Article

Title**Pregnant women living with obesity; a cross-sectional observational study of dietary quality and pregnancy outcomes**

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**Abstract:** Good maternal nutrition is key to optimal maternal and fetal health. A poor quality diet is often associated with obesity, and the prevalence and severity of maternal obesity has increased significantly in recent years. This study observed dietary intakes in pregnantt women living with obesity, assessing the quality of their diet. 140 Women with a singleton pregnancy, aged >18 years and BMI ≥35kg/m2 were recruited from antenatal clinics, weighed and completed food diaries at 16, 28 and 36 weeks’ gestation. Clinical data were recorded directly from the women's medical records. Nutrient intake was determined using ‘MicrodietTM’, then compared to Dietary Reference Values (DRVs). Energy intakes were comparable with DRVs, but intakes of sugar and saturated fatty acids were significantly higher. Intake of fibre and several key micronutrients (iron, iodine, folate and vitamin D) were significantly low. Several adverse obstetric outcomes were higher than the general obstetric population. Women with obesity, often considered ‘over nourished’, may have diets deficient in essential micronutrients, often associated with poor obstetric outcomes. To address the intergenerational transmission of poor health via poor diets, warrants a multi-disciplinary approach focusing away from 'dieting' onto positive messages, emphasising key nutrients required for good maternal and fetal health.

**Keywords:** pregnancy; obesity; nutrition; diet; BMI; malnutrition; micronutrients; macronutrients; clinical outcomes

1. Introduction

In England the majority of adults are overweight or obese (63%, NHS Digital, 2020), and within the pregnant population less than half are recorded as having a health weight, with over a fifth of pregnant women living with obesity [1]. The World Health Organization [2] define the degree of overweight or obesity in adults using the following classifications: Healthy weight – Body Mass Index (BMI) 18.5 kg/m2 to 24.9 kg/m2; Overweight – BMI 25 kg/m2 to 29.9 kg/m2; Obesity Class I – BMI 30 kg/m2 to 34.9 kg/m2; Obesity class II – BMI 35 kg/m2 to 39.9 kg/m2 and Obesity class III – BMI 40 kg/m2 or more [2] these classifications are also applied to clinical guidelines in England and Wales [3]. The Centre for Maternal and Child Enquiries (CMACE) and Royal College of Obstetricians and Gynaecologists jointly states that overweight and obesity during pregnancy significantly influence maternal mortality, with 49% of deaths occurring in women who are overweight (BMI ≥25kg/m2), and27% of deaths occur in women living with obesity (BMI≥30kg/m2) [4]. Obesity is often associated with poor quality diet. The World Health Organisation [5] acknowledges that good nutrition during early life is the most important factor in tackling both the double burden of disease and health inequalities worldwide. They assert that poor nutrition during early life, including pregnancy, can have detrimental, short-term and long-lasting effects. Maternal nutritional intake is an important determinant of Gestational Weight Gain (GWG), which influence maternal and child health outcomes.

In the UK, there are currently no official evidence-based guidelines for GWG during pregnancy, although the RCOG (2018) have acknowledged that there is “a lack of consensus” on optimal GWG, and therefore recommend that pregnant women living with obesity are encouraged to adopt a healthy diet rather than GWG targets, and receive advice from a dietitian [1]. However, in the absence of such guidance and limited access to dietetic input, Health Care Professionals (Midwifes) often refer to international guidelines to inform their advice and monitoring of pregnancy women [6]. Specifically, the USA Institute of Medicine guidelines [7] advises women to limit GWG according to pre-pregnancy BMI, as considered to be associated with optimal birth weight [8]. The IOM recommends that pregnant women living with obesity (BMI ≥30kg/m2) should limit their GWG to 11-20lbs ( 5- 9kg) in total, and those classified as overweight (BMI ≥25kg/m2) to 15-25lbs (7 – 11.5kg) [7]. GWG above these guidelines, would be classed as excessive. Maternal obesity and excessive GWG are associated with several adverse obstetric outcomes, including pre-eclampsia, Gestational Diabetes Mellitus (GDM), Type 2 Diabetes Mellitus (T2DM), macrosomia and Neural Tube Defects (NTD) [9], [10], [11], [12]. It has been observed that women living with obesity pre-gravid (BMI≥ 30kg/m2) often gain less weight than normal weight women during pregnancy, likely due to the more stringent parameters, however, they still gain more than IOM recommendations [13], and particularly so when advice regarding the ‘optimal’ amount is not offered [14].

In the UK, a study nested within routine antenatal care, ‘Fit for Birth’ (FFB), determined that older, primiparous pregnant women living with (class I & II) obesity, registering a BMI between 30-40kg/m2 at booking-in, were more at risk of excessive GWG, compared to women with a higher BMI (≥ 40kg/m2 ,class III+) and was significantly associated with adverse perinatal outcomes [12] . Further to this, Cassidy et al (2018) found women living with a healthy or over-weight status (BMI 20 to 29.9kg/m2) were more likely to have GWG in excess of IOM recommendations and women with a BMI 20 to 24.9 kg/m2 (considered healthy weight); who experienced excessive GWG, were more likely to need an assisted delivery, compared to those with lower GWG [15]. Excessive dietary intake and obesity or excessive GWG can have a significant impact on maternal metabolism, increasing insulin resistance, and thus glycaemic control, lipid oxidation and amino acid synthesis. The potential for increasing normal postprandial plasma concentrations of glucose, lipid and amino acids is also a consequence of excessive energy intake [16]. Furthermore, GWG is associated with increased levels of umbilical leptin, thus elevating the offspring’s risk of developing T2DM in adulthood [17]

Despite, levels of obesity in the UK, evidence reviewing dietary intake for women (aged 19-64 years old) in the UK National Diet and Nutrition Survey, reports overall sub-optimal diets with many women not consuming the recommended daily intake of fruit and vegetables, dietary fibre and omega-3-Fatty Acids; whilst intake of sugars and saturated fatty acids are too high [18]. Moreover, with reference to specific micronutrients, such as iron, intake is also lower than recommended. If this data is considered in the context of women within reproductive age, dietary intakes during pregnancy may remain sub-optimal or indeed decline further, given the increase in nutrient requirements of the mother and fetus during pregnancy. Deficiencies can negatively impact the health of the mother and the baby. Research examining the diet of pregnant women has increased in recent years and does indeed suggest issues in energy balance and nutrient intakes, with energy requirements being derived mainly from fat and protein with large contributions from saturated fat and sugar but with significantly lower intakes of dietary fibre, influencing maternal BMI and GWG but also increasing maternal metabolic stress and the risk for obesity in the offspring [19] [17]. Further to this, intakes of micronutrients are known to influence pregnancy outcomes and neonatal health. Folate, found in green leafy vegetables and citrus fruits, is essential for cell division, protein synthesis and neurotransmitters in embryonic and fetal growth and development. Deficiencies are linked to neural tube defects and insufficient intakes to impaired neurological development [20]. Iodine, derived from seafood, fortified foods and milk is required for cognitive development. Deficiencies can lead to a range of outcomes from mild cognitive impairments to endemic cretinism [21]. Iron deficiency anaemia is associated with low birth weight (LBW) or small for gestational age (SGA) infants, pre-term deliveries and abnormal psychomotor development and impaired cognitive function as well as increased risk of maternal infection [22]. Low maternal calcium status and low dietary intakes increase the risk for hypertensive disorders of pregnancy and LBW and vitamin D, required for maintaining calcium homeostasis and optimising bone health, also plays an essential role in glucose metabolism, immune function, inflammation and regulation of gene transcription and expression [22]. However, research evaluating the quality of diet for pregnant women living with obesity, is limited. Notable studies are the Australian WATCH study [23] and Motivations to eat and diet quality study [24]. Studies evaluating intakes of specific supplements such as vitamin D [25], [26].

Most studies are aimed at reducing risks, i.e., gestational diabetes, associated with GWG and obesity [27] [28] [29] [30] via lifestyle interventions or reducing GWG [31] [32] [33].

Given the paucity of studies evaluating the quality of dietary intake in pregnant women, and lack of aggregation to data to consider weight status variations, and the impact of living with obesity. The aim of this study was to observe dietary intakes in a cohort of pregnant women living with obesity and assess the quality of their diet. Make a statement on predicted hypotheses here.

2. Materials and Methods

*2.1. Study Design*

This was a cross-sectional observational study. This research and the write up of this study has applied STROBE guidelines (2009) to aid quality [34] An NHS ethics application was approved for this study (IRAS - ref number 09/H1005/23).

*2.2. Study Population*

A convenience sample of pregnant women living with obesity, with a recorded BMI ≥ 35 kg/m2, were approached by community midwives during their pregnancy booking-in appointment and invited to participate in a specialist research clinic (The Fit for Birth plus trial; FFB+). A BMI ≥ 35 kg/m2 being the threshold at which women were referred for antenatal bariatric services. Women with multiple pregnancies or below the age of 18 years old, were excluded from the study. The recruitment cycle for the study took place over 12 months. Written consent was obtained and the women advised that they could leave the study at any point without affecting routine antenatal care.

*2.3 Anthropometric & Dietary Measurements*

 Participants were weighed and completed 3-day estimated food diaries, at 3 different time points: 16 weeks, 28 weeks and 36 weeks gestation. Three-day food diaries were selected in preference to alternative food frequency questionnaires [35] as it has been argued that for longitudinal studies estimated food diaries include more food details and better able to demonstrate a relationship between food choices and nutrients [36]. Maternal weight change data was collected via community midwives during routine antenatal appointments. Data relating to age, weight, BMI, and birth weight were collated from the women’s medical health records. Maternal weight change was recorded at approximately 36 weeks gestation and birth weight data recorded following delivery of the baby.

*2.4 Procedure*

The diaries were posted out to participants 10 days prior to a research appointment which took place in a hospital setting. The instructions for these food diaries asked the women to record all food and drinks consumed over three days (including 1 weekend day and 2 week days) in as much detail as possible, specifying cooking methods and approximate portions.

Further detail with regards to food items and portion size were verified during the follow-up appointment with the lead researcher (first author). During this appointment the researcher used tools, such as images of household measures (e.g. spoons, cups; a photographic atlas of food portion sizes [37] and nutritional labelling on food packaging (looked up via supermarket websites) to aid discussion and clarify diary entries. For example, terms such as ‘butter’ were commonly used to describe all types of ‘spread’. The appointment allowed discussion so that terminology and amounts of food consumed could be confirmed, and this process aided the validation and reliability of dietary intakes recorded.

*2.5 Data analysis*

Data regarding individual and composite foods recorded in the 3-day diaries were individually coded by the researcher. Recipes for home-cooked composite meals were assessed and the weight of servings approximated to allow for wastage, including peel, seeds, stalks etc., during preparation. The weight loss/gain from the cooking process were estimated by the researcher prior to coding. Coded data was transferred into a food composition database (Microdiet™) and assessed for total energy intake in kcals. Macronutrients that contribute to total energy intakes: protein, carbohydrate (CHO) and fat, were reported in grams (g) and as a percentage of daily energy intake. Non-starch polysaccharide (NSP), starch and total sugars were used to differentiate between CHO fragments [35] and total fat comprised of saturated fatty acids [38], mono-unsaturated fatty acids (MUFA), poly-unsaturated fatty acids (PUFA) and trans fatty acids (TFA). Key micronutrients for pregnancy (dietary folate, iodine, vitamin D, calcium and iron) were measured as milligrams (mg) or micrograms (µg). Mean values for all the nutrients recorded in the 3-day food diaries were then calculated. Data were compared to Dietary Reference Values (DRV)[39],specifically Estimated Average Requirements (EAR) for energy where half the population will require more than the EAR, and half less [39]. Specific micronutrients, essential for optimum pregnancy outcomes were categorised into Reference Nutrient Intakes (RNI) and Lower Reference Nutrient Intakes (LRNI). The RNI is defined as 2 standard deviations above EAR and is deemed an adequate intake of a nutrient for 97.5 % of a normally distributed population. Conversely, the LRNI is defined as 2 standard deviations below the EAR and represents the lowest intakes, which may be adequate for a very low number of individuals (2.5%), but inadequate for the vast majority [39].

Alcohol was not included in the analysis, as intakes were negligible. Further to this, dietary supplements were not included in the analysis, as the main aim was to look at the adequacy and quality of dietary intakes.

Nutrition data were analysed using a statistical package (SPSS, IBM SPSS Statistics Version 23). Data were explored to provide a numerical description of maternal characteristics and mean values for nutrient intakes. Inferential statistics were used to explore relationships between variables. One sample t-tests were used to compare intakes to DRV’s. Some data violated statistical assumptions, and therefore non-parametric tests Krushal-Wallis and the Friedmen’s Test were used to determine within cohort differences in intakes, and between different time points. Chi-square tests and independent t-tests were used to explore differences between groups according to categorical variables such as BMI and nutritional DRVs, [39]. A p value < 0.05 was considered statistically significant. Dietary analysis considered the data primarily as one cohort considering nutritional status for the total sample of women living with obesity. Secondary analysis has investigated differences in dietary intakes relative to BMI (section 3.4) However, to account for sample size, participants were categorised into 2 BMI subgroups groups, either women with a BMI 35-39.9kg/ m2 (n= 80) or women with a BMI ≥ 40kg/m2 (n =60).

3. Results

3.1. Participant characteristics.

Baseline data, relating to age, BMI, maternal weight, were collected for 140 women at approximately 11 weeks gestation (see Figure 1).

Figure 1. Participant recruitment and data collection

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Data relating to maternal characteristics (age, parity and weight change) were collected via the women’s health records for 134 women at various points (Table 1). Data were categorised according to BMI classification. Over half of the women (57%), were categorised as obese class II (BMI =35–39.9kg/m2) whilst 6% had the highest levels of obesity (BMI ≥50kg/m2), mean BMI 40 (SD 5.73) at booking in. Three quarters of the women in the study were aged 25-39, with 11% being over 40 years old, the mean age of the total sample was 30 years old (SD 6.02). Nearly two thirds of women were multiparous. Chi square tests for independence revealed no statistical significance between BMI and parity (p >0.05) or BMI and age (p >0.05). Thirteen percentage of the sample classified themselves as current smokers.

**Table 1:** Participant characteristics, according to BMI classification.

|  |  |  |
| --- | --- | --- |
|  | **Body Mass Index\*** *n* = 140 |  |
| ***35-39.9****n = 80 (57%)* | ***40-44.9****n = 37 (26%)* | ***45-49.9****n = 15 (11%)* | ***50+****n = 8 (6%)* | **All BMI**(100%) |
| **Age** (*n =* 140) |
| 18-2425-2930-3940+ | 15 (11)32 (23)27 (19)6 (4) | 4 (3)13 (9)16 (11)4 (3) | 4 (3)6 (4)4 (3)1 (1) | 1 (1)4 (3)3 (2)0 | 24 (17)55 (39)50 (36)11 (8) |
| **Parity** (*n =* 140) |
| Primip (1st pregnancy)Multip (2nd+ pregnancy)Missing | 32 (23)47 (34)1 (1) | 10 (7)27 (19)0 | 6 (4)8 (6)1 (1) | 5 (4)3 (2)0 | 53 (38)85 (61)2 (2) |
| **Smoking status** (*n* = 140) |
| Given upNon-smokerSmokerMissing | 9 (7)62 (44)8 (6)1 (1) | 7 (5)24 (17)6 (4)0 | 010 (7)4 (3)1 (1) | 1 (1)7 (5)00 | 17 (12)103 (74)18 (13)2 (1) |

Key: number of participants within the range (% of participants within the range)

3.2 Clinical outcomes.

Of the 140 participants recruited into this study, 134 participants (4% attrition) remained in the study until completion with clinical outcome data collected from the women’s medical records (Table 2). There were relatively few pregnancy complications reported; in total 8% had GDM, 9% hypertension and 12% had pre-eclampsia. 99% of women had live births. Over half (57%) had a vaginal delivery (49% spontaneous). Nineteen percentage of women had elective caesarean, with 26% emergency caesarean. Low birth weight (defined as below 2.5kg) was recorded for 7% of the babies born. The majority of babies were born within normal weight range (2.5-4.5 kg). The majority of babies did not require admission to Special Care Baby Unit, and APGAR scores at 1 (79%) and 5 minutes (96%) were considered normal.

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| --- | --- | --- |
|  | **Body Mass Index** |  |
| ***35-39.9****n = 80 (57%)* | ***40-44.9****n = 37 (26%)* | ***45-49.9****n = 15 (11%)* | ***50+****n = 8 (6%)* | **All BMI**(100%) |
| **Weight gain at 36wks** (*n* =39) |
| Less than 00-4.9kg5-9kg9kg+ | 2 (5)9 (23)7 (18)7 (18) | 4 (10)4 (10)2 (5)1 (3) | 1 (3)1 (3)01 (3) | 0000 | 7 (18)14 (36)9 (23)9 (23) |
| **Birth weight kg** (*n* =134) |
| 0.1-2.492.5-4.494.5-6.00 | 6 (3)67 (50)3 (2) | 1 (1)33 (25)2 (2) | 1 (1)12 (9)1 (1) | 1 (1)6 (4)1 (1) | 9 (7)118 (88)7 (5) |
| **Hypertension** (*n* = 134) |
| YesNo | 7 (5)69 (52) | 1 (1)35 (26) | 2 (2)12 (9) | 2 (2)6 (5) | 12 (9)122 (91) |
| **Pre-eclampsia** (*n* = 134) |
| **Yes****No**  | 10 (8)66 (49) | 3 (2)33 (25) | 3 (2)11 (8) | 08 (6) | **16 (12)**118 (88) |
| **Gestational Diabetes** 28 weeks *(n* = 134) |
| **Yes****No** | 6 (5)70 (52) | 4 (3)32 (24) | 1 (1)13 (10) | 08 (6) | **11 (8)**123 (92)  |
| **Birth outcome** (*n* = 134)  |  |  |  |  |  |
| Live birthStillborn | 75 (56)1 (0.8) | 36 (27)0 | 14 (11)0 | 8 (6)0 | 133 (99)1 (1) |
| **Induction of labour** (*n* = 134) |
| **No****Yes** | 52 (39)24 (18) | 24 (18)12 (9) | 8 (6)6 (5) | 5 (4)3 (2) | 89 (66)45 (34) |
| **Mode of delivery** (*n* = 134) |
| SpontaneousInstrumentalElective caesareanEmergency caesarean (EmC)EmC with failure to progress | 39 (30)6 (5)13 (10)14 (11)4 (3) | 16 (12)2 (2)8 (6)8 (6)2 (2) | 7 (5)2 (2)2 (2)3 (2)0 | 3 (2)02 (2)2 (2)2 (2) | 65 (49)10 (8)25 (19)27 (20)8 (6) |
| **Admitted to Special Care Baby Unit** (*n* =133) |
| NoYes | 67 (50)8 (6) | 34 (26)2 (2) | 13 (10)1 (1) | 7 (5)1 (1) | 121 (91)12 (9) |
| ***APGAR score 1 minute*** (*n* =133) |
| Critically low 0-3Low 4-6Normal 7-10 | 3 (2)11 (8)61 (46) | 3 (2)4 (3)29 (22) | 1 (1)4 (3)9 (7) | 03 (2)5 (4) | 7 (5)22 (17)104 (78) |
| **APGAR score 5 minutes** *(n =133)* |
| Low 4-6Normal 7-10 | 2 (2)73 (55) | 3 (2)33 (25) | 014 (10) | 08 (6) | 5 (4)128 (96) |

 Key: number of participants within the range (% of participants within the range)

Weight change data at 36 weeks gestation was reported in clinical notes of only 39 women. GWG was less than 5kg for more than (54%) of the women, with 18% of these women gaining less than 0kg. Less than a quarter (23%) were recorded to gain weight within 5-9 kg, with 23% exceeded 9kg GWG, whom would be considered to have excessive GWG [7]. Chi square tests for independence revealed no statistical associations between BMI and weight change at 36 weeks (p >0.05).

3.3 Dietary Analysis.

Of the total sample recruited into this study, n = 140 women (100%) completed at least one 3-day food diary, during the study period. 66% and 71% of women completed the diary at time points 1 (T1) (16 weeks) and T2 (28 weeks), respectively. Although by 36 weeks gestation (T3) food diary submissions were provided by 52% of the total sample. A third of women repeated the food diaries at two time points (T2 & T3) and 26% of women submitted all three food diaries (T1, T2 & T3).

3.3.2 Macronutrients

The ratios of energy derived from the macronutrients, CHO and total fat were generally consistent with Estimated Average Requirements (EAR) [40] , although intakes of total fat were significantly lower than EAR at time point 1 and CHO at time point 3 (see Table 3).

**Table 3:** Reported macronutrient intakes as a percentage of total energy in kcals

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Dietary Reference Values (DRV) | Time 1(16-20WKS)(*n* = 93) | Time 2(28WKS)(*n* = 99) | Time 3 (36WKS)(*n* = 73) | Changed Over Time(*n* = 37) |
| **Macronutrient** | **EAR** | **Mean ± SD****% (EAR)** | **Mean ± SD** | **Mean ± SD** |  |
| **Total Energy (kcals)** | 1945kcal T1 & T22145kcals T3  | 1849 ± 59195% | 1984 ± 526102% | 2066 ± 58793% | P >0.05 |
| **Protein %E** | 51g/d (RNI)Approx. 15%  | 16.0 ± 3107% 1 | 16.2 ± 3.4108% 1 | 16.6 ± 3.3111% 1 | P = 0.031\* |
| **Total Fat %E** | 35%  | 33.4 ± 6.895% 2 | 34.8 ± 6.299%  | 35.7 ± 6.2102%  | P >0.05 |
| **SFA %E** | 11%  | 12.0 ± 3.3109%  | 12.9 ± 3.2117% 1 | 13.3 ± 3.2121% 1 | P = 0.0015\* |
| **MUFA %E** | 13%  | 10.7 ± 3.182% 2 | 11.3 ± 2.987% 2 | 11.5 ± 2.688% 2 | P >0.05 |
| **PUFA %E** | 6.5%  | 5.6 ± 2.486% 2 | 5.65 ± 2.187% 2 | 5.8 ±2.189% 2 | P >0.05 |
| **P:S Ratio** | 0.8:1 | 0.51 ± 0.2664% 2 | 0.47 ± 0.2359% EAR2 | 0.46 ± 0.2158% 2 | P >0.05 |
| **CHO %E** | 50%  | 50.7 ± 7.5101%  | 48.9 ± 6.698% EAR | 47.3 ± 6.895% 2 | P >0.05 |
| **NSP g/d** | 18g/d | 12.8 ± 5.271% 2 | 12.8 ± 4.171% EAR2 | 12.8 ± 4.171% 2 | P >0.05 |
| **Sugars %E** | 11%  | 23.5214% 1 | 24.9226% EAR1 | 22.5205% 1 | P >0.05 |
| **Starch %E** | 39%  | 2667% 2 | 2769% 2 | 2872% 2 | P >0.05 |

Key DRV – Dietary Reference Values , RNI – Reference Nutrient Intake , EAR – Estimated Average Requirements

1 Significant difference where nutrient intakes exceed DRV P < 0.05

2 Significant difference where nutrient intakes fail to meet DRV P < 0.05

 One-sample T-tests compared individual macronutrient intakes to dietary reference values (see Table 3). Results show that a number of nutrients including protein (p=0.00 at T1, 2 &3) and total sugars (p=0.00 at T1, T2 & T3) significantly exceeded recommendations at all 3 time points and SFA at T2 (p = 0.00) & T3 (p = 0.002). By comparison, intakes of MUFA’s (T1 p=0.00; T2 p=0.001 & T3 p=0.002) p = 0.002) and PUFA’s (T1 p=0.00; T2 p=0.003 & T3 p=0.009) significantly failed to achieve recommendations, this was further highlighted by the ratio of PUFA to SFA which were significantly different to the recommended 0.8:1 at each visit (P=0.00 at T1, 2 & 3). Data also shows that NSP (p=0.00 at T1,2 & 3) and starch intakes (p=0.00 at T1, 2 & 3) failed to reach recommendations at a significant level.

Non-parametric Friedman’s tests were conducted to determine changes from the mean macronutrient intakes between time points 1, 2 & 3 (Table 3). Macronutrient dietary make-up of the women’s diets was mostly consistent throughout pregnancy, with the exception of protein intake, which significantly increased during pregnancy (p = 0.031), and SFA, for which there was a highly significant increase in intake during pregnancy (p = 0.0015).

3.3.3 Micronutients

Intakes relating to iron, folate, calcium, iodine and vitamin D intakes were analysed to determine the percentage of women achieving RNI or more and the percentage of women failing to achieve LRNI (see Table 5).

Table 5: Percentage of women achieving RNI & LRNI for pregnancy related micronutrients

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Micronutrient & (UK recommended intake) | DRV | Ranges | Time 1 % achieved | Time 2 % achieved | Time 3 % achieved |
| Iron (14.8mg) | <LRNILRNI≥ RNI | <7.998.0-14.7≥14.8 | 31.254.8 214.0 | 23.266.7 210.1 | 17.863.0 219.2 |
| Calcium (700mg) | <LRNILRNIRNI | <399.9400-699.9≥700 | 5.428.0 166.7 | 2.023.2 174.7 | 5.515.1 179.5 |
| Iodine (140μg) | <LRNILRNIRNI | <69.970-139.9≥140 | 18.350.5 231.2 | 13.151.5 135.4 | 8.235.656.2 |
| Vitamin D (10μg) | <RNIRNI | <9.99≥10 | 96.8 23.2 | 98.0 22.0 | 98.6 21.4 |
| Folate (300μg) | <LRNILRNIRNI | <99.9100-299.9≥300 | 1.166.7 232.3 | 073.7 226.3 | 065.834.2 |

*Key* 1 Significant difference where nutrient intakes exceed DRV P < 0.05

2 Significant difference where nutrient intakes fail to meet DRV P < 0.05

Table 5, shows a small proportion of women (14%, 10% & 19% at T1, T2 and T3 respectively), achieving the RNI of 14.8 mg/d for iron, with the majority of women not consuming the recommended intake throughout pregnancy. Overall, the pregnant women living with obesity, recorded intakes of iron which differed significantly throughout pregnancy compared to the RNI. A significant proportion (55-67% of women had iron levels throughout pregnancy only within the LRNI range (LRNI, specified as appropriate for only 2.5% of a population). A high proportion of women (31% at T1, 23% at T2 and 18% at T3) failed to achieve the LRNI of 8 mg/d for iron, indicating inadequate intakes for the group.

Calcium intake was more positive, with two thirds to three quarters achieving RNI. Although, noteworthy was that 5.4% T1 and 5.5% T3 failed to achieve LRNI (above the accepted 2.5%) whereas those achieving levels somewhere between LRNI and RNI, ranged between 15 and 28% at T1, T2 & T3.

Intakes of iodine showed that approximately one third of women achieved RNI at T1 and T2, and around 50% of women achieving RNI by T3. At T1 and T2, over half of the women, and at T3, 36% of the women met the LRNI range. However, 18.3%, 13.1% and 8.2% were below the LRNI of 69.9 µg/d at T1, T2, & T3 (respectively).

Intakes of dietary folate presented a third to a quarter of women achieved the RNI of 300 µg/d., although 66-74% achieved levels above the LRNI but below RNI.

Consumption of vitamin D (10 µg/d) was not achieved via diet intake for the majority of women (96.8%+). The biological status of vitamin D as measured by serum 25 (OH) D3 was not assessed except for women of ethnic origin (n=7) where circulating levels were found to be insufficient or deficient and ranged from 5.6μg/L to 28.7μg/L as compared to observed levels of circulating 25(OH)D3 ofbetween 54-90μg/L in populations who have adequate to good exposure to sunlight [41].

3.4 BMI and dietary composition

Chi square tests revealed no significant statistical associations between micronutrient intakes and BMI subgroups (P>0.05). Kruskal- Wallis tests were used to explore whether differences in BMI impacted on intakes of micronutrients, there were no significant differences in intakes for vitamin D, calcium, folate, iodine ( p > 0.05) or iron at T 2 & 3. However, there was a statistically significant difference in iron intakes at T1 across BMI groups (p = 0.022) with participants with a BMI ≥50kg/m2 having lower intakes that participants with a BMI 40-44.9kg/m2. Further to this, Friedman tests were conducted to compare intakes of micronutrients between T1, T2 & T3 within the cohort; however, there were no significant differences (P>0.05), possibly due to the limited sample size.

**4. Discussion**

This study recruited a sample of pregnant women living with obesity and followed them through pregnancy to consider their obesity status, GWG, nutritional intake and associated clinical outcomes.

Our findings report adverse clinical outcomes, consistent with previous literature, and when compared to the general pregnancy (all data) population, for which such outcomes might be explained by the status of obesity itself. Although not specifically GWG, contrary to previous research, in this study, the majority of women (77%) (whose weight change was calculated) did not gain more than the IOM (2009) GWG recommendations, despite living with obesity. In line with previous evidence [15], increased BMI was not an indication of (excessive) GWG. These findings would support the UK's approach [1] in dismissing specific GWG targets recommended by American guidance [7] and promoting a healthy diet for pregnant women. However, our findings indicate that many pregnant women did not meet the recommendations for a range of nutrients essential for maternal health and fetal development, suggesting that pregnant women living with obesity have variable quality diets and may require specific guidance and tailored nutritional support. The following discussion provides consideration of the findings in this study relevant to the pregnant women's dietary intake; of macro and micro-nutrients and the recorded clinical outcomes for this group of women living with obesity.

4.1 Diet Quality

At first glance, the overall diet quality of the pregnant women living with obesity looks satisfactory. However, when evaluating dietary composition, the women showed varying levels of diet quality.

4.1.1 Macronutrients

With reference to macronutrient composition, total energy intake did not differ significantly from the EAR. Similar to NDNS findings, protein intake was significantly higher than the EARs, and increased throughout pregnancy. However it was not possible to ascertain protein quality in terms of biological value [42]. Further to this, European guidelines suggest that a protein intake of 10–25% of energy intake appears to be safe, and so the intakes recorded can be considered moderate. Total carbohydrate intake did not change significantly throughout pregnancy and achieved the EAR, although, in the third trimester, there was a significant reduction from EAR, though again here would be considered within an acceptable range. In line with the healthy diet approach of the eat well guide [35], carbohydrate intake should be consumed through starchy foods, with low glycemic index and high in dietary fibre, such as vegetables, legumes, fruits and whole grains. Further breakdown of carbohydrates composition, however, suggests the carbohydrate intake in the women's diets was poor quality, as sugar intake was significantly above EAR (> 5% of energy) throughout pregnancy; consistently recorded at more than double the recommended intake, and in contrast, significantly lower levels than recommended levels (< 30g/day) were recorded for dietary fibre .

Total fat intake was within the 35% of energy EAR range and did not differ significantly throughout pregnancy. However, it is noteworthy that in Europe, total fat intake recommendation has a range from 20% to 35%, which would suggest in comparison that the total fat intake of women in this study consistently measured towards the higher acceptable range. However, further breakdown of fat intake shows SFA as significantly above EAR, and SFA intake also increased significantly throughout pregnancy. In contrast, significantly lower than EAR levels were recorded for MUFA and PUFA. PUFAs are considered the essential fatty acids for foetal growth and development and health throughout the life course, whereas SFAs are synthesised by the body and are not required in the diet, though dietary recommendations acknowledge up to 10% of energy intake as acceptable [40].

4.1.2 Micronutrients

Our findings suggest that many pregnant women are not meeting the UK recommendations for a range of micronutrients essential for positive clinical outcomes for both the mother and her offspring. The findings suggest dietary intakes of very low levels of iron, with a significant deviation from the RNI, throughout pregnancy. Only 10-19% of women achieved the RNI of 14.8mg daily at any one-time point. A significant majority of women (55-67%) had iron intakes, throughout, at the LRNI, although up to 31% of women did not achieve the LRNI of 8mg per day. For this population to be considered as having adequate iron intakes, only 2.5% of women would be at LRNI [39], so 31% below LRNI indicates a very high level of inadequacy.

In the UK, the RNI for Iodine during pregnancy is 140μg/day [39],[43]. In this study one third to half of the women achieved this intake, with a significant proportion of women at the LRNI, and of concern 8-18% not meeting the LRNI of 70mg/day, again showing high level of inadequate intakes in this population. Only small amounts of iodine (150µg/day) are required to prevent deficiency. It is noteworthy that in Europe, the RNI for iodine is higher than in the UK at 250 µg/day [43].

Vitamin D is only found in a few foods, including oily fish or fortified dairy products. Dietary intake did not meet daily intake recommendations, and this is similar to the general population of women (childbearing age) [44]. The primary source of Vitamin D is the action of UV light on the skin, hence the UK recommendation for vitamin D supplementation of 10 µg per day for all adults in the population and throughout pregnancy and lactation [1], [45]. However, it highlights the substantial risk of deficiency in this group, should supplements be absent or not taken regularly.

In the UK, the RNI for folate intake during pregnancy is (300μg) [39], [20], in this study at any one time point, only a quarter to one third the women achieved the recommended intake, with over two thirds of women at the LRNI. A 400ug folic acid supplement is recommended for all pregnant women in the first trimester and preferably 3 months prior to conception to reduce the risk of deficiency [46].

The micronutrient evaluation of dietary composition in women living with obesity in this study is concerning. The LRNI values indicate an acceptable nutritional intake for only 2.5% of a population, with low requirements. In this sample, a high percentage of the women living with obesity were consistently at the LRNI, and a further percentage were not meeting these lower recommended intakes, indicating marked sub-optimal nutrition. Insufficient intake of these nutrients is associated with a range of severe adverse pregnancy outcomes, including preeclampsia, low birth weight and poor cognitive development [47,48] [49]. Folate, deficiency can increase the risk of adverse outcomes, including neural tube defects (in early pregnancy), preeclampsia and low birth weight, and Vitamin D deficiency may also contribute to these, as well as GDM. Previous research has highlighted that nutritional deficiencies may contribute to low Apgar scores, particularly Iron. Even a mild deficiency of iodine during pregnancy is associated with impaired IQ in children, and & this adverse effect is not improved by optimal iodine intakes during childhood [48]. Suboptimal maternal nutrition is also associated with poor fetal growth and development, plus increased risk of non-communicable disease later in life [50]; [51]. For both preeclampsia and GDM, prevention and treatment are promoted by healthy diets, and prevalence has been linked to various macro-micro nutrient deficiencies.

Overall, the findings suggest sub-optimal dietary macro and micro-nutrient intakes which may have contributed to adverse clinical outcomes in this sample.

4.2 Clinical outcomes

Considering the obstetric outcomes of the women in this study, over half of the women had a vaginal delivery (49% spontaneous; 8% instrumental), similar to that of the general population pregnancy delivery statistics (52% spontaneous, 12% instrumental) [52]. In line with previous research, the percentage of women who had (elective 19% / emergency 26%) caesarean was higher than the general population statistics (elective 12.6%; emergency 16.4%, [53]. The recorded Apgar score 5 minutes after birth was below normal for 4% of babies, compared to 1.4% of the general population.

Preeclampsia affects 3–5% of pregnancies in the general population, though in this study, preeclampsia occurred in 12% of the sample. Preeclampsia is of interest to fetal outcomes of birth weight. In this sample, birth weight (low birth weight at 7%) and admissions to special care baby units were in line with all pregnancy population data [52]

Prevalence of GDM was recorded at 8% in this study, in comparison the UK, the rate is around 4% [54], although individual characterises, such as ethnicity, increase the incidence; prevalence ranging between 1·2-8·7% in White British women, compared to 4-24% in South Asian women in the UK). This study was conducted in part of the UK, with low ethnic diversity, with 88.8% of the general population being white. Therefore, a GDM of 8% may be considered at the upper levels of GDM prevalence within the sample.

4.3 Implications for practice

Pregnant women are advised to consume a healthy diet and this study has evaluated actual diet composition in pregnant women living with obesity. The WHO (2020) state that “malnutrition refers to deficiencies, excesses, or imbalances in a person’s intake of energy and/or nutrients” [55]. This study reports sub-optimal diet consumption for a range of macro-and micro-nutrients in the study sample. It has been previously recognised that many healthcare professionals would fail to recognise malnutrition in individuals with obesity [56] though limited research has specifically explored diet quality in pregnant women living with obesity.

Midwives are the interface between clinical guidelines and pregnant women but there is a lack of confidence and expertise in delivering nutritional advice to pregnant women, particularly women living with obesity [6]. Nutrition education, needs to be more explicitly embedded into midwifery training, [57]. The RCOG (2018) suggests pregnant women living with obesity to be referred and supported by a dietitian [1], though women with obesity report rarely receiving support [6]. Carepathways need revising so that women living with obesity are supported throughout pregnancy to optimise their nutritional composition, with a view to improving preganancy and clinical outcomes.

A systematic review focused on dietary interventions [28] has highlighted the predominance of holistic lifestyle interventions during the antenatal period that exist to improve pregnancy outcomes, manage GWG, reduce incidences of GDM and large for gestational age babies. The review noted the wide range of dietary advice, which was generally based on healthy eating recommendations, with only two studies offering pregnancy specific advice. Studies have shown that improving maternal eating behaviours can reduce GWG, improving maternal inflammatory markers [58] reduce adipose tissue inflammation in the offspring [59] and influence positive weaning and early child feeding practices in their offspring [58] [60]. However, there is limited research targeting the improvement of diet quality in pregnant women living with obesity. However previous research on diet interventions in pregnancy, though not specifically targeting women living with obesity, has showed some improvements in diet quality and pregnancy outcomes. Another small scale study which focused on improving the dietary quality of pregnant women living with obesity showed promising outcomes.

Providing evidence-based and effective nutritional interventions to pregnant women living with obesity, may not only demonstrate better clinical outcomes, it is likely to be cost effective, reducing healthcare costs of treating associated conditions such as preeclampsia, GDM or ongoing medical and developmental needs of the newborn. Although further research is needed. All pregnant women living with obesity, should receive personalised and well-designed dietary interventions, our findings suggest the need for interventions to focus on reducing SFA and sugar intake, and promoting diets rich in food sources of key micronutrients (particularly iron and iodine).

4.4 Future research

Individual requirements for micronutrients have previously been defined as 'the amount required to prevent clinical signs of deficiency [39 pp2]. However, it is unclear whether obesity increases requirements for some nutrients [61], [62]requiring further investigation.

As previous research [15] suggested, women, living with healthy, overweight or class I obesity may also be at risk of excessive GWG or dietary composition limitations. Therefore, future research is warranted to evaluate the dietary make-up in these groups.

Furthermore, specific evaluation of women living with (or lived with) obesity who have previously undergone bariatric surgery are a particularly increased risk for nutritional deficiencies during pregnancy (due to poor intakes and/or poor absorption). Although limited, some research suggests women are at increased risk of low iron, vitamin B12, folate and fat-soluble vitamins, and deficiencies in macros-nutrients (fat and protein) and further evidence on this target sample is warranted.

4.5 Strengths and Limitations

This study has assessed direct dietary intake, given the assumption that women in pregnancy should be encouraged to consume a healthy diet. Understanding consumption through real-world application and not interfering with diet or healthcare practices can be considered a strength of this observational study. The analysis has not considered the biological mechanisms of dietary requirements, such as factors affecting the absorption of nutrients (e.g. high calcium intake may reduce iron absorption), moreover the analysis has not accounted for dietary supplements, for which there are two recommended Vitamin D, and Folic acid. However, women in the general population and those who are pregnant and living with obesity are less likely to take nutritional supplements, which highlights the need to consider diet consumption as a reflection on the lives of pregnant women living with obesity.

This study was an extension of an established FFB trial, and therefore the recruitment protocol was restricted to recruiting women living with obesity class II and above (BMI≥35). Whilst there was a range of BMI (35 to 50+), the participant characteristics were not significantly different. Analysis was conducted to assess obesity, nutritional and clinical outcomes. Further breakdown into sub-obesity classifications was not applied due to variable sample sizes. It is noteworthy that of the 140 women recruited, clinical outcomes data were recorded for 134 women, representing 96% of the original sample. However, we acknowledge that the measurement of weight was only recorded in 39 women's medical records, and therefore the calculation of GWG change and subsequent analysis of dietary composition in response to excessive GWG was not feasible. Self-reported GWG, or weight at birth, was not sought, given women have been found to under-report birth weight and over-report GWG, which would have reduced the reliability of data. However, the lack of recorded weight in health records highlights an additional issue in maternity care, relating to the recommendation to weigh women during later pregnancy weeks (for birth assessment) and this may be highlighting an issue with clinical practice that requires further investigation.

Whilst all women submitted a 3-day food diary at some point of the study, the number of women who submitted across specific time points varied from 71-52%. Furthermore, the number of women who submitted two (at Time points 1 and 3) or three diary entries (at Time points 1, 2 and 3) was 33 or 26 percent, respectively. Three-day food diaries were chosen as the best method for dietary collection for this study in recognition that other methods (such as food frequency questions are retrospective and may be less reliable). A strength of the method employed included the appointment to clarify and validate the quality of their diet records using various tools, which we suggest increased the accuracy and reliability of reported dietary intake and enhanced the subsequent nutritional analysis. However, it is noteworthy that for future research, online food diaries and research appointments may increase submission.

**5. Conclusion**

Women living with obesity are often considered to be adequately or even over nourished, however data analysed from the women in this study suggests variable diet quality. Women with obesity may present with a sub-optimal diet, with a high intake of energy from saturated fatty acid and sugar and consistently lower intakes of 'desirable' macronutrients (fibre/starch/ PUFA). Moreover, pregnant women with obesity may be more likely to consume sub-optimal intakes of essential micronutrients, and together nutritional status may contribute to increased risk for maternal and foetal outcomes. In this study, it may help understand the higher rates of preeclampsia, GDM , low birth weight, and high Apgar scores in this sample.

The UK's current approach, via national guidelines [54], [63], [1] targets obesity as the origins of adult-related non-communicable diseases, which fails to address the fundamental influence of nutritional quality on disease risk. Obesity is a consequence of suboptimal nutrition and not just the intake and storage of excess energy. To address the intergenerational transmission of poor health via poor quality nutrition warrants a multi-disciplinary and multi-modal approach to reverse the trend. A focus away from 'dieting' and weight onto positive, healthy eating messages that emphasise the critical nutrients required for good maternal outcomes and healthy development of unborn children needs urgent prioritisation for this group of women in the UK.

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References must be numbered in order of appearance in the text (including citations in tables and legends) and listed individually at the end of the manuscript. We recommend preparing the references with a bibliography software package, such as EndNote, ReferenceManager or Zotero to avoid typing mistakes and duplicated references. Include the digital object identifier (DOI) for all references where available.

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In the text, reference numbers should be placed in square brackets [ ] and placed before the punctuation; for example [1], [1–3] or [1,3]. For embedded citations in the text with pagination, use both parentheses and brackets to indicate the reference number and page numbers; for example [5] (p. 10), or [6] (pp. 101–105).

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