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ORIGINAL ARTICLE

An observational analysis of meal patterns in overweight and obese pregnancy: exploring meal pattern behaviours and the association with maternal and fetal health measures

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Abstract

Background Nutrient intakes are known to be poorer among pregnant women with raised body mass index (BMI) than those with a healthy BMI. While meal patterns have the potential to influence obstetric, metabolic and anthropometric measures for mother and infant, limited data exists regarding meal patterns among pregnant women with raised BMI.

Aim To identify categories of meal patterns among pregnant women with overweight and obesity and determine whether patterns change with advancing gestation. To determine if maternal meal patterns are associated with dietary intakes and pregnancy outcomes.

Methods Prospective, observational analysis of pregnant women ($n = 143$) (BMI 25–39.9 kg/m^2). Meal pattern data were analysed from 3-day food diaries at 16 and 28 weeks' gestation. Outcomes include maternal blood glucose, insulin resistance, gestational diabetes, gestational weight gain and infant anthropometry.

Results Three meal pattern categories were identified: 'main meal dominant' (3 main eating occasions + 0–3 snacks), 'large meal dominant' (≤ 2 main eating occasions + < 2 snacks), and 'snack dominant' (3 main eating occasions + > 3 snacks and ≤ 2 main + ≥ 2 snacks). A main meal–dominant pattern prevailed at 16 weeks' (85.3%) and a snack-dominant pattern at 28 weeks' (68.5%). Dietary glycaemic index was lower among the main meal versus large meal–dominant pattern at 28 weeks ($P = 0.018$). Infant birth weight (kg) and macrosomia were highest among participants with a large meal–dominant pattern at 28 weeks ($P = 0.030$ and $P = 0.008$, respectively).

Conclusion Women with raised BMI changed eating patterns as pregnancy progressed, moving from main meal–dominant to snack-dominant patterns. Large meal–dominant meal patterns in later pregnancy were associated with higher glycaemic index and greater prevalence of macrosomia.

Keywords Dietary glycaemic index · Infant birth weight · Maternal diet · Meal pattern behaviour · Overweight and obese pregnancy

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Introduction

Guidelines on healthy eating provided to pregnant women reflect national dietary recommendations and provide information specific to macronutrients and micronutrients of importance during pregnancy [1–4]. In pregnancies complicated by gestational diabetes mellitus (GDM), more specific dietary and lifestyle guidance is used as a method of treatment [5–8], including advice to improve glycaemic control through portion control, eating at regular intervals, and reducing dietary glycaemic index (GI) and glycaemic load (GL). In the absence of GDM, dietary information provided routinely in clinical practise contains no formal recommendations for meal

patterns during pregnancy. The Institute of Medicine (IOM) suggests eating small to 'moderate-sized meals at regular intervals, and eating nutritious snacks' [1] during pregnancy. Thus, given that pregnancy is an altered metabolic state [9], examining maternal meal patterns to provide a basis for advice may be of importance, particularly in overweight or obesity, to maintain glucose homeostasis.

Assessment of maternal diet to date has involved examination of nutrient intakes [10–12], dietary patterns [11, 13–15] and diet quality using scoring-based indices [16–19]. There is a dearth of evidence regarding optimal meal patterns in pregnancy, however. To date, only three studies have examined meal patterns during pregnancy [20–22]. It has been suggested that following a 'regular' meal pattern (three meals plus 2 or more snacks) results in more calories consumed and a reduced risk of pre-term delivery [21], while following a 'main meal' pattern is associated with a reduced risk of delivering pre-term [20]. Increased meal frequency has previously associated with higher 2-h post-prandial glucose, during the late-second trimester of pregnancy in a cohort of Asian women in Singapore [22]. The evidence to date suggests the potential for meal patterns to play an influential role in obstetric, metabolic and anthropometric measures for both mother and infant. However, no published studies to date have examined the relationship between maternal meal patterns and infant birth weight or gestational weight gain (GWG). Furthermore, despite our understanding that women with high body weight have poorer dietary intake and pregnancy outcomes, there is a lack of evidence regarding the way in which women with raised BMI construct their meals throughout the day. A deeper examination into their dietary patterns is warranted to understand their daily food habits. Adding evidence to this field of research could help to frame new dietary advice administered during pregnancy. This may add value to existing dietary recommendations by providing practical advice on meal and snack patterns and frequency.

The primary aim of this research is to identify categories of meal patterns and to determine whether patterns change with advancing gestation. The secondary aims of this research are to determine whether differences exist in maternal demographic profiles and nutrient intakes across meal pattern categories, and to prospectively analyse whether any relationship exists between meal patterns and maternal and infant outcomes.

Methods

Study design and sample selection

This is a prospective observational study using data from the control group of the PEARs (pregnancy exercise and nutrition with smartphone application support) randomised controlled trial [23, 24] carried out at The National Maternity Hospital, Dublin, Ireland, between March 2013 and February 2016. This study received ethical approval from The National Maternity Hospital Research Ethics Committee, and written informed consent was obtained from participants.

A total of 565 women aged between 18 and 45 years, with a BMI ≥ 25 kg/m^2 and ≤ 39.9 kg/m^2 and with a singleton pregnancy attending antenatal clinics were randomised in early pregnancy between 10 and 15 weeks' gestation. To assess typical meal patterns during pregnancy, data from participants randomised to the control group only ($n = 287$) were included in this analysis. The control group received no individual dietary advice, as is current practise for standard antenatal care. All women attending the hospital received a copy of the Health Service Executive's Healthy Eating in Pregnancy booklet [2] at their first hospital visit.

Collection and assessment of maternal demographic data

Education level, maternal ethnicity and parity data were collected. Socioeconomic status was assessed as a level of deprivation according to The Pobal Haase-Pratschke (HP Pobal) Deprivation Index, a neighbourhood deprivation score based on Irish census data [25].

Collection and assessment of dietary data

Dietary intakes were assessed using 3-day food diaries, completed prior to the first study visit at 16 weeks' gestation, and following the second study visit at 28 weeks' gestation. Participants completed the food diaries at home. They received written instructions that were prepared by the research dietitian and nutritionist. Two weekdays and one weekend day were included to capture meal patterns throughout the week. Nutritics® Professional Nutrition Analysis Software, version 4.267, Research Edition (Nutritics, Dublin, Ireland, www.nutritics.com) was used to assess dietary intakes. Trained research nutritionists entered food diaries. Time of day, day of the week and the type of eating occasion (breakfast, lunch, dinner or snack) were recorded. Participants provided portion sizes as household measures. Macronutrient and micronutrient composition of foods were calculated from validated food composition databases [26–28]. Mean daily macronutrient and micronutrient intakes, GI, GL and macronutrients as percentages of total energy intake were calculated.

Meal pattern classification

Eating occasions were classified as breakfast, lunch, dinner or snacks based on the time of day and/or order in which they were reported, and their composition [29], e.g. Spaghetti Bolognese considered dinner. Where time of day was not specified, the order in which an eating occasion was reported

and its composition were used to determine the meal type, taking the structure and composition of a typical western diet into account. There is at present, no general agreement in the literature on how to distinguish snacks from main meals when not specified by participants [29]. Breakfast, lunch and dinner meal types were later collapsed into a single category, titled 'main meals' and the mean number of total eating occasions, main meals and snacks were computed. From here, meal pattern categories were derived from the data. Patterns were based on preferences for consuming main meals or snacks. Participants were considered to have a 'main meal–dominant' pattern if they had all three main meals; breakfast, lunch and dinner on average over the three days, with or without snacks, up to a maximum of three snacks (3 main meals + 0–3 snacks). Participants were considered to have a 'snack-dominant' meal pattern if they consumed more snacks than main meals per day. This included those who consumed all three main meals but greater than 3 snacks (3 main + > 3 snacks), and those consuming fewer than 3 main meals and 2 or more snacks (≤ 2 main + ≥ 2 snacks). The third pattern was termed the 'large meal–dominant' pattern, as participants had fewer total eating occasions per day, typically up to 2 main meals but fewer than 2 snacks (≤ 2 main + < 2 snacks).

Assessment of energy under-reporting

Energy under-reporting was assessed using the Goldberg method [30] which has been previously used among pregnant cohorts [10, 31]. Firstly, participants' basal metabolic rate (BMR) was calculated using Henry-Oxford Equations [32]. Goldberg ratios were then calculated using participant's energy intake (EI) in calories, to their BMR (EI:BMR). A Goldberg ratio of ≤ 0.9 was used to define energy under-reporting.

Assessment of maternal and neonatal outcomes

Early pregnancy weight (kilogram) was routinely recorded at the first hospital visit (between 10 and 15 weeks' gestation). Gestational weight gain was calculated as the difference between weight at initial visit and term (last recorded weight between 36 weeks' gestation and delivery). Participants were categorised as having met or exceeded IOM guidelines.

GDM was diagnosed at 28 weeks' gestation using International Association of Diabetes Pregnancy Study Group (IADPSG) criteria post 75 g oral glucose tolerance test [31]. Fasting insulin and c-peptide samples were analysed and HOMA2-IR was calculated [33].

Gestational age at delivery and infant birth weight (kg) were obtained from medical records. Birth weight centiles were calculated with Gestation-Related Optimal Weight (GROW) software, version 6.7.5.1 (Gestation Network, Perinatal Institute, Birmingham, UK). Large-for-gestational-age infants were those with a birth weight > 90th centile. Macrosomic infants were considered those with a birth weight of ≥ 4 kg. Pre-term was defined as delivered < 37 weeks' gestation.

Data analyses

Of the 287 participants in the control group, 143 participants returned complete dietary data at both time points. All analyses were performed among those with dietary data at both time points. Analysis was conducted including those who were classified as under-reporters and sensitivity analysis was subsequently carried out excluding the under-reporters. Variables were visually assessed for normality using histogram outputs. Non-normally distributed variables were log transformed for analysis. Continuous data are reported as mean (SD), and categorical data are reported as n (%). Independent sample t tests were used to compare meal frequencies and mean daily nutrient intakes between 16 and 28 weeks' gestation using time as the grouping variable among the whole group. Chi-squared analyses were used to compare the proportion of participants within each meal pattern category between time points. In the sensitivity analysis, paired sample t tests were used to compare meal frequencies and nutrient intakes, and McNemar's test compared meal pattern categories between time points. One-way analysis of variance (ANOVA) was

Table 1 Baseline characteristics for participants with complete dietary data (n = 143)

	Mean	SD
Age (year)	32.10	3.98
Early-pregnancy weight (kg)	79.57	10.59
Height (m)	1.65	0.06
Gestational age (weeks)	15.64	1.57
Early-pregnancy body mass index (kg/m^2)	29.11	3.22
BMI category, n (%)		
25.0–29.9 (kg/m^2) (overweight)	101	70.6
30.0–39.9 (kg/m^2) (obese)	42	29.4
Primiparous, n (%)	88	61.5
Ethnicity, n (%)		
Caucasian	126	88.1
Other	17	11.9
SES, n (%)		
Advantaged	101	70.6
Disadvantaged	42	29.4
Completed 3rd-level education, n (%)	109	76.2
Smoker, n (%)	5	3.6

BMI, body mass index; *SES*, socioeconomic status

Values are mean SD unless otherwise indicated

SES determined by HP Pobal Deprivation Index

used to compare maternal characteristics between meal pattern categories at both 16 and 28 weeks' gestation. Subsequently, one-way ANOVA compared macronutrient intakes and maternal and infant outcomes between meal patterns at the same intervals. Analyses were performed among the whole group, and in those in the sensitivity analysis. Post hoc tests were performed on all one-way ANOVA using Dunnett's T3 due to unequal sample sizes between meal pattern categories. Where means violated the homogeneity of variances assumption, the Welch test statistic for significance was reported. Chi-squared analyses were used where maternal and infant outcomes were categorical. Bivariate associations with significance of $P < 0.05$ were further analysed using multiple regression models. Models were created using a forced-enter approach and were adjusted for confounders.

IBM SPSS software for Mac version 24.0 (SPSS Inc., Chicago, IL) was used to perform all statistical analyses.

Results

Study participants

The characteristics of the cohort ($n = 143$) are listed in Table 1.

Meal patterns at 16 and 28 weeks' gestation

On average, participants had four eating occasions per day at 16 weeks' gestation and this predominantly consisted of an average of 3 main meals with 1 additional snack (Table 2). Participants increased the number of eating occasions to 4.7 at 28 weeks, with fewer main meals and more snacks. At 16 weeks', most participants had a main meal–dominant pattern but by 28 weeks', the majority were considered snack dominant (Table 2, Fig. 1). There were no differences in maternal characteristics between those within the different meal pattern categories at 16 weeks' gestation (Table 3). More participants with a main meal pattern at 28 weeks' gestation were primiparous compared with other meal patterns (Table 3).

Comparison of nutrient intakes

There were no differences in nutrient intakes between meal patterns at 16 weeks' gestation (Table 4). At 28 weeks' gestation, there was a significant difference in dietary GI ($P = 0.018$). Those in the main meal–dominant pattern had a significantly lower GI (55.85 ± 4.51) compared with those in the large meal–dominant pattern (59.80 ± 4.85); however, dietary GI among the snack-dominant pattern did not significantly differ from other patterns.

Comparison of mean daily nutrient intakes between 16 and 28 weeks' gestation showed the percentage of energy from saturated fat was higher at 28 weeks' gestation (13.98 ± 2.59) compared with 16 weeks' gestation (13.24 ± 2.98) ($P = 0.005$) (Table 5). The percentage of energy from carbohydrates was lower at 28 weeks' gestation than at 16 weeks' gestation (45.17 ± 5.50 vs. 46.34 ± 6.11) ($P = 0.031$) (Table 5).

Table 2 Comparison of meal frequencies and meal pattern categories between 16 and 28 weeks' gestation among participants with complete dietary data ($n = 143$)

|	16 weeks ($n = 143$)		28 weeks ($n = 143$)		P
	Mean	SD	Mean	SD	
Meal frequencies					
Total eating occasions	4.04	1.33	4.67	1.29	< 0.001
Main meals	2.85	0.24	2.23	0.36	< 0.001
Snacks	1.18	1.31	2.45	1.17	< 0.001
Meal patterns categories	n	%	n	%	
Main meal dominant					
3 main +0–3 snacks	122	85.3	20	14.0	< 0.001
Large meal dominant					
≤ 2 main + < 2 snacks	8	5.6	25	17.5	0.001
Snack dominant	13	9.1	98	68.5	< 0.001
3 main + > 3 snacks	8	5.6	5	3.5	0.581
≤ 2 main + ≥ 2 snacks	5	3.5	93	65.0	< 0.001

Data are mean SD unless otherwise indicated

Where data are non-normally distributed, they were log transformed for analysis; total eating occasions, snacks

P values were calculated using paired sample t tests for continuous variables and McNemar's chi-squared tests for independence for categorical variables

Main meals include breakfast, lunch and dinner

Fig. 1 Proportion of participants in each meal pattern category, at both 16 and 28 weeks' gestation, and movement over time
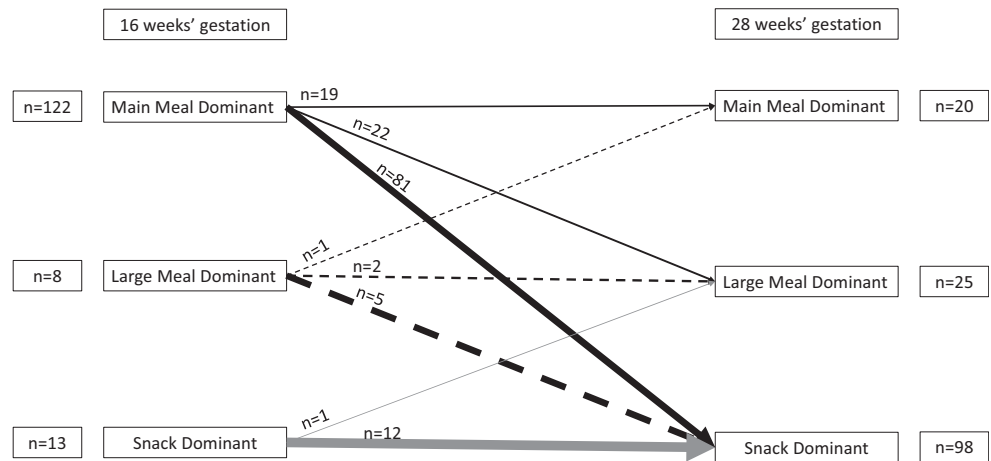
Comparison of maternal and infant outcomes

Those with a large meal–dominant pattern at 16 week's gestation had significantly lower GWG to term (6.92 ± 3.01) compared with those with a main meal (13.10 ± 5.10) or snack (12.34 ± 7.59) dominant pattern (P = 0.025) (Table 6). No association was observed between meal patterns at 28 weeks' gestation and weight gain.

Infant birth weight (kg) differed significantly between meal pattern categories at 28 weeks' (main meal dominant, 3.65 ± 0.49; large meal dominant, 3.93 ± 0.66; and snack dominant, 3.62 ± 0.49; P = 0.030). Approximately half (52%) of those with a large meal–dominant pattern at 28 weeks' gestation gave birth to a macrosomic infant compared with 20% in the main meal–dominant pattern and 21% in the snack-dominant pattern (P = 0.008) (Table 6).

Table 3 Comparison of maternal characteristics between meal pattern categories at 16 and 28 weeks' gestation among participants with complete dietary data at both time points (n = 143). Mean and SD are presented, unless otherwise indicated

	16 weeks' gestation (n = 143)					28 weeks' gestation (n = 143)					
	Main meal (n = 122)		Large meal (n = 8)		Snack (n = 13)	P	Main meal (n = 20)		Large meal (n = 25)		Sack (n = 98)	P
Age (years)	31.99	4.10	32.51	3.42	32.95	3.20	0.679	31.09	4.30	32.68	4.21	32.16	3.86	0.399
Early-pregnancy weight (kg)	79.65	10.18	78.15	13.49	79.75	13.19	0.927	78.64	10.41	83.77	12.36	78.69	9.98	0.092
Height (m)	1.66	0.07	1.63	0.06	1.63	0.04	0.161	1.66	0.06	1.67	0.06	1.65	0.07	0.417
Early-pregnancy BMI (kg/m^2)	28.99	3.05	29.29	3.22	30.11	4.59	0.486	28.56	3.23	30.10	3.57	28.97	3.10	0.208
BMI category, n (%)													
25.0–29.9 (kg/m^2) (overweight)	85.0	69.7	7.0	87.5	9.0	69.2	0.559	15.0	75.0	14.0	70.6	72.0	73.5	0.208
30.0–39.9 (kg/m^2) (obese)	37.0	30.3	1.0	12.5	4.0	30.8		5.0	25.0	11.0	44.0	26.0	26.5	
Primiparous, n (%)	79.0	64.8	3.0	37.5	6.0	46.2	0.151	16.0	80.0	11.0	44.0	61.0	62.2	**0.046**
Ethnicity, n (%)													
Caucasian	110.0	90.2	5.0	62.5	11.0	84.6	0.059	18.0	90.0	22.0	88.0	86.0	87.8	0.961
Other	12.0	9.8	3.0	37.5	2.0	15.4		2.0	10.0	3.0	12.0	12.0	12.2	
SES, n (%)													
Advantaged	87.0	71.3	5.0	62.5	9.0	69.2	0.863	17.0	85.0	15.0	60.0	69.0	70.4	0.187
Disadvantaged	35.0	28.7	3.0	37.5	4.0	30.8		3.0	15.0	10.0	40.0	29.0	29.6	
Completed 3rd-level education, n (%)	94.0	77.0	4.0	50.0	11.0	84.6	0.166	15.0	75.0	19.0	76.0	75.0	76.5	0.989
Smoker, n (%)	5.0	4.2	0.0	0.0	0.0	0.0	0.633	1.0	5.0	1.0	4.0	3.0	3.2	0.914

BMI, body mass index; SES, socioeconomic status

Significance is set at alpha 0.05 using chi-squared tests for independence for categorical variables and one-way analysis of variance (ANOVA) for continuous variables using post hoc Dunnett's T3 tests for unequal sample sizes

Table 4 Comparison of mean daily nutrient intakes between meal pattern categories at 16 and 28 weeks' gestation among participants with complete dietary data at both time points (n = 143). Mean and SD are presented

	16 weeks' gestation (n = 143)							28 weeks' gestation (n = 143)						
	Main meal (n = 122)		Large meal (n = 8)		Snack (n = 13)		P	Main meal (n = 20)		Large meal (n = 25)		Snack (n = 98)		P
Energy (kcal/day)	1880.54	406.46	1719.34	501.26	1896.74	499.91	0.564	1867.35	349.55	1786.25	462.46	1897.89	461.00	0.538
Protein (g/day)	79.33	19.10	65.91	15.49	86.75	26.33	0.065	81.06	13.91	79.90	23.66	82.40	20.77	0.851
%TE protein	17.03	2.97	16.21	5.50	18.18	3.15	0.450[1]	17.66	3.18	17.87	2.52	17.57	3.18	0.905
Carbohydrates (g/day)	216.49	52.39	206.45	70.95	217.49	42.08	0.868	207.46	40.37	197.04	54.45	215.59	57.19	0.305
% TE carbohydrates	46.18	6.01	47.54	6.80	47.13	6.97	0.741	44.59	5.10	44.40	6.50	45.48	5.33	0.603
Sugars (g/day)	84.77	32.45	78.19	44.96	99.09	41.77	0.292	87.77	26.94	71.87	29.45	87.22	34.42	0.103
%TE sugars	17.88	5.18	17.20	5.92	20.97	7.54	0.139	18.74	4.70	16.13	5.69	18.30	4.96	0.126
Free sugars (g/day)	37.19	22.09	45.00	31.35	36.58	23.8	0.882	40.35	21.30	31.37	17.94	37.45	24.87	0.354
%TE free sugars	7.73	4.12	9.65	5.01	7.88	4.45	0.628	8.40	3.65	7.17	4.12	7.75	3.91	0.478
Fat (g/day)	75.91	22.64	67.94	24.71	74.32	31.07	0.644	77.97	23.49	73.93	24.20	76.99	23.37	0.812
%TE fat	36.02	5.52	35.20	3.70	34.13	6.11	0.479	37.07	5.57	37.01	5.58	36.25	4.77	0.690
GI	57.86	5.14	59.41	5.46	57.12	5.25	0.610	55.85[b]	4.51	59.80[a]	4.85	57.43	4.74	**0.018**
GL	125.64	33.55	121.42	36.58	123.18	21.25	0.915	116.73	27.47	117.47	31.81	124.28	36.45	0.518

Where data are non-normally distributed, they were log transformed for analysis; free sugars (g/day), %TE free sugars

Significance is set at alpha 0.05 using chi-squared tests for independence for categorical variables and one-way analysis of variance (ANOVA) for continuous variables using post hoc Dunnett's T3 tests for unequal sample sizes

[1] Significance according to Welch's test for equality of means when equal variances are not assumed

Multivariate regression analysis was carried out to examine the association between meal pattern and birth size. Women who followed a snack-dominant pattern were at a lower risk of having an infant with macrosomia compared with those following a large meal–dominant pattern at 28 weeks, controlling for glycaemic index, parity, gestation at birth and sex of the infant (OR 0.39; 95% CI 0.12–0.98; P = 0.45). On multiple linear regression, controlling for confounds above, large meal–dominant pattern was not significantly associated with birth weight (g; B, 91.4; 95% CI, 3.44–186.27; P = 0.59).

Analysis excluding energy under-reporters

There were 7 participants identified as under-reporters of energy at both 16 and 28 weeks' gestation.

On analysis of normal reporters, at 28 weeks' gestation, the difference in GI between main meal and large meal–dominant patterns was not significant (P = 0.064). The main meal–dominant pattern had a significantly higher percentage of energy from sugars compared with the large meal–dominant pattern at 28 weeks' gestation (19.67 ± 3.95 vs. 15.55 ± 5.31) (P = 0.021). Birth weight (kg) was not significantly different between meal pattern categories at 28 weeks' gestation (P = 0.092) using Welch's test for significance.

Discussion

Main findings

The results presented here provide an insight into meal patterns adopted at two stages of pregnancy among women with a raised BMI and their association with health outcomes. As pregnancy progressed, participants increased the number of eating occasions and snacks consumed per day and reduced the number of main meals consumed. There were few differences in nutrient intakes between those who adopted different meal patterns at both time points; however, the incidence of macrosomia was highest among those with a large meal–dominant pattern at 28 weeks' gestation compared with those with a main meal– or snack-dominant pattern at this time point.

The average number of eating occasions of the current study population is similar to general pregnant cohorts reported to date. Those closely following a main meal pattern in the Norwegian Mother and Child Cohort Study (MoBa) at 22 weeks' gestation ate four times per day [20], and roughly one-third of participants in the Growing Up in Singapore Towards Healthy Outcomes study (GUSTO) had an average of four daily eating occasions between 26 and 28 weeks' gestation [22]. Over 70% of participants in the Pregnancy, Infection and Nutrition Study (PIN) in the US ate on five or more occasions per day during the second trimester [21]. The

Table 5 Comparison of mean daily nutrient intakes between 16 and 28 weeks' gestation among participants with complete dietary data at both time points ($n = 143$). Mean and SD are presented

	16 weeks ($n = 143$)		28 weeks ($n = 143$)		P
	Mean	SD	Mean	SD	
Energy (kcal/day)	1872.99	419.18	1874.11	446.57	0.978
Protein (g/day)	79.25	19.91	81.77	20.40	0.168
%TE protein	17.09	3.17	17.63	3.06	0.057
Carbohydrates (g/day)	216.02	52.37	211.21	54.81	0.349
% TE carbohydrates	46.34	6.11	45.17	5.50	0.031
Sugars (g/day)	85.71	34.13	84.62	32.98	0.740
%TE sugars	18.12	5.50	17.98	5.09	0.781
Free sugars (g/day)	37.57	22.71	36.79	23.34	0.755
%TE free sugars	7.85	4.19	7.74	3.90	0.720
Fat (g/day)	75.32	23.49	76.59	23.40	0.541
%TE fat	35.80	5.49	36.50	5.01	0.134
Saturated fat (g/day)	28.01	10.24	29.49	10.39	0.121
%TE SFA	13.24	2.98	13.98	2.59	0.005
Polyunsaturated fat (g/day)	11.77	4.62	11.79	4.11	0.969
%TE PUFA	5.64	1.76	5.66	1.52	0.896
Monounsaturated fat (g/day)	27.06	9.63	26.97	9.24	0.913
%TE MUFA	12.85	2.82	12.85	2.68	0.987
Calcium (mg/day)	918.35	330.73	959.92	346.18	0.230
Iron (mg/day)	12.29	5.37	11.90	3.85	0.384
Total folates (µg/day)	282.29	112.27	279.88	100.93	0.789
Vitamin D (µg/day)	3.45	2.24	3.30	2.69	0.307
GI	57.88	5.15	57.62	4.83	0.620
GL	125.18	32.63	122.04	34.51	0.331

Where data are non-normally distributed, they were log transformed for analysis; free sugars (g/day), %TE free sugars, vitamin D

P values were calculated using paired samples t tests for continuous variables

overall number of main meals and snacks consumed as part of these eating occasions were not explicitly reported, however [20, 22].

Meal pattern categories observed in the present analysis are also comparable with those reported in the PIN and MoBa cohorts [20, 21]. In the PIN study, the majority of women (71.5%) were classed as having a 'regular' meal pattern (3 meals plus 2 or more snacks) [21]. In the MoBa study, women with a BMI in the overweight and obese categories had adhered mostly to an 'evening meal' pattern [20]. Women who were younger or achieved lower levels of education were also more likely to adopt an 'evening meal' pattern [20]. The PIN study reported that women with a higher pre-pregnancy BMI and those who were older were less likely to have a 'regular' meal pattern [21]. In the current study, fewer primiparous women adopted a large meal–dominant pattern in later pregnancy compared with main meal– or snack-dominant patterns.

Those adopting the snack-dominant meal pattern in the current study had a higher number of total eating occasions. There was a higher dietary GI among the large meal–dominant

pattern at 28 weeks' gestation. However, there were no differences in reported measures of energy or nutrient intakes between meal pattern categories. The PIN study found that women following a 'regular' meal pattern had significantly higher energy intake than those not following this pattern [21].

Overall mean daily nutrient intakes reported in the current study are similar to those of pregnant women within other studies who are in the same BMI categories [10, 34], general pregnant cohorts (where the mean BMI is 26 kg/m^2) [11] and non-pregnant adult women [35].

In the MoBa study, women with a BMI ≥ 25 kg/m^2, who showed a higher adherence to a 'main meal' pattern had a reduced risk of delivering a pre-term infant [20]. In the PIN study, those who did not follow a 'regular' meal pattern had a higher risk of delivering a pre-term infant [21]. Contrary to these findings, neither pre-term birth nor gestational age at birth differed between meal patterns in the current study.

No differences were observed in glucose concentrations, insulin resistance or GDM incidence between women who adopted different meal patterns in the current analyses. This

Table 6 Comparison of maternal and infant outcomes between meal pattern categories at 16 and 28 weeks' gestation among participants with complete dietary data at both time points (n = 143). Mean and SD are presented, unless otherwise indicated

	16 weeks' gestation (n = 143)							28 weeks' gestation (n = 143)						
	Main meal (n = 122)		Large meal (n = 8)		Snack (n = 13)		P	Main meal (n = 20)		Large meal (n = 25)		Snack (n = 98)		P
Maternal outcomes														
Glucose homeostasis														
28 weeks														
Fasting glucose	4.45	0.38	4.49	0.31	4.52	0.48	0.825	4.46	0.31	4.51	0.32	4.44	0.41	0.758
1 h post-prandial	7.20	1.69	6.51	2.51	8.06	1.77	0.134	7.33	1.98	7.33	1.64	7.19	1.76	0.913
2 h post-prandial	5.74	1.14	5.06	1.49	6.24	1.58	0.118	5.55	1.18	6.07	1.14	5.71	1.23	0.306
GDM incidence (n (%))	12.0	10.0	0.0	0.0	2.0	16.7	0.506	2.0	10.0	1.0	4.0	11.0	11.7	0.524
HOMA2-IR	1.67	0.86	1.72	0.56	2.17	1.39	0.448	1.78	0.75	1.97	0.87	1.60	0.90	0.080
Gestational weight gain														
34 weeks	10.50	4.47	6.45	4.28	11.15	5.92	0.048[2]	10.30	5.29	10.83	4.23	10.20	4.69	0.852
Term[4]	13.10[b]	5.10	6.92[a,c]	3.01	12.34[b]	7.59	0.025[1]	13.37	5.37	13.23	5.44	12.31	5.50	0.711
Exceeded IOM (n (%))	57.0	72.2	0.0	0.0	5.0	55.6	0.001	11.0	73.3	14.0	87.5	37.0	58.7	0.077
Infant outcomes														
Gestational age														
Gestation (days)	281.50	10.25	280.00	8.45	280.75	6.48	0.895	280.75	10.88	284.60	7.14	280.62	10.16	0.191
Pre-term (n (%))	3.0	2.5	0.0	0.0	0.0	0.0	0.773	0.0	0.0	0.0	0.0	3.0	3.2	0.480
Birth weight measures														
Birth weight (kg)	3.70	0.54	3.47	0.70	3.63	0.25	0.550[3]	3.65	0.49	3.93	0.66	3.62	0.49	0.030[2]
Birth weight centile	49.65	27.34	35.65	28.10	44.29	21.11	0.315	49.61	21.68	54.13	29.62	46.59	27.27	0.454
LGA (n (%))	11	9.2	0.0	0.0	0.0	0.0	0.366	1.0	5.0	2.0	8.0	8.0	8.5	0.870
Macrosomia (n (%))	34	28.3	2.0	25.0	2.0	16.7	0.680	4.0	20.0	13.0	52.0	21.0	22.1	0.008

Data are mean SD unless otherwise indicated

Where data are non-normally distributed, they were log transformed for analysis; HOMA2-IR

Significance is set at alpha 0.05 using chi-squared tests for independence for categorical variables and one-way analysis of variance (ANOVA) for continuous variables using post hoc Dunnett's T3 tests for unequal sample sizes

[1] Significant ANOVA with significant post hoc analysis (a,b,c denote significance between columns)

[2] Significant ANOVA, however post hoc analysis was not significant

[3] Significance according to Welch's test for equality of means when equal variances are not assumed

[4] Gestational weight gain to term defined as the last recorded weight between 36 weeks' gestation to delivery

is unlike findings from the GUSTO study that found that 2-h post-prandial glucose concentration was positively associated with increasing meal frequency [22]. No published studies to date have examined the relationship between maternal meal patterns and infant birth weight or GWG; thus, this research contributes new insights to this field [36–38]. The finding that women following a large meal–dominant pattern at 28 weeks had infants with greater risk of macrosomia is surprising, particularly since no differences in energy intake was reported. This finding persisted even when controlling for GI, a factor known to be associated with greater birth weight [39], gestation, sex of the infant and parity. A cautious interpretation of the association between GWG and meal pattern at 16 weeks' gestation is warranted given the small sample size (n = 8) in the large meal–dominant group.

Interpretation and clinical implications

It is thought that eating at regular intervals could improve glucose homeostasis among those with diabetes and may aid weight loss or maintenance in overweight and obesity in non-pregnant states [40, 41].

Pregnancy is an altered metabolic state, considered diabetogenic, and metabolism may be further influenced by increasing maternal pre-pregnancy BMI which itself has been identified as the main predictor of an array of adverse pregnancy outcomes [36, 38]. Thus, considering all of the evidence, meal patterns may have a greater impact on health outcomes in population groups such as pregnant women or those with type 2 diabetes where metabolic function has adapted through increases in insulin resistance.

The majority of participants in this analysis, who received no formal dietary advice, naturally increased the number of eating occasions and migrated towards a snack-dominant meal pattern in later pregnancy. It is possible that this occurred due to the expansion of the uterus and abdomen, compressing the stomach and making larger meals more difficult to finish as pregnancy progressed. Pregnant women should be provided with appropriate dietary advice on healthy, low-GI snacks or light meal options to ensure nutrient intakes are in accordance with current dietary recommendations [42]. We also reported a difference in meal patterns by parity, demonstrating that snacking was more prevalent among those with children at home. It is plausible that snacking may be a more convenient method to meet nutrient intakes in a busy household; however, this association requires further research before conclusions can be drawn.

Strengths

The current study is the first examining meal patterns in pregnancy to use a food diary for the collection of dietary data; food diaries are considered more precise measurement tools than food frequency questionnaires or 24-h recalls [43]. The current study analysed meal patterns at two time points in pregnancy, whereas others have focused on one time point only [20–22]. To our knowledge, there is no published evidence examining the change in meal patterns as pregnancy progresses.

Limitations

There is a risk of error with self-reported data due to misreporting [43] which must be considered when interpreting the data. With regard to meal classification, subjective interpretation of what constituted a meal or snack by the nutritionists entering dietary data is a possible limitation. With no global consensus as to what constitutes a snack and how snacks differ from main meals, nor any formal recommendations regarding meal patterns during healthy pregnancies, there is a degree of subjectivity with this type of research. Lastly, these results may not be generalizable across other populations as this sample of women had raised BMI, was predominantly of Caucasian ethnicity and high socioeconomic status. Furthermore, given the number of statistical tests conducted in this study, the possibility of chance findings as a result of multiple testing should be considered. Finally, this was a cohort of women with pre-pregnancy BMI in the overweight and obese categories only; thus, we could not determine if meal patterns were different to women with a healthy BMI. Future research should aim to compare meal patterns across BMI categories as this could lead to greater awareness of dietary behaviours among this group of women.

Conclusion

This study provides an insight into the meal patterns of women with raised BMI as pregnancy progresses. A migration from main meal–dominant patterns towards a snack-dominant meal patterns were observed. Those in the main meal and snack-dominant patterns in later gestation had lower dietary GI intakes, gave birth to infants with lower rates of macrosomia compared with those with a large meal–dominant pattern. These novel findings may inform future dietary recommendations which could benefit both short- and long-term maternal and offspring health.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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