	79 (8)	78 (8)	78 (8)	78 (8)	0 (7)	0 (8)	0 (7)
Physical activity	(n=223)	(n=75)	(n=148)	(n=223)	(n=75)	(n=148)	(n=223)	(n=75)	(n=148)
Minutes of moderate to vigorous physical activity / day (MVPA)	26 (21)	21 (18)[12]	29 (22)[27]	33 (25)	21 (19)	38 (26)	7 (21)	1 (12)	10 (24)

a = $p<0.05$; b = $p<0.005$; c = $p<0.001$ women vs. men at baseline
x = $p<0.05$; y = $p<0.005$; z = $p<0.001$ baseline vs. 6 month
Numerical superscripts indicate number of participants with missing data for the variable of interest. Cases with missing data are excluded listwise

Table 2: Nutrient intake at baseline and 6 months

Mean daily intake nutrients	Baseline			6 months			Change (6 months - baseline)		
	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)
Energy (kcal)	1796 (461)	1582 (379)	1903 (462)[c]	1610 (418)	1459 (326)	1685 (439)[c]	-187 (315)[z]	- 123 (270)[z]	- 218 (332)[a z]
Protein (g)	80 (19)	73 (16)	83 (20)[c]	74 (19)	68 (13)	77 (20)[c]	- 6 (17)[z]	- 5 (15)[y]	- 6 (19)[z]
Total carbohydrates (g)	202 (55)	186 (48)	211 (57)[b]	186 (53)	170 (39)	194 (58)[b]	- 17 (41)[z]	- 15 (33)[z]	- 17 (45)[z]
Total sugar (g)	81 (32)	77 (28)	83 (34)	75 (31)	71 (23)	77 (34)	- 6 (26)[z]	- 6 (21)[x]	- 6 (28)[y]
Starch (g)	119 (36)	105 (30)	126 (37)[c]	109 (31)	97 (26)	115 (32)[c]	-10 (28)[z]	- 9 (24)[y]	- 11 (30)[z]
Non-starch polysaccharide (g)	17 (5)	16 (5)	17 (5)	16 (5)	15 (4)	17 (5)[a]	- 1 (5)	- 1 (4)	0 (5)
Total fat (g)	69 (22)	61 (20)	73 (220)[c]	61 (20)	56 (19)	64 (20)[b]	- 8 (18)[z]	- 5 (17)[x]	- 9 (18)[z]
Saturated fat (g)	23 (9)	21 (8)	24 (9)[b]	20 (9)	19 (9)	21 (9)	- 3 (8)[z]	- 2 (7)[x]	- 3 (8)[z]
Trans fat (g)	2.3 (1.1)	2.0 (1)	2.4 (1.1)[b]	2.1 (1.1)	1.9 (1.1)	2.2 (1.1)[a]	- 0.2 (1.1)[y]	- 0.1 (1.1)	- 0.3 (1.2)[y]
Monounsaturated fat (g)	24 (8)	21 (8)	26 (8)[c]	22 (8)	20 (7)	23 (8)[b]	- 2 (7)[z]	- 1 (8)[x]	- 3 (7)[z]
Polyunsaturated fat (g)	13 (6)	12 (6)	14 (6)[a]	12 (4)	11 (4)	13 (5)[a]	- 1 (5)[z]	-1 (6)	- 1 (5)[y]
Alcohol,median (IQR)(g)	7 (0-23)	1 (0-12)	13 (0-27)[a]	4 (0-16)	0 (0-11)	5 (0-18)[b]	0 (-3-1)[z]	0 (-3-4)	-3 (-14-0)[c z]
% Energy from protein	18.3 (3.6)	19.0 (3.7)	18.0 (3.5)[a]	18.8 (3.5)	19.0 (3.3)	18.7 (3.6)	0.5 (3.7)[z]	0.0 (3.6)	0.7 (3.8)[y]
% Energy from total carbohydrates	43.2 (6.6)	44.8 (6.4)	42.4 (6.6)[a]	44.1 (6.5)	44.7 (6.2)	43.8 (6.6)	0.9 (6.0)[z]	- 0.1 (6.2)	1.4 (5.9)[y]
% Energy from total fat	33.5 (5.6)	33.4 (5.8)	33.6 (5.5)	33.3 (5.8)	33.3 (6.4)	33.3 (5.4)	-0.2 (5.9)	- 0.1 (6.3)	- 0.3 (5.7)
% Energy from saturated fat	11.2 (3.1)	11.4 (3.4)	11.2 (3.1)	11.0 (3.4)	11.1 (3.6)	10.9 (3.2)	- 0.3 (3.3)	- 0.3 (3.1)	- 0.3 (3.5)
% Energy from trans fat	1.1 (0.4)	1.1 (0.43)	1.1 (0.5)	1.1 (0.5)	1.1 (0.4)	1.1 (0.5)	0.0 (0.5)	0.0 (0.5)	0.0 (0.5)
% Energy from monounsaturated fat	11.7 (2.5)	11.5 (2.6)	11.9 (2.5)	11.9 (2.5)	11.7 (2.7)	12.0 (2.5)	- 0.2 (2.8)	0.2 (3.2)	0.1 (2.6)
% Energy from polyunsaturated fat	6.5 (2.2)	6.7 (2.4)	6.4 (2.1)	6.6 (1.9)	6.6 (1.9)	6.6 (1.9)	0.1 (2.4)	0.0 (2.6)	0.2 (2.3)
% Energy from total sugar	17.2 (5.7)	18.7 (5.5)	16.5 (5.6)[b]	17.7 (5.7)	18.8 (5.4)	17.2 (5.8)[a]	0.5 (5.0)	0.2 (5.2)	0.7 (4.9)
% Energy from alcohol	3 (0-8)	1 (0-5)	5 (0-9)[c]	2 (0-7)	0 (0-6)	2 (0-7)[a]	0 (-3-1)[z]	0 (-1-2)	-1 (-4-0)[c z]

a = p<0.05; b = p<0.005; c = p<0.001 women vs. men
y = p<0.005; z = p<0.001 baseline vs. 6 months

Table 3: Associations between macronutrients and metabolic outcomes in men (n=148) and women (n=75) who provided physical activity data.

Macronutrient		Metabolic outcomes	Regression coefficient, β (95% Confidence interval)	p value
Change to % energy from total carbohydrates	Men	HbA1c % (mmol/l)	-0.003 (-0.006, -0.001) (-0.005 (-0.009, -0.001))	0.009
Change to fibre (nsp) intake (g)	All	Total cholesterol	-0.023 (-0.044, -0.002)	0.033
	Men	Total cholesterol	-0.025 (-0.047, -0.003)	0.023
Change to % energy from total fat	All	LDL cholesterol	0.018 (0.003, 0.032)	0.016
	Men	LDL cholesterol	0.024 (0.006, 0.042)	0.011
Change to % energy from trans fat	All	Waist circumference	0.014 (0.003, 0.024)	0.011
	Women	Waist circumference	0.029 (0.006, 0.052)	0.015
		Total cholesterol	0.399 (0.028, 0.770)	0.036
		LDL cholesterol	0.365 (0.042, 0.688)	0.028
Change to % energy from monounsaturated fats	All	LDL cholesterol	0.036 (0.006, 0.065)	0.018
Change to % energy from alcohol	All	Diastolic blood pressure	0.217 (0.020, 0.414)	0.031
	Men	Diastolic blood pressure	0.276 (0.055, 0.497)	0.015

All models are adjusted for change in energy intake, outcome at baseline, age, BMI, time since diagnosis, relevant hypoglycaemic mediation (metformin, sulphonylureas, glitazones), lipid lowering medication or anti-hypertensives, dietary supplements, mean daily minutes of moderate to vigorous physical activity.
For each macronutrient listed a 1% (1g for fibre) increase is associated with the change in outcome listed

Dietary changes and associations with metabolic improvements in adults with Type 2 diabetes during a patient-centred dietary intervention: an exploratory secondary analysis

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Running title: Dietary change in adults with Type 2 diabetes

Keywords: Type 2 diabetes, dietary analysis, dietary change

Bath Research Ethics Committee (05/Q2001/5)

<u>Word count</u>

Abstract: 299

Main text: 3758

Number of tables: 3

Abstract

Objectives: Describe dietary intake of participants enrolled in a non-prescriptive dietary intervention and ~~Examine dietary~~ dietary changes at 6 months ~~reported during a non-prescriptive dietary intervention~~ and explore whether these changes had a role in observed improvements in HbA1c, weight, lipids and blood pressure.

Design: Secondary analysis of data from the Early ACTivity in Diabetes randomised controlled trial.

Participants 262 patients with newly diagnosed Type 2 diabetes randomised to the dietary intervention.

Outcomes and analysis: Changes in energy intake, macronutrients, fibre and alcohol and in weight, waist circumference, lipids, HbA1c and blood pressure at baseline and 6 months. Multivariate models were used to examine associations between dietary changes and metabolic variables.

Results: Men reported reducing mean energy intake from 1903 ± 462kcal to 1685kcal ± 439kcal (p<0.001), increasing carbohydrate intake from 42.4 ± 6.6% to 43.8 ± 6.6% (p=0.002) and reducing median alcohol intake from 13~~8~~ (0-27)g ~~± 20g~~ to ~~11~~5 ~~± 14g~~(0-18)g (p<0.001). Women reported reducing mean energy intake from 1582 ± 379kcal to 145~~0~~9 ± 326kcal (p<0.001) with no change to macronutrient distribution and ~~no reduction in~~ alcohol. Fibre intake was maintained. In men (n=148) weak and clinically insignificant associations were found between increased carbohydrates and reduction in HbA1c (β= -0.003 [-0.006, -0.001]; p=0.009), increased fibre and reduction in total cholesterol (β= -0.023 [-0.044, -0.002]; p=0.033), decreased total fat and reduction in LDL-cholesterol (β= 0.024 [0.006, 0.001]; p=0.011), and decreased alcohol and reduction in diastolic blood pressure (β= 0.276 [0.055, 0.497]; p=0.015). In women (n=75) associations were found between a decrease in trans-fats and reductions in waist circumference (β= -0.029 [0.006, 0.052]; p=0.015), total cholesterol (β= 0.399 [0.028, 0.770]; p=0.036) and LDL cholesterol (β= 0.365 [0.042, 0.668]; p=0.028).

Conclusion: Clinically important~~significant~~ metabolic improvements observed in a patient-centred dietary intervention were~~are~~ not explained by changes in ~~percentage intake of~~

macronutrients. However, a non-prescriptive approach may promote a reduction in total energy intake whilst maintaining fibre consumption.

Article summary

Strengths and limitations

- Describes the dietary intake of people soon after diagnosis of Type 2 DM living in the UK, the dietary changes made during a dietary intervention and exploresamines associations between dietary changes and changes in metabolic outcomes. This intervention was based on the dietary advice that is given in routine clinical practice in the UK.

- Only 53% of the participants provided food diary data at the end of the trial and these people showed greater improvements in metabolic outcomes than those who did not return food diaries. It is probable that they were more motivated than a typical patient group and this limits the generalizability of the findings.

Introduction

Dietary management is recognised as highly important in the treatment of Type 2 diabetes (Type 2 DM). Based upon meta-analyses of exercise and diet studies, the American Diabetes Association (ADA) and European Association for the Study of Diabetes (EASD) recommend that lifestyle interventions should be initiated as the first step in treating new-onset Type 2 DM [1]. Over the last 3 years, The Look Ahead research group, the Lifestyle Over and Above Drugs in Diabetes (LOADD) and Early Activity in Diabetes (Early ACTID) randomised controlled trials (RCTs) have shown that dietary interventions which target weight reduction are beneficial and improve glycaemic control [2-4]. These trials achieved reductions in HbA1c comparable to reductions demonstrated in patients starting metformin or a gliptin as monotherapies [5] and, although the Look Ahead trial showed no reduction in cardiovascular events after 9.6 years, participants in the intervention arm were less likely to be treated with insulin [6].

It has been reported that changes to the macronutrient composition of the diet may impact upon glycaemic control, blood lipids and weight [7], but ~~T~~the effect of specific dietary changes on these metabolic outcomes are~~is~~ still~~,~~ unclear and no single ‘diet for diabetes’ has been identified [8]. In recognition of this, both the 2012 ADA and EASD joint guidelines and 2011 Diabetes UK nutritional guidelines emphasise the importance of an individualised, patient-centred approach to diet rather than a prescriptive approach [1 ,9]. This approach recognises that different people have ~~different~~individual dietary habits and may find certain dietary changes more straightforward than others. T~~T~~here is evidence that men and women living in the UK have differing dietary patterns [10]. Men have been reported to drink more alcohol and consume more meat but less fruit and diet soft drinks than women [11]~~.~~ Few studies have looked at what changes ~~to macronutrients~~ are made to macronutrients in response to non-prescriptive dietary advice, whether men and women make different changes ~~this type of dietary advice~~ and whether ~~how~~ these changes impact on metabolic control.

The Early ACTID trial included a non-prescriptive, patient-centred dietary intervention. The trial aimed to assess whether adding physical activity to a dietary intervention produced greater benefit than diet alone or usual care in individuals newly diagnosed with Type 2 DM [4]. Participants who received the lifestyle interventions had better HbA1c, lower body weight, less insulin resistance, and were on less medication than the control group at 6 and 12 months. During the intervention participants in this cohort reported small changes to higher calorie, low fibre foods. Examination of the specific changes to foods and food groups reported by participants has been previously published [12] and this current paper focuses on macronutrients.

The aim of this paper is to describe baseline energy and macronutrient intakes of men and women who were enrolled into the dietary intervention in the Early ACTID study and to examine the reported dietary changes made after 6 months. by men and women newly diagnosed with Type 2 DM who were enrolled into the dietary intervention in the Early ACTID study.

We conducted exploratory analysis to examine the following hypotheses:

- Men and women with Type 2 DM make different dietary changes in response to a dietary intervention.
- The changes to energy intake and macronutrients are associated with the observedbeneficial changes to glycaemic control, weight, waist circumference, blood pressure and lipids. The associations between changes to energy, macronutrients and metabolic outcomes were explored to determine the effect of dietary changes on the metabolic variables.

Subjects and methods

Subjects

This paper is an exploratory secondary analysis of data from the Early ACTID randomised controlled trial. Early ACTID was a diet and physical activity trial involving patients living in the South West of England who were recruited within 5 to 8 months of a diagnosis of Type 2 DM from December 2005 to September 2008. Full trial procedures with the CONSORT diagram and results are described elsewhere [4 ,13 ,14]. The analysis is limited to participants in the intervention arms who returned valid food diary data.

Overview of the dietary intervention

Patients in the diet alone and the diet and physical activity groups received the same dietary intervention. For the first 6 months the intervention aimed to promote dietary change. At randomisation patients attended a one-hour appointment with a study dietitian followed by 2 further visits of 30 minutes. These visits were supported by 6 additional visits with a research nurse, where 15 minutes were used to discuss dietary matters for both groups, reinforcing dietary goals, and 15 minutes to discuss either physical activity or other matters pertinent to the patient, depending upon intervention group allocated to. Maintenance was the primary goal of the second 6 months and consisted of 2 more 30 minute dietitian visits and 4 additional visits with the research nurses.

The dietary intervention was based upon the 2003 Diabetes UK healthy eating guidelines [15] and employed goal oriented motivational interviewing [16]. Patients were encouraged to discuss their reasons for change, any ambivalence about change and to set their own dietary goals and identify their own strategies for achieving these goals. Prescriptive daily requirements for energy or macronutrients were not calculated unless requested by the patient and prescriptive meal plans or food lists were not used. Instead patients received study specific written dietary information at each visit (available here: http://jcrubristol.org.uk/EA/ACTID%20patients%20Handbook/Forms/AllItems.aspx) and were encouraged to use this to evaluate their own eating habits. The materials included information on maintaining a regular meal pattern and including starchy carbohydrates as a part of each meal, reducing total, saturated and *trans* fat intake, limiting non-milk extrinsic sugars, aiming for 5 portions a day of fruit and vegetables and gave guidance on portion control. Specific food choices were discussed and participants were advised on choosing wholegrain and higher fibre foods, reducing fatty and processed meats and, high fat dairy products,e and increasing oily fish and limiting foods like cakes, biscuits, salty snacks and take-away meals. The benefit of aiming for a 5 to 10% weight loss by reducing overall energy intake was discussed with everyone. Goals were reviewed at each appointment and successes, difficulties and new strategies discussed. Patients were encouraged to self-monitor their weight and diet.

Measurements

Measures were taken at baseline (prior to randomisation) and repeated 6 and 12 months later. Baseline and 6 month data were used in the current analysis, since outcomes at 6 months were defined as the primary endpoint of the study. Measurements used in this analysis were weight, height (to calculate body mass index (BMI)), waist circumference, blood pressure, HbA1c, fasting lipids and minutes of moderate to vigorous physical activity (MVPA) measured using accelerometry and defined as activity expending greater than 3kcal/kg/hour . As previously described, blood measurements and anthropometric measures were carried out using standardised procedures [13]. Smoking habits and use of dietary supplements were assessed by a research nurse. The UK Index of Multiple Deprivation (IMD) 2007 was calculated from home postcode and used as an indicator of socio-economic position [17].

Dietary assessment and analysis

Patients in the intervention arms were asked to complete 4-day food diaries, to include 2 weekdays and 1 weekend day, prior to each dietitian appointment, recording all foods and drinks consumed during those 4 days. Portion sizes were estimated using household measures and package weights and brands indicated where appropriate. The diaries were discussed during the appointments and used to identify potential areas for change, difficulties in making change, and for patients to observe change in their diets over time. Patients were asked to return all the diaries at the final visit for further analysis. Those who did not return diaries at the visit were reminded by telephone and e-mail to post outstanding diaries to the research team after the visit.

Baseline and 6-month food diaries were coded by one coder and checked for accuracy and agreement by a second coder, using the dietary coding programme Diet in Data Out (DIDO), developed at the Medical Research Council Human Nutrition Unit in Cambridge, UK [18]. Diaries were analysed with the nutrient analysis programme Bristol General Analysis of Dietary Experiments (BRIGADE) [19]. The nutrient database is based on *McCance and Widdowson's Composition of Foods, 5th edition* [20], updated with the supplements to that edition, new data from the 6th edition and manufacturers' data. Additional nutrient data from the INTERMAP nutrient database for the UK were also used [21]. If no portion size information was given, age-appropriate portion sizes were assigned [22]. The mean daily consumption of each nutrient was calculated for each participant.

Statistical analysis

As the dietary intervention was designed to be identical for both intervention groups and there were no difference in outcomes between the diet and diet and physical activity groups, the data were analysed as a cohort. Patients in the usual care group were excluded from the analysis since they did not receive the dietary intervention and were not asked to complete a diary at 6 months. Descriptive statistics were used for patient characteristics and for intakes of macronutrients at baseline and 6 months. Variables were checked for normal distribution; non-normal variables were log transformed prior to analysis. For ease of interpretation, arithmetic means and back transformed variables are presented. Independent *t*-tests were used to explore differences in continuous variables between men and women at baseline and between those who did and did not return food diaries, and chi-squared tests were used to explore differences in dichotomous variables. Paired sample *t*-tests were used to describe differences in energy and macronutrient intake between baseline and 6 months. McNemar tests were used to explore differences in numbers of people meeting recommendations at baseline and 6 months. As alcohol variables could not be transformed, the Mann Whitney U and paired sample Wilcoxon signed rank test were used to describe differences. Cases with missing data were excluded listwise. Data were assumed to be randomly missing and table 1 includes numerical superscripts to indicate the number of participants with missing data for the variable of interest.

Multivariate regression models were used to conduct exploratory analysis to investigate associations between changes in energy and macronutrient intake and the metabolic variables at 6 months in those who provided valid physical activity data. Changes in energy intake were~~as~~ explored using a standard multivariate model. Each macronutrient was explored independently using a multivariate nutrient density model to adjust for change in energy intake. Change in percentage energy from each macronutrient was calculated and entered into the model with change in total energy included as a covariate. Change in fibre intake was explored using a standard multivariate model and entered as an absolute intake (in grams) with change to total energy intake as a covariate [23]. Models were adjusted for age, BMI, time since diagnosis, minutes of moderate to vigorous physical activity (MVPA) and dichotomous yes/no variables for smoking status, relevant lipid lowering, blood pressure and diabetes medication and dietary supplement use at 6 months.

Due to the number of different analyses that were conducted the results are interpreted in terms of strength of evidence of associations [24]. This is an exploratory analysis and as such has not been adjusted for multiple comparisons [25 ,26], consequently p values of <0.05 are interpreted as some evidence of association, p<0.01 as increasing evidence and p<0.001 as strong evidence.

Results

Study participants

A total of 593 patients were recruited into the Early ACTID study, with 494 being assigned to one of the intervention groups. 396 (80%) patients were recorded as completing food diaries at both baseline and 6 months but only 262 (53%) patients returned them. Metabolic and dietary outcomes at baseline and 6 months are presented for these 262 patients. , and 223 of these had valid accelerometry data at both time points. At 6 months 491 (99%) patients assigned to one of the intervention arms remained in the study, with 434 (88%) attending all scheduled visits up to that point and a further 37 (8%) attending all except one.

Mean age was 62.4 (9.0) years, 97% of patients were white, 83% were married or with a long term partner and 41% were in the lowest IMD quartile. At baseline 104 (40%) of participants were on oral hypoglycaemic medication, 170 (65%) on lipid lowering medication and 174 (66%) on blood pressure medication. Only 6% of patients were current smokers at baseline. Men and women had similar characteristics, although there was some evidence that men were more likely to be on lipid lowering medication than women (69% vs. 56%, p=0.041). At 6 months, 105 (40%) of participants were on oral hypoglycaemic medication, although 12 (5%) participants had increased the dose and 4 (2%) had decreased; 177 (68%) were on lipid lowering medication and 175 (67%) were on blood pressure medication.

Compared to the patients who did not return food diaries, those who did were older (62 years vs 57 years, p<0.001), with a lower mean weight (88.2 kg vs 93.3 kg, p=0.001), lower mean BMI (30.7 vs 32.5, p=0.001) and lower mean waist circumference (105 cm vs 108 cm, p=0.025), but there was no difference in glycaemic control, lipids and blood pressure.

Metabolic outcomes

Table 1 shows the metabolic outcomes at baseline and 6 months for those who returned food diaries. There was no difference in glycaemic control or blood pressure between men and women, but women had higher total (p<0001), LDL (p<0.001) and HDL (p=0.015) cholesterol levels.

Weight, waist circumference and BMI improved at 6 months for both men and women (p<0.001). Men and women improved their HbA1c (men: p=0.006; women: p<0.001). Men improved their fasting blood glucose (p=0.006) and there is some evidence that women increased their HDL cholesterol (p=0.033).

At 6 months those who returned food diaries had lost more weight (2.4 kg vs 1.3 kg, p=0.001), reduced waist circumference more (2.7 cm vs 1.3 cm, p=0.022) and reduced HbA1c (0.18% (2 mmol/l) vs 0% (0 mmol/l), p=0.02).

Nutrient analysis

Table 2 shows the mean reported energy and nutrient intakes at baseline and 6 months and their mean reported changes.

At baseline participants reported generally good dietary habits. 61% of women and 59% of men reported the recommended total fat intake (less than 35% of energy from total fat) and 55% of women and 66% of men reported a low to moderate carbohydrate intake (<45% of energy). Men were more likely to drink alcohol and more likely to drink to excess than women with 49% of women and 28% of men recording no alcohol during the 4 days and 8% of women and 19% of men reporting more than 30g of alcohol per day (p=0.022).

At 6 months mean daily reported energy intake was reduced by 187 kcal (p<0.001). Men reduced their energy intake more than women (218 ± 332 vs. 123 ± 270 kcal/day, p=0.022). This was achieved by small reductions in all macronutrients, whilst maintaining fibre intake. The mean percentage energy from macronutrients was unchanged for women whilst men reported a small mean increase of 1.4 ± 5.9% (p<0.001) of energy from carbohydrates. Men reported reducing ~~mean~~ median alcohol intake (p<0.001), with 40% reporting no alcohol during the 4 days and 15% reporting more than 30g per day. There was no reported median~~mean~~ change in alcohol intake for women. Despite no mean change to energy from saturated fat, more men met recommendations at 6 months (35% men at baseline vs. 49% at 6 months reporting less than 10% energy from saturated fat, p=0.007). There was no change in the number of women meeting recommendations (40% baseline vs 44% at 6 months, p=0.71).

Valid physical activity data and dietary data were provided by 223 (45%) participants. Table 3 shows the regression coefficients and confidence intervals for changes in energy and macronutrients that show evidence for associations with specific metabolic variables. In men a 1% reduction in energy from alcohol was associated with a 0.276 mmHg reduction in diastolic blood pressure (95% CI= 0.055 to 0.497). In women a 1% reduction in energy from trans-fat was associated with a decrease in cholesterol of 0.399 mmol/l (95% CI= 0.028 to 0.770). In men a 1% increase in energy from carbohydrate was associated with a decrease in HbA1c of 0.003% (95% CI= -0.006 to -0.001). There were no associations between change in energy intake and the metabolic variables.

Discussion

Main findings

The main findings from this exploratory analysis are that patients who were randomised to the intervention arms in the Early ACTID study and returned food diaries reported a good diet at baseline but still achieved small dietary changes. They reported a mean decrease in energy intake of around 200 kcal per day, during the first 6 months. This is a modest reduction in calorie intake but, if sustained, will have an impact on weight and glycaemic control. It has been argued that long-term small changes are more effective for weight management than short-term large changes [27]. Men reported a reduced alcohol intake that produced a greater reduction in energy and reported a small increase in the percentage energy from carbohydrate. Women reported modest reductions to all macronutrients but made no changes to alcohol, their energy reduction was less and the macronutrient ratio of their diets did not change. Both sexes maintained fibre intake. Although changes in percentage intake of macronutrients were associated with metabolic outcomes, these effect sizes were too small to be of clinical significance.

~~These results suggest that current recommendations that dietary advice is personalised, flexible and focuses on realistic, achievable, and sustainable reductions in intake may promote dietary change in people with T2 DM.~~

Comparison with other studies

The Early ACTID dietary intervention was a pragmatic, ‘real world’ intervention, in which participants discussed dietary advice with dietitians and nurses to decide on their own dietary changes. The approach contrasts with dietary studies where participants are asked to make specific, prescribed changes to the macronutrient composition, by lowering carbohydrate and increasing protein [28-30] or to lower the glycaemic index [31 ,32]. The LOADD trial [3] based a successful dietary intervention in patients with poor glycaemic control on very similar recommendations to those used in the Early ACTID intervention, but total energy intake and macronutrient ratios for each participant were calculated and diets were prescribed according to these calculations taking into account personal preference, budget and sociocultural factors. The Early ACTID intervention did not compare a prescriptive with a non-prescriptive approach so cannot be used to demonstrate that this is superior but reductions in weight, waist circumference and HbA1c were achieved that are comparable to those achieved during these interventions. Withdrawal rates for prescriptive dietary interventions range from 10% to 30% and these higher withdrawal rates may suggest that in routine clinical care a more flexible approach can be advantageous in promoting retention. Of those participants in Early ACTID who either did not attend all appointments or withdrew completely, only one person stated that they did not see the benefit of the trial. The majority could not schedule all 9 dietitian and nurse visits because of other commitments, 5 cited other health issues, 3 moved too far away, 1 said they ‘did not want to diet,’ 1 wanted to take orlistat from baseline and 3 gave no reasons. What is common to intervention trials in diabetes is that patients receive individual support and attend multiple appointments with a dietitian or a health practitioner who is expert in promoting dietary change. It is important to emphasise that this model is not routinely replicated in primary care for patients with Type 2 DM.

Exploratory analysis of ~~T~~the associations between specific dietary changes and metabolic outcomes found small ~~have not, as far as we are aware, previously been examined in patients with Type 2 DM. E~~effect sizes ~~were small and not~~that are not clinically important,~~significant~~ but they are consistent with existing nutritional data on the benefits of a reduction in trans fats on lipids and waist circumference [33], an increase in fibre on LDL cholesterol [34] and a reduction in alcohol and blood pressure [35]. It is of interest that this analysis found that there was no benefit in carbohydrate reduction in men with good glycaemic control who are already consuming a low to moderate carbohydrate diet. It is not possible to determine whether there is an optimum macronutrient distribution for T2 DM from this analysis, particularly in those with poor glycaemic control, but there is no unequivocal evidence that low carbohydrate diets produce better blood glucose control or weight loss than higher carbohydrate diets [36]. A meta-analysis of low carbohydrate diets versus low fat diets conducted in 2012 [37] concluded that there was evidence of a small but beneficial effect on lipid profiles of a low (defined as <45% energy from carbohydrate) or very low carbohydrate (<60g carbohydrate) diet but no difference in improvements to weight or glycaemic control. Larsen et al [29] correlated dietary change with metabolic outcomes and found associations with energy reduction and HbA1c and waist circumference.

Strengths and weaknesses

To our knowledge this is the first study to describe the dietary intake of people soon after diagnosis with Type 2 DM living in the UK, the dietary changes made during an intervention based on patient-centred, non-prescriptive dietary advice and that examines associations between dietary change and metabolic variables. The demographics of the Early ACTID participants included in this analysis suggest that these findings are only representative of the white population; however the sample is socio-economically diverse with 40% of participants living in areas of high economic deprivation. Ethical approval was granted to make no changes to hypoglycaemic, lipid lowering or blood pressure medications during the first 6 months, unless absolutely necessary and this was controlled by a strict protocol. Due to small numbers those participants who made medication changes were included in the analysis without correction.

The study has important weaknesses. Only 53% of the participants returned baseline and 6 month food diaries at the end of the trial and these people had a lower BMI and waist circumference at baseline and achieved greater metabolic improvements. The participants who did not return diaries reported mislaying them which may indicate less motivation and less engagement with the trial. Participants who did return diaries could have been more motivated to make dietary changes than a typical patient population, and, given that their diets were good at baseline, may already have made dietary changes prior to entry into the Early ACTID study. The relative lack of dietary data limits our ability to generalise these findings to broader patient groups. Furthermore this was an exploratory analysis using an existing dataset and as such an estimation of sample size was not conducted in advance. .

However, post hoc sample calculations indicate that the study was underpowered to detect small associations between dietary changes and metabolic outcomes, having 15% power for women and 52% for men at an alpha of 0.05.

The use of any self-reported measure of diet, including 4-day food diaries, is a recognised limitation in dietary studies. Under-reporting of food intake and selective under-reporting or under-eating of foods perceived to be 'bad' are commonly documented, especially in people who are obese [38 ,39]. Measurement of alcohol can be problematic due to the episodic nature of consumption, although including at least one weekend day can improve estimates by including alcohol consumption of 'weekend-only' drinkers [40]. Methods exist to estimate under-reporting, using calculated basal metabolic rate and estimates of physical activity [41 ,42] but these methods assume that an individual's weight is stable and are consequently inappropriate for use during a weight loss trial. It should be noted that other dietary interventions in patients with Type 2 DM have reported similar energy intakes [28 ,31] and an energy reduction of around 200kcal/day is plausible assuming a dynamic model of energy balance [43] and given the modest weight reduction observed. It is also important to note that this is a secondary analysis so cause and effect cannot be assumed. It was not possible to perform a formal mediation analysis since participants from the control arm were not asked to complete a food diary at 6 months.

Conclusion

The Early ACTID trial indicates that a flexible, non-prescriptive approach to dietary advice based on standard healthy eating guidelines in Type 2 DM given soon after diagnosis may be effective in promoting small dietary change, even in patients with good glycaemic control. This supports current clinical practice and guidelines. The current analysis suggests that changes in percentage intake of macronutrients did not have any clinically significant effect on metabolic outcomes during the trial but this needs confirmation in a larger cohort, with less good glycaemic control. Further research is needed on whether dietary changes made using a non-prescriptive approach are sustainable and beneficial in the longer term in a more typical patient population.

Acknowledgements

We would like to acknowledge the participants in the Early ACTID trial, members of the Early ACTID team and steering committee, Dr Pauline Emmett for advice on dietary analysis, Dr Rosemary Greenwood for advice on statistical analysis and Professor Debbie Sharp for assistance in manuscript preparation.

Funding

The Early ACTID trial was supported by Diabetes UK, the UK Department of Health and Western Comprehensive Local Research Network. Pilot dietary analysis was supported by the Above and Beyond Foundation. C.Y. England is supported by NIHR Clinical Doctoral Research Fellowship 10-017.

Authors' contributions

This work forms part of the PhD of CYE which is supervised by RCA, JLT and RJ. RCA led the Early ACTID study and advised on clinical application of this work. CYE participated in data collection, data entry and was responsible for data analysis with guidance from JLT and RJ. ARC was responsible for the design of the ACTID physical activity intervention and for processing and analysis of the physical activity data. The first draft of the manuscript was prepared by CYE with critical input and revisions by all other authors. All authors approved the final manuscript.

Conflicts of interests

The authors declare that they have no conflict of interest

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Table 1: Metabolic characteristics at baseline and 6 months

Metabolic characteristics	Baseline			6 months			Change (6 months - baseline)		
	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)
Weight, kg	88.2 (16.1)	83.1 (17.9)	90.7 (14.5)[e]	85.9 (16.3)	80.7 (17.7)	88.5 (15.0)	- 2.3 (3.3)[z]	- 2.5 (3.3)[z]	- 2.3 (3.3)[z]
Body mass index, kg/m^2	30.7 (5.3)	31.9 (6.9)	30.2 (4.7)[a]	29.9 (5.4)	30.9 (6.2)	29.4 (4.9)	- 0.8 (1.2)[z]	- 1 (1.0)[z]	- 0.8 (1.1)[z]
Waist circumference, cm	105 (12)	102 (13)[1]	107 (11)[b]	103 (12)	100 (13)	104 (12)	- 3 (4)[z]	- 3 (4)[z]	- 3 (4)[z]
HbA1c, % (mmol/l)	6.66 (0.94) (49.0 (10.3))	6.67 (0.91) (49.0 (9.9))	6.65 (0.95) (49.0 (10.4))	6.47 (0.89) (47.0 (9.7))	6.41 (0.63) (47.0 (6.9))	6.51 (0.99)[1] (48.0 (10.8))	- 0.18 (0.72)[z] (- 2.0 (7.9))	- 0.27 (0.63)[z] (- 3.0 (6.9))	- 0.14 (0.75)[x] (- 1.5 (8.2))
Total cholesterol, mmol/l	4.33 (0.90)	4.66 (0.89)[1]	4.16 (0.86)[1c]	4.29 (0.93)	4.66 (0.98)	4.11 (0.84)	- 0.03 (0.69)	0.01 (0.79)	- 0.06 (0.63)
LDL-cholesterol, mmol/l	2.30 (0.78)	2.55 (0.81)[3]	2.18 (0.74)[2c]	2.27 (0.81)	2.51 (0.88)[3]	2.15 (0.75)[1]	- 0.03 (0.67)	- 0.03 (0.76)	- 0.03 (0.62)
HDL-cholesterol, mmol/l	1.29 (0.33)	1.37 (0.39)[1]	1.25 (0.29)[1a]	1.34 (0.37)	1.45 (0.47)	1.28 (0.30)	0.05 (0.27)[y]	0.09 (0.37)[x]	0.03 (0.21)
Systolic blood pressure, mmHg	134 (16)	133 (16)	134 (15)	134 (15)	135 (16)	134 (14)	1 (12)	2 (13)	0 (12)
Diastolic blood pressure, mmHg	79 (8)	78 (8)	79 (8)	78 (8)	78 (8)	78 (8)	0 (7)	0 (8)	0 (7)
Physical activity	(n=223)	(n=75)	(n=148)	(n=223)	(n=75)	(n=148)	(n=223)	(n=75)	(n=148)
Minutes of moderate to vigorous physical activity / day (MVPA)	26 (21)	21 (18)[12]	29 (22)[27]	33 (25)	21 (19)	38 (26)	7 (21)	1 (12)	10 (24)

a = $p<0.05$; b = $p<0.005$; c = $p<0.001$ women vs. men at baseline
x = $p<0.05$; y = $p<0.005$; z = $p<0.001$ baseline vs. 6 month
Numerical superscripts indicate number of participants with missing data for the variable of interest. Cases with missing data are excluded listwise

Table 2: Nutrient intake at baseline and 6 months

Mean daily intake nutrients	Baseline			6 months			Change (6 months - baseline)		
	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)	Total (n=262) Mean (SD)	Women (n=87) Mean (SD)	Men (n=175) Mean (SD)
Energy (kcal)	1796 (461)	1582 (379)	1903 (462)[c]	1610 (418)	1459 (326)	1685 (439)[c]	-187 (315)[z]	- 123 (270)[z]	- 218 (332)[a z]
Protein (g)	80 (19)	73 (16)	83 (20)[c]	74 (19)	68 (13)	77 (20)[c]	- 6 (17)[z]	- 5 (15)[y]	- 6 (19)[z]
Total carbohydrates (g)	202 (55)	186 (48)	211 (57)[b]	186 (53)	170 (39)	194 (58)[b]	- 17 (41)[z]	- 15 (33)[z]	- 17 (45)[z]
Total sugar (g)	81 (32)	77 (28)	83 (34)	75 (31)	71 (23)	77 (34)	- 6 (26)[z]	- 6 (21)[x]	- 6 (28)[y]
Starch (g)	119 (36)	105 (30)	126 (37)[c]	109 (31)	97 (26)	115 (32)[c]	-10 (28)[z]	- 9 (24)[y]	- 11 (30)[z]
Non-starch polysaccharide (g)	17 (5)	16 (5)	17 (5)	16 (5)	15 (4)	17 (5)[a]	- 1 (5)	- 1 (4)	0 (5)
Total fat (g)	69 (22)	61 (20)	73 (220)[c]	61 (20)	56 (19)	64 (20)[b]	- 8 (18)[z]	- 5 (17)[x]	- 9 (18)[z]
Saturated fat (g)	23 (9)	21 (8)	24 (9)[b]	20 (9)	19 (9)	21 (9)	- 3 (8)[z]	- 2 (7)[x]	- 3 (8)[z]
Trans fat (g)	2.3 (1.1)	2.0 (1)	2.4 (1.1)[b]	2.1 (1.1)	1.9 (1.1)	2.2 (1.1)[a]	- 0.2 (1.1)[y]	- 0.1 (1.1)	- 0.3 (1.2)[y]
Monounsaturated fat (g)	24 (8)	21 (8)	26 (8)[c]	22 (8)	20 (7)	23 (8)[b]	- 2 (7)[z]	- 1 (8)[x]	- 3 (7)[z]
Polyunsaturated fat (g)	13 (6)	12 (6)	14 (6)[a]	12 (4)	11 (4)	13 (5)[a]	- 1 (5)[z]	-1 (6)	- 1 (5)[y]
Alcohol, median (IQR) (g)	7 (0-23)~~14 (18)~~	1 (0-12)~~7 (11)~~	13 (0-27)~~18 (20)~~[a]	4 (0-16)~~10 (13)~~	0 (0-11)~~7 (9)~~	5 (0-18)~~11 (14)~~[b]	0 (-3-1)~~- 5 (14)~~[z]	0 (-3-4)~~(10)~~	-3 (-14-0)~~- 7 (15)~~[c z]
% Energy from protein	18.3 (3.6)	19.0 (3.7)	18.0 (3.5)[a]	18.8 (3.5)	19.0 (3.3)	18.7 (3.6)	0.5 (3.7)[z]	0.0 (3.6)	0.7 (3.8)[y]
% Energy from total carbohydrates	43.2 (6.6)	44.8 (6.4)	42.4 (6.6)[a]	44.1 (6.5)	44.7 (6.2)	43.8 (6.6)	0.9 (6.0)[z]	- 0.1 (6.2)	1.4 (5.9)[y]
% Energy from total fat	33.5 (5.6)	33.4 (5.8)	33.6 (5.5)	33.3 (5.8)	33.3 (6.4)	33.3 (5.4)	-0.2 (5.9)	- 0.1 (6.3)	- 0.3 (5.7)
% Energy from saturated fat	11.2 (3.1)	11.4 (3.4)	11.2 (3.1)	11.0 (3.4)	11.1 (3.6)	10.9 (3.2)	- 0.3 (3.3)	- 0.3 (3.1)	- 0.3 (3.5)
% Energy from trans fat	1.1 (0.4)	1.1 (0.43)	1.1 (0.5)	1.1 (0.5)	1.1 (0.4)	1.1 (0.5)	0.0 (0.5)	0.0 (0.5)	0.0 (0.5)
% Energy from monounsaturated fat	11.7 (2.5)	11.5 (2.6)	11.9 (2.5)	11.9 (2.5)	11.7 (2.7)	12.0 (2.5)	- 0.2 (2.8)	0.2 (3.2)	0.1 (2.6)
% Energy from polyunsaturated fat	6.5 (2.2)	6.7 (2.4)	6.4 (2.1)	6.6 (1.9)	6.6 (1.9)	6.6 (1.9)	0.1 (2.4)	0.0 (2.6)	0.2 (2.3)
% Energy from total sugar	17.2 (5.7)	18.7 (5.5)	16.5 (5.6)[b]	17.7 (5.7)	18.8 (5.4)	17.2 (5.8)[a]	0.5 (5.0)	0.2 (5.2)	0.7 (4.9)
% Energy from alcohol	3 (0-8)~~5.0 (6.1)~~	~~2.9 (4.3)~~1 (0-5)	~~6.1 (6.6)~~5 (0-9)[c]	~~3.9 (4.9)~~2 (0-7)	0 (0-6)~~3.0 (3.9)~~	~~4.3 (5.3)~~2 (0-7)[a]	~~-1.2 (4.7)~~0 (-3-1)[z]	~~0.2 (4.0)~~0 (-1-2)	~~-1.8 (5.0)~~-1 (-4-0)[c z]

a = p<0.05; b = p<0.005; c = p<0.001 women vs. men

y = p<0.005; z = p<0.001 baseline vs. 6 months

Table 3: Associations between macronutrients and metabolic outcomes in men (n=148) and women (n=75) who provided physical activity data.

Macronutrient		Metabolic outcomes	Regression coefficient, β (95% Confidence interval)	p value
Change to % energy from total carbohydrates	Men	HbA1c % (mmol/l)	-0.003 (-0.006, -0.001) (-0.005 (-0.009, -0.001))	0.009
Change to fibre (nsp) intake (g)	All	Total cholesterol	-0.023 (-0.044, -0.002)	0.033
	Men	Total cholesterol	-0.025 (-0.047, -0.003)	0.023
Change to % energy from total fat	All	LDL cholesterol	0.018 (0.003, 0.032)	0.016
	Men	LDL cholesterol	0.024 (0.006, 0.042)	0.011
Change to % energy from trans fat	All	Waist circumference	0.014 (0.003, 0.024)	0.011
	Women	Waist circumference	0.029 (0.006, 0.052)	0.015
		Total cholesterol	0.399 (0.028, 0.770)	0.036
		LDL cholesterol	0.365 (0.042, 0.688)	0.028
Change to % energy from monounsaturated fats	All	LDL cholesterol	0.036 (0.006, 0.065)	0.018
Change to % energy from alcohol	All	Diastolic blood pressure	0.217 (0.020, 0.414)	0.031
	Men	Diastolic blood pressure	0.276 (0.055, 0.497)	0.015

All models are adjusted for change in energy intake, outcome at baseline, age, BMI, time since diagnosis, relevant hypoglycaemic mediation (metformin, sulphonylureas, glitazones), lipid lowering medication or anti-hypertensives~~medication~~, dietary supplements, mean daily minutes of moderate to vigorous physical activity.
For each macronutrient listed a 1% (1g for fibre) increase is associated with the change in outcome listed