Research: Pregnancy

Dietary intakes of women with Type 1 diabetes before and during pregnancy: a pre-specified secondary subgroup analysis among CONCEPTT participants

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Abstract

Aim   To describe the dietary intakes of women with Type 1 diabetes before and during pregnancy.

Methods   This was a pre-specified subgroup analysis of CONCEPTT involving 63 women planning pregnancy and 93 pregnant women from 14 sites in England, Scotland and Ireland. Two hundred and forty-six 3-day food diaries (104 planning pregnancy, 142 pregnant) were matched to data source and food reference codes, and analysed using dietary software. Participants were informed that food diaries would be de-identified and used only for research purposes.

Results   Mean (SD) daily energy intake was 1588 (346) kcal and 1673 (384) kcal in women planning pregnancy and pregnant women respectively. Total carbohydrate intake was consistent with dietary guideline recommendations [180 (52) g planning pregnancy, 198 (54) g pregnant], but non-recommended sources (e.g. sugars, preserves, confectionery, biscuits, cakes) contributed to 46% of total daily carbohydrate intake. Fat consumption exceeded guideline recommendations [70 (21) g planning pregnancy, 72 (21) g pregnant]. Fibre [15.5 (5.3) g planning pregnancy, 15.4 (5.1) g pregnant], fruit and vegetable intakes [3.5 (2.2) and 3.1 (1.8) serves/day] were inadequate. Twelve women planning pregnancy (19%) and 24 pregnant women (26%) did not meet micronutrient requirements.

Conclusions   The diets of pregnant women from England, Scotland and Ireland are characterized by high fat, low fibre and poor-quality carbohydrate intakes. Fruit and vegetable consumption is inadequate, with one in four women at risk of micronutrient deficiencies. Further research is needed to optimize maternal nutrition for glycaemic control and for maternal and offspring health.

Diabet. Med. 00: 1–8 (2019)

Introduction

Women with Type 1 diabetes enter pregnancy at increased risk of maternal and neonatal complications, such as pre-eclampsia, preterm and caesarean delivery [1,2]. In the United Kingdom (UK), babies of mothers with diabetes are nearly five times as likely to be stillborn and twice as likely to have a major congenital anomaly [3]. Fetal macrosomia rates remain high [4,5] and this is associated with the longer-term development of obesity, metabolic and lipid abnormalities in the offspring [6,7].

Maternal glycaemic control is widely accepted as the key potentially modifiable determinant of obstetric and neonatal complications. This is reflected in clinical guidelines, which recommend that pregnant women aim for optimal glucose control, with maternal $HbA_{1c} < 43$ or < 48 mmol/mol (6.0% or 6.5%) [8,9]. In reality, such tight glycaemic control is difficult to achieve, even among women who plan for pregnancy and attend pre-pregnancy care services [10].

Maternal diet is an important consideration when improving glycaemic control. Carbohydrate is the primary macronutrient contributing to postprandial hyperglycaemia and insulin dosing at mealtimes should be matched to anticipated consumption. At large quantities, dietary fat and protein are also relevant to glycaemic control with recent studies

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What's new?

- Maternal glycaemic control is the main modifiable determinant of pregnancy outcomes in Type 1 diabetes. Maternal diet influences insulin dosing and glycaemia; and contributes to the overall health of the mother, yet this has not been described previously.

- This study demonstrates that pregnant women with Type 1 diabetes have higher than recommended intakes of fat and inadequate intakes of fibre, fruit and vegetables.

- One in four women are at risk of micronutrient deficiencies suggesting substantial scope for improvement.

- Further research is required to understand how to optimize maternal nutrition both for achieving glucose control targets and for improving overall maternal and infant health.

demonstrating additive effects resulting in sustained and late postprandial hyperglycaemia [11–13].

The American Diabetes Association's (ADA) recommendations for all pregnant women with diabetes are 175 g of carbohydrate per day, including 28 g of fibre, aiming for optimal glycaemic control without hypoglycaemia or ketonaemia. Adequate protein consumption is defined as 1.1 g per kg per day [14]. A registered dietitian should also be involved in antenatal care to establish a food plan, determine gestational weight gain goals, and help women with Type 1 diabetes balance the demands of glucose control, insulin dosing and healthy eating during pregnancy [8].

Although nutritional guidelines exist, data regarding current dietary habits of pregnant women with Type 1 diabetes are limited. Our aim is to describe the detailed dietary intakes of women before and during pregnancy. Additionally, we describe the spread of carbohydrate consumption; fibre, fruit and vegetable intakes and closeness to current dietary recommendations.

Methods

CONCEPTT study design

Continuous Glucose Monitoring in Pregnant Women with Type 1 Diabetes (CONCEPTT) (NCT 01788527) was an open-label, multicentre, randomized controlled trial (RCT) with two parallel arms: one of women planning pregnancy and the other of pregnant women. Participants were aged between 18 and 40 years, and had Type 1 diabetes of > 12 months' duration treated with intensive insulin therapy. Women planning pregnancy were eligible if their baseline HbA$_{1c}$ was between 53 and 86 mmol/mol (7.0% and 10.0%). Pregnant women were eligible if their HbA$_{1c}$ level

was between 48 and 86 mmol/mol (6.5% and 10%) at < 13 weeks 6 days' gestation with a singleton fetus.

Participants entered a 7-day run-in phase wearing masked continuous glucose monitoring (CGM; iPro2, Medtronic, Minneapolis, MN, USA) and performing self-monitoring of blood glucose (SMBG). CGM and SMBG data were reviewed to determine device use. If satisfactory, participants were randomized to either real-time CGM (intervention) or SMBG (control) for 24 weeks in those planning pregnancy or until delivery in those who were pregnant. Full details of the clinical study protocol were previously published [15].

CONCEPTT-Diet protocol

All participants from England, Scotland and Ireland were invited to the dietary study. Women who consented completed 3-day baseline food diaries during the CGM run-in phase. For pregnant women, these were completed no later than 13 weeks 6 days' gestation. Women planning pregnancy repeated a follow-up food diary at 24 weeks from randomization. Pregnant women completed their follow-up food diary at 34 weeks' gestation (~ 24 weeks from randomization). Ethics approval for the dietary study was obtained from the Essex NRES East of England Research Ethics Committee (Ref:12/EE/0310).

Baseline data

The age, ethnicity, obstetric history, education level, duration of diabetes, history of hypoglycaemia, method of insulin delivery and presence of diabetes complications were self-reported to site investigators. A standard physical examination (vital signs, weight and height) was performed. Bloods for HbA$_{1c}$ were drawn at randomization and analysed at a central laboratory. Further details regarding the CONCEPTT study protocol are available [5,15].

Food diaries

Local study coordinators (comprising specialist diabetes nurse educators, specialist dietitians, diabetes midwives and endocrinologists) provided participants with 3-day food diaries to complete at baseline and follow-up. Participants were asked to record their diets on two weekdays and one weekend day, choosing typical days of diet and activity. The diaries were structured into main meals (breakfast, lunch and dinner) and snack times (morning tea, afternoon tea and supper), typically eaten mid-morning, mid-afternoon and after dinner and/or before bed. Participants were encouraged to include portion weights, carbohydrate contents and brand names for foods where possible. An example of a completed food diary was provided for reference. Participants were informed that their food diaries would be de-identified and used only for research purposes.

Food coding

Dietary analysis was performed using Dietplan 6.70.75 (Forestfield Software Ltd, Broadbridge Heath, Horsham, UK). This software is supplied with data from the UK Nutrient Databank, mainly comprising *McCance & Widdowson's The Composition of Foods* (sixth edition) and the Composition of Foods Integrated Data Set (IDS) [16]. Recorded food and drink items were matched to data-source and food-reference codes.

Portion sizes were determined using weight and carbohydrate information from the food diaries. For items without this information, 'medium' portions were selected using default portion sizes in Dietplan 6.70.75, or, by referencing the Food Standards Agency's 'Food Portion Sizes' [17]. All food and drink coding was performed by one researcher (SLN), who was blinded to treatment allocation. Queries regarding food coding were resolved by discussion with the study dietitian (JAG), who also independently reassessed the diaries of outliers reporting extreme quantities.

Dietary analysis

Data containing macronutrient and micronutrient content of each food diary were exported to Excel v. 14.7.3 (Microsoft, Redmond, Washington, DC, USA). Baseline and follow-up diaries for women planning pregnancy were combined to provide one set of pre-pregnant food data. Analysis of baseline and follow-up diaries for pregnant women demonstrated no statistically significant differences in macronutrient intakes between timepoints (Table S1) and diaries were therefore pooled to provide one set of food data collected during pregnancy. Women in the planning pregnancy group who became pregnant completed food diaries on conception and these were used in the pregnancy group. Each day of a food diary was treated equally, and the results represent total data for the two cohorts divided by the number of participant-days.

The percentage of under-reporters was determined using the Henry equation [18,19] and the Goldberg method [20]. The ratio of energy intake to basal metabolic rate was calculated for each participant. A threshold of 0.9 was used in accordance with previous studies involving pregnant women [21,22].

Atwater figures were used to determine the contributions of carbohydrates, proteins and fats to total energy. Food and drink items were classified into 14 food groups, in accordance with the National Diet and Nutrition Survey [23] as follows: cereals and cereal products; milk and milk products; eggs and egg dishes; vegetables and potatoes; fruit; meat and meat products; fish and fish dishes; fat spreads; sugars, preserves and confectionery; savoury snacks; nuts and seeds; non-alcoholic beverages; alcoholic beverages and miscellaneous food items.

When assessing fruit and vegetable consumption, one serve was defined as 80 g of fresh fruit, beans and lentils, vegetables or vegetable dishes. One serve of fruit juice was defined as 150 ml of all fruit and vegetable juices. For the calculation of '5 a day' intakes, the number of fruit and vegetable portions were added to the number of portions of fruit juice (to a maximum of one serve/150 ml per day), following the methodology of the National Diet and Nutrition Survey [24].

The Medical Nutrition Therapy guidelines from the ADA [25] were used to assess carbohydrate intake from recommended and non-recommended sources. These guidelines, which promote eating patterns for overall health (including adequate fibre and sufficient micronutrient intakes) recommend preferential carbohydrate intake from vegetables, fruits, whole grains, legumes and dairy products. Food reference codes for the following foods were therefore classified as ADA recommended carbohydrate sources: cereal grains, brans and germs; pasta, noodles and couscous; breads; milk and yogurt products; vegetables and vegetable dishes (including potatoes steamed, baked and boiled but excluding chipped potatoes and fries); fruit and fresh fruit juice. The remaining food-reference codes were classified as ADA non-recommended carbohydrate sources.

Referenced UK dietary recommended values (DRVs) are from the Department of Health's 'Dietary Reference Values for Food Energy and Nutrients' [26]. Micronutrient intakes were compared to Reference Nutrient Intakes (RNI), the amount required to ensure the needs of 97.5% of the population studied are being met. If the average intake of a group is at RNI, the risk of deficiency is small [26]. The percentage of the groups whose mean intake achieved the RNI using the population compliance method [27] is also reported. Nutritional adequacy was assessed by determining the proportion of individuals with intakes below the lower reference nutrient intakes (LRNI), the amount sufficient for the few people in a group who have low needs [26]. UK average values are taken from National Diet and Nutrition Survey data for non-pregnant women aged between 19 and 64 years, referred to as the UK background population [23].

Statistical analysis

Data analysis was performed using Excel v. 14.7.3 and SPSS v. 21.0 (IBM, Armonk, NY, USA). Macronutrient and micronutrient intakes are described as mean (SD). Independent *t*-tests were used to assess differences in macronutrient intakes between the planning pregnancy and pregnant groups. Data was normally distributed, and the significance threshold was set at 0.05.

Results

Study population

63 women planning pregnancy and 93 pregnant women provided 104 and 142 three-day food diaries respectively. Food diaries were collected from CONCEPTT participants at 11 National Health Service (NHS) hospitals in England, two

in Scotland (Edinburgh, Glasgow) and one Health Service Executive (HSE) hospital (Galway) in Ireland from March 2013 to August 2016. Nine diaries (3.6%) were incomplete with data provided for less than 3 days. For these diaries, only data from completed days were used. This provided a total of 307 participant-days in women planning pregnancy and 421 participant-days in pregnant women.

27 food diaries from the planning pregnancy group (26%) and 33 from the pregnant group (23%) were identified as being from under-reporters. Macronutrient intakes of carbohydrate, protein and total fat were analysed with and without exclusion of known under-reporters. With the exclusion of under-reporters, total energy and saturated fat intakes were high during pregnancy compared to pre-pregnancy (Table S2). However, to avoid misclassification of true low energy intakes and to allow comparison with the UK National Dietary Nutritional Survey, which does not adjust for under-reporting [28], food diaries from all participants, including under-reporters are included in the main analyses.

Maternal age, BMI, duration of diabetes, education level, baseline HbA_{1c} and insulin pump use did not differ between those who did and those who did not consent to participate in the CONCEPTT-Diet study [5]. There were more women of European origin, and more women with microvascular complications, especially retinopathy, in the CONCEPTT-Diet study compared with the full randomized controlled trial (data not shown).

Baseline characteristics of the participants are detailed in Table 1. The majority of participants were recruited from English sites. Gestational age in the pregnancy group at randomization was mean (SD) 10.3 (2.8) weeks. Baseline BMI was in the overweight category in both groups.

Total energy intake

Mean (SD) energy intakes were 1588 (346) kcal/day in women planning pregnancy and 1673 (384) kcal/day in pregnant women (Table 2). The major sources of energy were similar between groups, consisting of cereals and cereal products (30–33%), meat and meat products (15–18%), vegetables and potatoes (12%), and milk and milk products (10%). The energy intake derived from alcoholic beverages was negligible in both groups (1.5% of mean daily energy intake in women planning pregnancy and < 0.1% in pregnant women).

Fibre, fruit and vegetables

Daily fibre intakes were below dietary recommendations of 28 g per day in both groups; mean (SD) 15.5 (5.3) g/day in women planning pregnancy and 15.4 g/day (5.1) in pregnant women. Fibre intakes were mainly derived from bread, vegetables, fruit and breakfast cereals.

Table 1 Baseline characteristics of CONCEPTT-Diet study participants

	Planning pregnancy ($n = 63$)	Pregnant ($n = 93$)
Age (years)	33.3 (3.5)	31.8 (4.9)
European origin*	59 (94)	86 (92)
Recruitment from*		
England	62 (98)	73 (78)
Scotland	1 (2)	16 (17)
Ireland	0 (0)	4 (4)
Primiparous*	NA	36 (38.7)
BMI (kg/m²)	27.0 (4.9)	26.2 (4.6)
Duration of diabetes (years)	17.8 (7.9)	17.0 (7.7)
HbA_{1c} (mmol/mol)	58 (7.2)	52 (5.9)
HbA_{1c} (%)	7.5 (0.7)†	6.9 (0.5)‡
Smoking prior to pregnancy*	6 (9.5)	17 (18.3)
Post-secondary school education*	52 (83)	71 (76)
Folic acid (prior to pregnancy)*	36 (57)	54 (58)
Insulin pump therapy*	47 (75)	38 (41)
Multiple daily insulin injections*	16 (25)	55 (59)
Total insulin dose (U/kg/day)	0.60 (0.17)	0.72 (0.21)
Diabetes complications*	29 (46)	41 (44)
Retinopathy	27	41
Nephropathy	3	4
Neuropathy	2	1
Chronic hypertension*	14 (22.2)	7 (7.5)
SBP (mmHg)	122.1 (12.9)	121.5 (13.0)
DBP (mmHg)	74.2 (8.6)	71.3 (8.6)
History of severe hypoglycaemia (requiring third party assistance) in past 12 months*	4 (6.3)	5 (5.4)

Data are given as mean (SD) or *number (%).
Thirteen women in the planning pregnancy group conceived and food diaries during their pregnancies were included in the pregnant group.
†Eight missing central laboratory HbA_{1c} values, data for $n = 55$ (87.3%).
‡Seven missing values, data for $n = 86$ (92.5%).
NA, not applicable.

The average consumption of fruit and vegetables was mean (SD) 3.5 (2.2) serves per day in women planning pregnancy and 3.1 (1.8) serves per day (1.8) in pregnant women. Thirty food diaries (29%) from women planning pregnancy included fruit juice and, in these participants, mean (SD) consumption was 82 ml/0.54 (0.51) serves. Among pregnant women, 51 food diaries (36%) included fruit juice and mean daily consumption in these women was 133 ml or 0.89 (1.12) serve. Only 25 food diaries (24%) from women planning pregnancy and 29 food diaries (20%) from pregnant women met the '5 a day' UK fruit and vegetables recommendation. Approximately 10% of food diaries from

Table 2 Macronutrient intakes of CONCEPTT-Diet study participants

	CONCEPTT planning pregnancy	CONCEPTT pregnant	Mean difference (95% CI); P-value	UK average for women aged 19–64 years	UK DRV for women aged 19–50 years
Energy (kcal/day)	1588 (346)	1673 (384)	85 (−9, 178); 0.08	1632 (503)	1940 / 2140 (pregnant)
Protein (g/day)	65.5 (15.8)	69.3 (15.7)	3.9 (−0.1, 7.9); 0.06	66.6 (20.8)	45 / 51 (pregnant)
Carbohydrate (g/day)	180 (51.6) / 42.5% food energy	198 (54.3) / 44.4% food energy	18 (5, 32); 0.008	199 (66)	50% of food energy
Total fat (g/day)	69.9 (21.3) / 39.6% food energy	72.1 (21.5) / 38.8% food energy	2.2 (−3.2, 7.6); 0.43	62.4 (25.1)	< 35% of food energy
Saturated fat	25.7 (8.4)	27.4 (8.5)	1.1 (−0.4, 3.9); 0.12	NA	< 11%
Monounsaturated fat	23.6 (8.1)	23.8 (7.6)	0.2 (−1.8, 2.2); 0.81	NA	12%
Polyunsaturated fat	12.2 (6.0)	12.2 (4.9)	0 (−1.4, 1.3); 0.96	NA	6%
Trans-fat	1.5 (0.8)	1.7 (0.9)	0.2 (−0.02, 0.4); 0.07	0.9 (0.5)	< 2%

Data are mean (SD).
P-values calculated using independent t-tests.
Macronutrient consumption in the background UK population and UK Dietary Recommended Values (DRV) are provided for reference.
NA, data not available.

both groups reported an average daily intake of less than one serve of fruit and vegetables.

Macronutrients

Mean daily carbohydrate intake was higher in the pregnancy group compared to the planning pregnancy group ($P = 0.008$) (Table 2). Women consumed nearly 80% of carbohydrates at meal times (Table 3). Carbohydrates were similarly spread across the day in both groups, with women consuming ~ 20% (35 g) of daily carbohydrates at breakfast, ~ 30% (50 g) at lunch and ~ 30% (60 g) at dinner. Sources of carbohydrates differed by meals and snack times (Tables 3, S3 and S4).

Recommended sources of carbohydrates contributed to 54% of mean daily carbohydrate intake in the planning pregnancy group and to 56% of mean daily carbohydrate intake in the pregnancy group. Major sources of non-recommended carbohydrates were sugars, preserves and confectionery; biscuits and cakes and sweet buns; non-alcoholic beverages (including soft drinks, Lucozade) and savoury snacks. Of the non-recommended carbohydrates, approximately two-thirds were consumed at main meals (~ 56 g) and one-third (~ 30 g) at snack times.

Mean (SD) daily protein intake was 65 (16) g in women planning pregnancy and 69 (16) g in pregnant women (Table 2). The three most significant sources of protein were meat and meat products, cereal and cereal products, and milk and milk products. Protein consumption occurred almost exclusively (90%) at meal times.

Table 3 Contribution of food groups to carbohydrate intake at mealtimes and snack times in CONCEPTT-Diet study participants

	Planning pregnancy		Pregnant	
	Main meals	Snack times	Main meals	Snack times
Cereals and cereal products	41.48	7.41	39.07	8.87
Vegetables and potatoes	12.92	0.42	14.09	0.17
Milk and milk products	4.40	1.24	3.68	2.16
Meat and meat products	4.34	0.14	5.23	0.36
Fruit	4.08	2.79	3.22	3.91
Sugars, preserves and confectionery	3.59	5.09	2.20	4.84
Savoury snacks	2.64	1.19	2.04	1.63
Beverages (non-alcoholic)	2.03	2.49	2.98	2.33
Miscellaneous	1.94	0.09	1.76	0.05
Fish and fish dishes	0.79	0.01	0.57	0.00
Beverages (alcoholic)	0.31	0.15	0.01	0.01
Nuts and seeds	0.18	0.14	0.41	0.19
Eggs and egg dishes	0.10	0.00	0.19	0.02
Fat spreads	0.03	0.00	0.02	0.00
Total	78.82	21.19	74.47	24.54

Values are percentages.

Table 4 Contribution of food groups to average daily total fat intake at mealtimes and snack times in CONCEPTT-Diet study participants

	Planning Pregnancy		Pregnant	
	Main meals	Snack times	Main meals	Snack times
Meat and meat products	18.62	0.56	20.65	0.98
Cereals and cereal products	13.55	4.68	13.68	5.40
Milk and milk products	11.71	2.03	11.67	4.16
Vegetables and potatoes	11.21	0.31	10.80	0.12
Fat spreads	6.40	0.76	6.06	0.96
Eggs and egg dishes	4.86	0.09	2.78	0.37
Miscellaneous	4.67	0.13	4.73	0.07
Savoury snacks	3.97	1.87	3.18	2.67
Fish and fish dishes	3.73	0.05	2.17	0.00
Sugars, preserves and confectionery	2.26	2.88	1.11	3.11
Fruit	1.59	0.09	0.84	0.15
Nuts and seeds	0.97	1.82	1.62	1.97
Beverages (non-alcoholic)	0.52	0.67	0.32	0.40
Beverages (alcoholic)	0.00	0.00	0.00	0.00
Total	84.06	15.94	79.61	20.39

Values are percentages.

Total fat and saturated fat intakes were similarly high between groups ($P = 0.43$) (Table 2). Consumption of fat occurred mainly at mealtimes (85% in the planning pregnancy group and 80% in the pregnant group), with major sources being meat and meat products, cereal and cereal products, milk and milk products, and vegetables and potatoes (Table 4). At snack times, cereal and milk products, savoury snacks, and sugars, preserves and confectionery were the main sources of fat.

Micronutrients

Mean daily consumption of most minerals (sodium, calcium, phosphorous, chloride and zinc) and vitamins (C, D, E, thiamine, retinol and B6) met RNIs (Table S5). Mean sodium intake was higher than the RNI of 1600 mg/day, both before and during pregnancy (2389 and 2570 mg/day respectively). Mean daily intakes of potassium, magnesium, iron, selenium and iodine were below RNIs, similar to the background population. Twelve women planning pregnancy (19%) and 24 pregnant women (26%) did not meet nutritional requirements, i.e. their intakes were below LRNIs, the most commonly affected vitamins being riboflavin and folate.

Discussion

This is the first multicentre study to describe the dietary habits of women with Type 1 diabetes before and during pregnancy. Overall, participants' intakes are characterized by being high in fat and low in fibre, fruit and vegetables compared with current nutritional guidelines. Fewer than one-quarter of participants met the UK '5 a day' fruit and vegetable target [29], and nearly one in four women were at risk of micronutrient deficiencies.

The total carbohydrate intakes of 180–200 g per day met recommendations [14] and carbohydrates were evenly distributed throughout the day at meals and snack times. However, nearly half of these daily carbohydrates were derived from non-recommended sources. Protein consumption was sufficient and similar to the UK background population. Energy intake derived from fat appeared higher than the UK background population (~ 40% in CONCEPTT-Diet compared with 34% in the background population). Micronutrient intakes in our study participants appear comparable with the background population for most vitamins and minerals.

The dietary patterns observed in our participants have been reported previously in other Type 1 diabetes cohorts outside of pregnancy [30–32]. These studies reported high fat diets, low fibre, fruit and vegetable consumption, and suboptimal micronutrient intakes in children, adolescents and adults living with Type 1 diabetes. The goals of optimizing glycaemic control and minimizing postprandial excursions may have resulted in the habitual substitution of carbohydrates for fat. Additionally, in our study, high intakes of confectionery and sugars were observed, possibly consumed to treat and/or prevent hypoglycaemia. We were unable to distinguish between these rapidly absorbed carbohydrates eaten as snacks and those used for management of hypoglycaemia due to limitations of the dietary software.

There are only two prior studies evaluating maternal dietary intake during Type 1 diabetes pregnancy. The first, conducted during 1983–1991, focused on dietary fibre, describing 16–18% lower total daily insulin doses in women with higher fibre intakes [33]. A more recent Danish study examined total carbohydrate consumption, demonstrating a positive association between carbohydrate intake and maternal HbA_{1c} level in early pregnancy [34]. Neither study reported total energy or micronutrient intake.

The impact of a high-fat diet in Type 1 diabetes pregnancy is unknown. Data from studies in women with gestational diabetes suggest that high dietary fat intake (45% fat) is associated with increased maternal insulin resistance and new-born adiposity compared with a low-fat, high-carbohydrate diet [35]. We speculate that dietary fat intake may also be relevant for women with Type 1 diabetes, for whom the risk of a large for gestational age infant persists despite good glycaemic control [36].

The strengths of this study include the large sample sizes, the inclusion of women from across 14 sites in England, Scotland and Ireland, and the choice of methodology for dietary assessment. Compared with alternative methods, the food diary has been found to be more repeatable and accurate [37]. The total energy intake and macronutrient consumption in our study are very close to those in the background UK population. Sufficient detail was provided for descriptions of whole foods rather than single nutrients.

There are a number of limitations to consider when interpreting the results of our study. As with all dietary studies, under-reporting is an important issue and verification of actual consumption with a structured interview or photographs did not occur. Where portion sizes were not provided in the food diaries, 'medium' portions were selected, and the dietary software used does not allow us to audit the frequency of this occurrence. Food diaries from under-reporters were retained for analysis, which is likely to have resulted in total energy intakes being lower than expected. Additionally, food diaries from pregnant women in both early and late gestation were combined for analysis and we are therefore unable to describe dietary differences across trimesters. The study could have been strengthened by the collection of food data during the second trimester.

The generalizability of this study is affected by several factors. Participation in CONCEPTT-Diet was offered only at sites within the UK and Ireland, and the majority of women were from England. Additionally, the women in our study had relatively long durations of diabetes (mean 17 years) and a high proportion (> 75%) had achieved post-secondary school education.

Conclusion

The CONCEPTT-Diet study provides a comprehensive analysis of the current dietary habits of women with Type 1 diabetes before and during pregnancy in the UK and Ireland. Overall, nutritional guidelines are not being met. Of particular concern, are the high fat and low fibre dietary intake, with nearly half of mean daily carbohydrate intake being from non-recommended sources (e.g. confectionery, biscuits and cakes). Fruit and vegetable intake is inadequate, with between one in four and one in five women at risk of micronutrient deficiencies. The emphasis on achieving tight glycaemic targets in pregnancy may have resulted in the substitution of carbohydrates for fat, and the consumption of sweets and confectionery to prevent and/or treat hypoglycaemia. It is difficult to maintain healthy nutritional choices while at the same time aiming for strict glycaemic control.

This study demonstrates that there is significant scope for dietary improvement, but further research is required to determine whether, and to what extent, dietary behaviour is modifiable. Further studies are also required to understand the impact of maternal diet on glycaemic control and infant health outcomes. Optimizing maternal nutrition should be considered alongside intensive insulin therapy, in the clinical management of women with Type 1 diabetes.

Author contributions

HRM and SLN designed the CONCEPTT-Diet study. SLN and JAG collected the data and coded the food diaries. SLN and HRM wrote the first draft of the manuscript and all authors (SLN, JAG, DSF, HRM) contributed to data interpretation, reviewing and editing of the manuscript.

Participating investigators from UK CONCEPTT sites are listed in the Supporting Information.

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Supporting Information

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

Table S1. Energy and Macronutrient Intakes of CONCEPTT-Diet Pregnant participants during early and late gestation.

Table S2. Macronutrient intakes of CONCEPTT-Diet study participants, excluding food diaries from identified under-reporters.

Table S3. Contribution of food groups to average daily total carbohydrate intake in CONCEPTT-Diet study participants planning pregnancy.

Table S4. Contribution of food groups to average daily total carbohydrate intake in pregnant CONCEPTT-Diet Study participants.

Table S5. Micronutrient intakes of CONCEPTT-Diet study participants.

Doc. S1. The CONCEPTT-Diet study investigators.