Fit for Birth- the effect of weight changes in obese pregnant women on maternal and neonatal outcomes: a pilot prospective cohort study.

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What is already known about the subject

Maternal obesity is a risk factor for adverse maternal and foetal perinatal outcomes.

The Institute of Medicine gives recommendations for weight gain during pregnancy based on initial body mass index (BMI) category, but the effects of these weight changes on pregnancy outcomes has not been adequately described.

What this study adds:

- This study supports an association between gestational weight gain and adverse outcomes in obese pregnant women.
- Older and primiparous women in the cohort had the highest rates of weight gain, while socioeconomic deprivation did not influence weight changes.
- Trajectories of weight change in an individual obese woman in pregnancy can be highly variable

Abstract

Objective: The 'Fit for Birth' study aimed to explore patterns of gestational weight gain and their relationship with pregnancy outcomes.

The study had three aims:

a) To explore the feasibility of conducting a large cohort study in this setting

b) To describe patterns of weight gain through pregnancy in obese women

c) To explore associations of weight change during pregnancy with outcomes

Study Population: Pregnant women with a BMI ≥ 30 kg/m^2at first antenatal clinic visit

Methods: This was a single centre pilot observational study based at the Liverpool Women's Hospital, a large UK maternity hospital.

Women were recruited into the study at their antenatal booking visit and had weights measured throughout pregnancy. Patterns of weight gain were described and related to maternal and neonatal outcomes.

Main outcome measure: The primary outcome was a composite measure consisting of any of twelve adverse maternal and fetal outcomes. This was compared by categorised pregnancy weight gain (<0 kg, 0-5 kg, 5.1-9 kg and >9 kg).

Results: Eight hundred and twenty four women consented to participation between June 2009 and June 2010. Weight data were collected on 756 women. Only 385 women had weights measured in all three study assessment periods (6-20 weeks, 20+1 to 32 weeks and >32 weeks gestation) while 427 women had weights measured in Period 3. Individual

patterns of weight gain varied widely and missing data was common and non-random. There was a significant association between increased weight gain during pregnancy and poor maternal and fetal outcome.

Conclusions: Weight gain in obese women during pregnancy can be highly variable. Our study supports an association between increased weight gain in pregnancy and adverse perinatal outcomes.

Introduction

Rates of obesity are increasing worldwide, with a considerable impact on maternity services. In a previous study, 44% of pregnant women booking into maternity services at one UK centre were classified as overweight or obese (1).

Maternal obesity is a risk factor for pre-eclampsia and eclampsia, gestational diabetes (GDM), increased rates of caesarean delivery, intrauterine death (IUD) and large-for-gestational-age babies (2,3) and also contributes towards instrumental delivery, postpartum haemorrhage, urogenital infection, longer duration of hospital stay and increased neonatal intensive care requirement (4-6). Maternal obesity is also an identified risk factor for offspring obesity (7), type 2 diabetes and cardiovascular disease (8).

The English National Institute for Health and Care Excellence (NICE) encourages weight loss in obese women before pregnancy (9). Regular weight checks for the mother during pregnancy are not endorsed by NICE unless clinically indicated (9).

The USA's Institute of Medicine (IOM) recommendations from 2009 state that women with normal BMI (18.5-24.9 kg/m^2) should gain 11.4-16 kg during pregnancy, but women whose BMI is ≥30 kg/m^2 should only gain between 5 and 9 kg (10). Based on limited

data however correlations between gestational weight gain and offspring birth weight as well as childhood obesity have been demonstrated(11-14).

Systematic reviews have highlighted the paucity of data about the safety of weight gain restrictions in obese pregnant women (15,16). We therefore undertook a pilot study of the relationship between gestational weight gain and feto-maternal outcomes in pregnant obese women in a large maternity service in a mid-sized UK city.

Materials and Methods

The Fit for Birth (FFB) project was funded by the Liverpool Primary Care Trust (PCT) in order to explore how to optimise the care given to pregnant women with BMI ≥30 kg/m^2 at their antenatal booking visit. The project was managed by a multidisciplinary team of obstetricians (AW, SQ, JT), a midwife (HL), dietitians (JA, MC), a statistician (AH), a neonatologist (MAT), a project manager (DR), a public health physician (JC) and a physician with an interest in obesity (JW). There were three main aims of the 'Fit for Birth' (FFB) study:

a) To explore the feasibility of running a large cohort study in this setting

b) To describe patterns of weight gain through pregnancy in obese women

c) To explore associations of weight change during pregnancy with outcomes

It was intended that this study would lead to focussed further studies aimed at improving delivery of antenatal care for obese pregnant women.

Women with a BMI >30 kg/m^2 when booked at the Liverpool Women's Hospital (LWH) maternity services between June 2009 and June 2010 were approached to take part in the study. Women aged under 18 years old at booking or with multiple pregnancies were excluded.

Maternity services at LWH were based on English national guidelines current at that time (17). In brief, a booking assessment was done at 12-14 weeks gestation by a midwife who triaged women to low-risk or high-risk groups. Low-risk women were seen by community midwives at specified stages in pregnancy. High-risk groups were offered individualised care involving a consultant obstetrician. Women with a BMI ≥30 kg/m^2 and no other risk factors were cared for by community midwives whilst those with a BMI ≥35 kg/m^2 were seen at least once by a consultant obstetrician. A specialist clinic for class III (morbidly) obese pregnant women (BMI ≥ 40 kg/m^2) is run by a clinician with a special interest in this area (AW). Study entry was offered at the initial antenatal appointment (usually at 12 weeks gestation) when women were asked to consent to being weighed at each of their antenatal appointments, rather than just at booking as is current practice. They were also asked for permission to collect data about their pregnancy and newborn child from the hospital's paper and electronic records.

Anonymised comparative data was collected for all women booked to deliver in the hospital from the electronic hospital database (MEDITECH®, Westwood, Massachusetts, USA). This contains all the required information except for weights from the antenatal visits subsequent to booking.

Study staff aimed to obtain a minimum of three weights from each participating woman, one in each assessment period. The three assessment periods were: 6-20 weeks (Period 1), 20+1 to 32 weeks (Period 2) and 32+1 weeks to delivery (Period 3); preferred dates were 16, 28 and 36 weeks. Staff midwives were asked to record the maternal weight without shoes or coat at every antenatal visit, and standard antenatal case notes were modified to assist with this. Due to logistical constraints, each centre used its own weighing

scales, these were regularly calibrated to ensure accuracy. Antenatal care and advice was provided as in routine clinical practice, with subjects reviewed by their usual midwives and appointment duration and frequency determined by clinical need.

Once the women had delivered, the following data were collected from the hospital's computerised record system: live or still birth, second trimester miscarriage or termination, date of delivery, whether labour was induced or augmented, mode of delivery, post partum haemorrhage >1000ml, antepartum haemorrhage, hypertension, pre-eclampsia, gestation at delivery, retention of placenta for over 30 minutes, GDM, genital tract or perineal tear, shoulder dystocia, mother's length of hospital stay, baby's sex, birth weight, umbilical cord arterial pH <7.2, Apgar Scores at 1 and 5mins, and admission of neonate to the Special Care Baby Unit.

Similar data (with the exception of serial weight measurements) was collected routinely for all pregnancies, and was used to compare outcomes for two comparison groups: all women of any BMI booking at Liverpool Women's Hospital over the same period, and women of BMI ≥30 kg/m^2 who were not recruited to the FFB cohort.

The identification of suitable outcomes for a study of obesity is challenging. Focus on individual poor outcomes, for example, deliveries through caesarean section may be misleading as they may have been performed in order to prevent other potentially worse adverse outcomes. For this study we therefore chose a composite primary outcome reflecting a range of adverse outcomes –a pregnancy was considered to be normal only if there were no complications and the mother and baby had a normal outcome.

Women were defined as having an adverse pregnancy outcome (representing a complicated pregnancy or birth) in the presence of any of the following: stillbirth,

termination or spontaneous abortion, gestational hypertension, pre-eclampsia, gestational diabetes, labour induction, augmentation of labour (non-induction use of oxytocin), caesarean section, operative vaginal delivery, shoulder dystocia, 3rd or 4th degree tear, antepartum haemorrhage (moderate or severe), postpartum haemorrhage (>1000ml), birth before 37 completed weeks, birth weight >90th centile (macrosomia), birth weight <10th centile (IUGR), mother's hospital stay of over 3 days and baby requiring advanced special care. Gestational hypertension and pre-eclampsia were as defined in the NICE guidelines current at the time (17) while women were diagnosed as having GDM if they had a fasting plasma glucose >7.0mmol/l and/or a 2 hour plasma glucose ≥7.8 mmol/l on a 75g oral glucose tolerance test.

All data taken from consent forms, hospital notes and the hospital's computer records (MEDITECH®) were collated and anonymised prior to statistical analysis. Analyses were carried out in Intercooled Stata11 (Statacorp, College Station, TX, USA). A random effects model was used to model weight gain during pregnancy. This took account of age, BMI group (30-34.9, 35-39.9, ≥40) kg/m^2, ethnic group (White British or not), primiparity/multiparity, smoking status (current smoker, never smoked, previous but not at booking), Index of Multiple Deprivation (IMD) score (18), and allowed for both a random average weight for each woman and a random growth rate. In subsequent analyses, gestational weight gain was defined as weight change from booking to birth, classified in four categories as <0 kg, 0-5 kg, 5.1-9 kg and greater than 9 kg respectively. Imputation was used to estimate weight gain and to investigate the association between gestational weight gain and the primary outcomes. Total weight gain was defined as change from booking to the last recorded Period 3 weight (32+1 weeks gestation onwards), or imputed by ordinal

regression using: age, weight at booking, BMI group, IMD score, primiparous /multiparous, smoking status, whether or not the mother was of White British ethnicity, whether or not the baby was breastfed and weight gain up to the second trimester. Weight gain up to Period 2 (up to 32 weeks gestation) was derived from the latest recorded weight in Period 2 or imputed using ordinal regression and the same set of variables as for the imputation of total weight gain. Logistic regression and linear regression were used to model the composite adverse pregnancy outcomes (as defined previously) and birthweight respectively. Overall gestational weight gain as an outcome was adjusted for age, BMI group, primiparity, IMD, smoking status and season of birth. Composite adverse outcomes were adjusted for the above variables as well as gestational weight gain.

Ethical approval was received from the Liverpool (Adult) Research Ethics Committee (09/H1005/23) to analyse the data collected from participants as well as anonymised data on non-participants from the hospital computer system.

Results

The participant flow is summarised in Figure 1. The characteristics of women who were recruited to the study are summarised in Table 1 with comparative data from those who were eligible but not recruited and all women booked to deliver at the hospital. Compared to eligible women who were not recruited, the group recruited to the FFB tended to be primiparous, to have a higher BMI, be White British, but were less likely to smoke.

There were 756 women in the cohort, but only 476 women had weights measured in the third trimester (>29 weeks), and only 427 had weights recorded in Period 3 (>32 weeks). Two hundred and sixty two women (34.6% of the study cohort) had their initial weights measured in the second trimester (>12 weeks gestation); all but nine women in the total

cohort were measured in Period 1 (<20 weeks). In 200 women, only one weight was recorded (see Figure 1); with the exception of four women these initial weights were recorded in Period 1. There was a median time from the last recorded weight to delivery of 5.2 weeks (interquartile range 2 to 16.8). An analysis of missing values suggested that dropout from the study was not completely at random (Table 2) and that women with weight measurements from early in pregnancy only were: more likely to have given birth in summer or autumn; have lower initial BMI; be White British; be a non-smoker. IMD was not associated with the availability of weight measurements later in pregnancy.

Fifty nine women in the cohort delivered (or completed pregnancy) before term (before 37 weeks of gestation).Of the 13 women completed pregnancy in the second trimester (before 28 weeks), nine did not result in live births (4 spontaneous abortions, 4 terminations, 1 stillbirth). Additionally there were two stillbirths in women whose pregnancies proceeded to term.

Patterns of weight gain

Analysis of individual plots showed that there was wide variation in the individual patterns of weight gain through pregnancy, with only a minority showing steady weight gain. There was strong evidence of curvature in many weight trajectories, suggesting more weight gain in later pregnancy for some women. However, the random effects also confirmed that some women gained very little weight or even lost weight (figure 2).

Estimates of weight gain during pregnancy

Total weight gain during pregnancy was calculated in those for whom there was at least one recorded weight in Period 3. It shows that 8.4% of women lost weight; 28.1 % gained 0-5 kg, 22.9% gained 5.1-9 kg and 40.5% gained more than 9 kg.

The relationship between initial weight and gestational weight gain on clinical outcomes

Table 4 summarises the clinical outcomes for all women booked at the hospital during the study period according to according to initial BMI. It shows increasing rate of many complications with increasing BMI, with the exception of fetal growth restriction and operative vaginal delivery, which tended to be less frequent in those with higher BMI.

Logistic regression analyses suggested that gestational weight gain in our cohort predicted an adverse pregnancy outcome after adjustment for age, BMI, ethnicity, smoking status at antenatal booking and IMD [OR 1.07, 95% CI 1.03 to 1.12, p=0.001]. When gestational weight gain was categorised as less than 5 kg, 5 to 9 kg and over 9 kg, each category increment was associated with higher odds of sustaining an adverse pregnancy outcome after adjustment for age, BMI, ethnicity, smoking status and IMD [OR 1.74, 95% CI 1.34 to 2.25, p<0.001]. Women in the category of less than 5 kg gestational weight gain were less likely to have a poor outcome compared with the recommended weight gain of 5 to 9 kg, while those with gestational weight gain over 9 kg had the highest odds for adverse outcomes. Women with gestational weight loss had greater odds of adverse outcomes than women with gestational weight maintenance or gain [OR 0.17, 95% CI 0.08 to 0.37, p<0.001], but the sample size of women who lost weight during pregnancy was very small (n=36). The results from the random effects model without imputed values are qualitatively similar to the estimates using imputation (data not shown).

These associations for adverse outcomes appear stronger for women with a booking BMI between 35 and 39.9 kg/m^2 (p= 0.001) than women with booking BMI measures below 35 kg/m^2 (p=0.05) and above 40 kg/m^2 (p=0.38). Given the small numbers it was not possible to model the individual components of the composite outcome.

In a model to assess predictors of gestational weight gain, older maternal age (β 0.06, 95% CI 0.01 to 0.12, p=0.018) and primiparity (β 2.2, 95% CI 1.6 to 2.8, p<0.001) were identified as predictors of increased gestational weight gain, while smoking (β -1.2, 95% CI -2.0 to -0.4, p=0.002) and a higher booking BMI (β -0.25, 95% CI -0.32 to -0.19, p<0.001) were negatively associated with gestational weight gain. IMD and ethnicity were not associated with weight gain during pregnancy.

Additional analyses were also performed on the subgroup of women in the cohort with at least one weight measured in each study period (n=385). As in the larger cohort, gestational weight gain was associated with increased odds for adverse pregnancy outcomes in this subgroup after adjustment for age, booking BMI, IMD, smoking status at booking and ethnicity [OR 1.08, 95% CI 1.03 to 1.13, p=0.001]. When women were categorised by weight gain during pregnancy [<0 kg (n= 33), 0 to 5 kg (n=110), 5.1 to 9 kg (n=88) and >9 kg (n=154)], each increment in weight gain category in this subgroup was associated with increased odds of adverse outcomes [OR 1.58, 95% CI 1.23 to 2.03, p<0.001] after adjustment for the covariates described earlier.

Of the small number of women who lost weight (n=36) and had at least one weight measured in Period 3, the average weight loss was 2.8 kg (SD 2.16). Eight of the 36 women were primiparous, and 30 were of White British ethnicity. Sixteen women had a baseline BMI ≥ 40 kg/m^2 while 11 had a baseline BMI between 30 and 34.9 kg/m^2. Fifty percent of the women developed at least one of the adverse outcomes defined in the study. Deliveries were after 37 weeks of gestation in all 36 cases.

Discussion

Our observational pilot study suggests an association between gestational weight gain and poor outcome in overweight and obese women. Patterns of weight change during pregnancy appeared to be random and non-linear. This would suggest that predicting weight change in an individual overweight or obese woman over the course of pregnancy is challenging. Overall, primiparous and older women had the highest rates of gestational weight gain, while women with higher booking BMI levels and those who were smokers at the time of booking appeared to gain the least weight. Another study has identified clusters of weight change patterns in pregnancy (19), but overall weight trends may mask appreciable interval changes in weight during the course of pregnancy.

Gestational weight gain over 9kg was associated with higher rates of adverse maternal and fetal outcomes, as compared to weight gain below 9kg. This is in line with other studies that link obesity and gestational weight gain with adverse pregnancy outcomes, particularly caesarean section rates (20-23). Secondary analysis of a large multicentre randomised controlled trial has previously reported no consistent associations between insufficient weight gain as per IOM criteria (rather than weight loss) and the adverse pregnancy outcomes they studied. This study was conducted in a cohort of primiparous females carrying singletons recruited from multiple centres in the United States and excluded women with pre-existing medical issues (24). In this study women who were overweight by self-reported pre-pregnancy weights and gained more weight during pregnancy than recommended by IOM criteria had higher rates of pre-eclampsia, caesarean section deliveries and large for gestational age babies as compared to overweight women who gained weight within the IOM guidelines. The authors reported similar findings (and

additionally increased rates of gestational hypertension) when first measured pregnancy weights were used for weight gain calculations in place of self reported pre-pregnancy weights (24). Obese women in this study with weight gain above IOM recommendations had higher rates of pre-eclampsia as compared to obese women who gained weight within IOM recommendations during pregnancy (24). Another study reported favourable gestational outcomes in obese women who gained less than 5 kg in weight over the course of pregnancy as compared to those who gained more than 5 kg (25). A large study on pregnant women in China followed over a 13 year period has also reported higher maternal and fetal adverse outcomes with excess gestational weight gain, as well as low birth weight following insufficient weight gain in pregnancy (26).

Previous observational studies have indicated that a number of obese women lose weight over pregnancy, but a Cochrane review into the effectiveness of weight loss interventions in obese pregnant women concluded that there was no randomised controlled trial evidence in this area (15). However another review of the evidence from 44 randomised controlled trials studying the effect of diet, lifestyle or a mixed approach on weight in pregnant women across a range of BMI categories (excluding women with a BMI <18.5 kg/m^2) concluded that, on average, intervention of any nature led to a reduction of weight gain of 1.42 kg as compared to women who had not had any intervention, with the dietary intervention group achieving the most reduction in weight gain (16). There was a mean reduction of gestational weight gain in overweight and obese women of 2.1kg with intervention (16). Dietary intervention in these women was reported to decrease the risk of pre-eclampsia, GDM and gestational hypertension without increasing the risk of them

delivering small for gestational babies, while physical activity or mixed diet and exercise based interventions did not achieve these outcomes (16).

In our observational study we did not specifically offer any dietary or lifestyle advice towards weight loss or reduction in gestational weight gain, as in routine UK obstetric practice maternal weights in pregnancy are only measured at booking. Women with gestational diabetes receive dietary advice directed towards glycaemic control but a proportion of these women also receive metformin and/or insulin in addition, both of which can individually influence maternal weight in addition to influencing decisions about mode of delivery and neonatal special care arrangements. It is therefore difficult for us to extrapolate any results from the previous meta-analyses (16) to our study.

In our study women with a BMI between 30 and 40 kg/m^2 were at most risk of excessive weight gain (>9 kg). Considering that specialist (rather than routine) antenatal care is generally provided at present only to women with a baseline BMI>40 kg/m^2, we should consider offering specialist services to some women with a baseline BMI between 30 and 40 kg/m^2.

The strength of our single centre study is the large number of overweight and obese women longitudinally followed up using a research design nested in routine clinical care. The collection of data within a routine clinical setting however, means that weight measurements varied in time points, measurement frequency as well as the instruments used. This means that interpreting trends in weight change are likely to be more meaningful than a focus on individual statistical values. Furthermore, this study was designed as an observational study as close to a 'real world' setting as possible, but study participants were

aware of their participation in a study and this could have also influenced their dietary and lifestyle behaviour during pregnancy. This study did not specifically explore attitudes to weight among the women in the study, and whether some of them actively tried to lose weight during pregnancy. The study is also limited by the amount of missing data and the unavailability of pre-pregnancy weight measures.

Implications of methodology

Data collected during routine clinical care may not be missing at random. However the gaps may be informative. Weight measurement was less likely if the later stages of pregnancy fell in summer or autumn. We do not know the reasons for this, but it is a popular time for staff annual leave. It is therefore possible to speculate that the increased clinical workload contributed to midwives not according priority to measuring the women's weights.

The harder to reach groups in this population were relatively less obese, non-smoking women. As these groups comprise women otherwise likely to be amenable to health advice, and women with a lower booking BMI within the overweight and obese cohort appear to be at higher risk of gestational weight gain, perhaps it is worth identifying reasons for gaps in data collection in these patients for future studies. We also did not collect data on inter-pregnancy weight gain or study obesity related gene variants in our study cohort, though these have been identified as predictors of gestational outcomes in other studies (27;28).

Research within routine obstetric care

An important objective of this research project was to study the feasibility of embedding research within regular obstetric clinic activity. This study required NHS midwives in the region to merely measure women's weights, a relatively simple exercise during their antenatal clinic visits, in addition to their routine obstetric care. Midwives and other

obstetric healthcare professionals were not incentivised for this. Current recommendations in England and Wales recommends measurements of weights at booking, but only suggest further antenatal weight measurements if there is a clinical indication to do so.

It is revealing that just over 50% of women had weights measured in all three study periods. While we did not expect all women in the study to have complete weight measurements, we were surprised by the extent of the missing data. As we did not specifically assess the reasons for underperformance, we can only speculate on potential reasons. This was a study embedded in clinical care in a busy maternity unit, and there may have been reluctance on the part of healthcare staff or patients to undertake even simple measurements that were perceived as being clinically unnecessary. Measurements were undertaken by clinical rather than research midwives at multiple peripheral sites, and their appreciation of research may have been constrained by competing clinical priorities. Midwives were not financially incentivised for their time and efforts - this was a conscious decision in order to realistically assess the feasibility of future studies within a clinical setting. It appears from our study that in the absence of incentivisation (financial or otherwise) it is difficult to sustain clinical trial related requests within real world care over a period of time, even if the measurements required are relatively simple.

Women in the study would have also differed in the number of antenatal clinic visits according to their clinical requirements. The study catchment area has a population of predominantly White British ethnicity with high levels of unemployment and socioeconomic deprivation, and it is possible that the challenges reflected in this study would not be directly applicable to other settings (29; 30). Future studies in settings where weight is not routinely measured (for example in the UK) are needed to address this issue. Alternatives

would be to incentivise staff or to arrange for research staff to collect all the data, or gestational weight assessments could be introduced for all women. Although this would go against current NICE guidance it would prevent the need for weight data to only be collected in women with increased BMI – a factor that prevents many midwives from collecting data for fear of causing stigmatisation.

While comparing the weight trends in the different BMI cohorts it is worth considering that women with an antenatal booking BMI >40 kg/m^2 were offered specialist input in a dedicated antenatal clinic which may have influenced their weight change during pregnancy.

Implications of missing data:

Imputation was performed in the data analyses to account for missing weight measurements. Analyses that included and excluded imputed weights did not appear different, and analyses of the study population subset with measurements in each time period yielded comparable results to those involving the whole cohort. However we do recognise that there was significant variation between and within women, and data from more time points would have been ideal.

Utility of gestational weight gain measurements:

Gestational weight gain has been linked with increased future risk of obesity, cardiovascular risk and gestational diabetes for the mother as well as fetal macrosomia and childhood obesity for this offspring. However in individual cases, increased weight can occur for other reasons, for example polyhydramnios or maternal systemic diseases causing fluid retention,

that would be included in the gestational weight figures but are likely to differ from the remainder of the cohort in weight change as well as future risk trajectories. This reduces the utility of gestational weight gain as a measure of change in adiposity. Whilst whole body adipose tissue measurements using whole body plethysmography (BodPod) would be more accurate, they are unworkable for clinical practice and other simple markers such as skinfold measurements skin thickness or mid upper arm circumference should be explored further.

Conclusions

Gestational weight changes in overweight and obese women are often non-linear, with some women having sharp increases in weight in the latter stages of pregnancy, while for other women weight was maintained or indeed decreased. The more obese women in the cohort appeared to gain less weight overall and would therefore be difficult to predict an individual woman's weight change during pregnancy. The message for the individual patient, in line with UK national guidelines (9), should perhaps focus on a healthy diet and regular exercise during the pregnancy, with emphasis on weight loss in overweight and obese women offered before pregnancy and after delivery rather than during the pregnancy itself . There is evidence from this and other studies that the IOM recommended weight gain for obese women of 5-9 kg may be too high – but more robust data is needed before a change can be recommended.

Performing clinical studies on pregnant women within routine clinical care poses challenges, but our study does support previous evidence linking weight gain in pregnancy with poor obstetric outcomes. Larger studies that ensure weight measurements at more timepoints in pregnancy, together with interventional studies in obese pregnant women

with varying weight change goals, may definitively clarify the association between gestational weight gain and perinatal outcomes.

Conflicts of Interest

The authors declare that they have no conflicts of interest

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Contribution to authorship:

The project was set up by a multidisciplinary team of obstetricians (AW, SQ, JT), midwife (HL), dietitians (JA, MC), a neonatologist (MAT), project manager (DR), public health physician (JC) and a physician with an interest in obesity (JW). RPN and AH conducted the data analyses. RPN, JW, MT and AW were involved in writing the paper while all the other authors made critically important revisions. All authors approve this manuscript for publication and agree to be accountable for the integrity of the study.

Ethics Approval: Liverpool (Adult) Research Ethics Committee on 7th April 2009 (09/H1005/23)

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Table 1.

Characteristics of women recruited to the study and in comparator groups.

	Fit for Birth cohort (n = 756)	BMI ≥30 (not in cohort) (n = 836)	All women not in FFB cohort (n = 7310)*
Booking BMI			
< 30	0 (0%)	0 (0%)	6430 (88.8%)
30 – 34.9	425 (56.2%)	547 (67.8%)	547 (7.56%)
35 – 39.9	218 (28.8%)	181 (22.4%)	181 (2.5%)
40+	113 (14.9)	79 (9.4)	79 (1.1%)
Ethnicity (% White British)	88.9	84.3	81.5
Parity (% primiparous)	39.3	34.3	46.7
Smokers (%)	17.8	19.2	21.6
Age (mean, range)	28.8 (18 – 43)	29.3 (18 – 46)	28.6 (18 – 47)
Mean IMD value	51.1	51.9	48.1

*Data in this column refers to characteristics at booking visit with respect to all women booked at Liverpool Women's Hospital between June 2009 and June 2010 except for participants in the FFB cohort. Of the 7348 women in this category, data was unavailable for 38 women, hence n=7310. Booking BMI was unavailable for 73 of the 7310 women, so n=7237 for data on booking BMI.

Table 2 Demographics and key outcomes for the whole group, and by availability of weights by time periods as defined in the methods (note that this does not take account of very premature births which are not 'dropouts').

	Whole cohort (n=756)	**Weight in P1 only (n=196)**	**Weights in P1 and P2 only (n=135)**	**Weights in all 3 periods (n=385)**
Age	28.8 (5.7)	28.4 (6.0)	28.6 (5.7)	29.1 (5.4)
BMI group				
30- 34.9	56.2% (425/756)	65.8% (129/196)	53.3% (72/135)	52.2% (201/385)
35- 39.9	28.8% (218/756)	26.5% (52/196)	25.2% (34/135)	30.9% (119/385)
40 +	14.9% (113/756)	7.7% (15/196)	21.5% (29/135)	16.8% (65/385)
White British	88.9% (672/756)	92.9% (182/196)	89.6% (121/135)	86.7% (334/385)
IMD score	51.1 (19.8) n=740	49.3 (20.7) n=192	51.2 (18.5) n=131	51.5 (19.9) n=378
Smoker (Y)	17.9% (135/756)	14.8% (29/196)	21.5% (29/135)	17.4% (67/385)
Season of birth				
Spring	28.4% (202/710)	20.3% (32/157)	22.3% (23/103)	33.8% (122/360)
Summer	27.1% (193/710)	35% (55/157)	22.3% (23/103)	25.8% (93/360)
Autumn	24.7% (176/710)	29.3% (46/157)	30.1% (26/103)	21.1% (76/360)
Winter	19.5% (139/710)	15.3% (24/157)	25.2% (31/103)	19.1% (69/360)
Multiparous	60.7% (459/756)	60.2% (118/196)	61.5% (83/135)	60.7% (234/385))
Composite adverse pregnancy outcome	79.8% (603/756)	82.1% (161/196)	88.1% (119/135)	75.8% (292/385)

Table 3. Total weight gain in those who had at least one weight measured in period 3 by IOM BMI categories.

Initial BMI (number of women with first and third period weights)	Gestational weight gain	N (% of BMI group)
30-34.9 (226)	>9 kg 5.1-9 kg 0-5 kg Weight loss	102 (45.1) 51 (22.5) 62 (27.4) 11 (4.9)
35-39.9 (132)	>9 kg 5.1-9 kg 0-5 kg Weight loss	53 (40.1) 33 (25.0) 37(28.0) 9 (6.8)
≥ 40 (69)	>9 kg 5.1-9 kg 0-5 kg Weight loss	18 (26.0) 14 (20.3) 21 (30.4) 16 (23.2)
All (427)	>9 kg 5.1-9 kg 0-5 kg Weight loss	173 (40.5) 98 (22.9) 120 (28.1) 36 (8.4)

Table 4 Maternal and neonatal outcomes by BMI group for all deliveries during the study period

	Whole hospital data by initial BMI (n=7237)				
	< 20	20-29.9	30-34.9	35-39.9	≥ 40
Composite of adverse pregnancy outcomes	554/789 70.2%	4191/5641 74.3%	437/547 79.9%	151/181 83%	72/79 91%
INDIVIDUAL ADVERSE OUTCOMES					
Pre-eclampsia	19/789 2.4%	220/5641 3.9%	37/547 6.8%	18/181 10%	14/79 18%
Hypertension	8/789 1.0%	127/5641 2.3%	32/547 5.9%	20/181 11%	7/79 9%
Gestational Diabetes	6/789 0.8%	70/5641 1.2%	17/547 3.1%	11/181 6%	7/79 9%
IUGR	139/784 17.7%	864/5618 15.4%	92/546 16.8%	29/179 16%	10/79 13%
Macrosomia	53/784 6.8%	511/5618 9.1%	56/546 10.3%	12/179 7%	9/79 11%
Post-dates pregnancy	89/789 11.3%	823/5641 14.6%	90/547 16.5%	28/181 15%	13/79 16%
Induction	195/789 24.7%	1457/5641 25.8%	172/547 31.4%	78/181 43%	26/79 33%
Augmentation	68/789 8.6%	485/5641 8.6%	40/547 7.3%	9/181 5%	9/79 11%
Caesarean section	128/789 16.2%	1198/5641 21.2%	151/547 27.6%	47/181 26%	38/79 48%
Operative vaginal delivery	128/789 16.2%	904/5641 16.0%	55/547 10.1%	19/181 10%	7/79 9%
Premature delivery (<37wks)	75/789 9.5%	375/5641 6.6%	41/547 7.5%	10/181 6%	8/79 10%
Shoulder dystocia	3/789 0.4%	40/5641 0.7%	7/547 1.3%	3/181 2%	0/79 0%
3rd or 4th degree perineal tear	15/789 1.9%	111/5641 2.0%	12/547 2.2%	1/181 0.5%	1/79 1%
Maternal stay > 3 days	84/789 10.6%	512/5641 9.1%	53/547 9.7%	19/181 10%	12/79 15%
APH moderate/severe	11/789 1.4%	42/5641 0.7%	6/547 1.1%	0/181 0%	0/79 0%
PPH	12/789 1.5%	157/5641 2.8%	15/547 2.7%	6/181 3%	7/79 9%
Spontaneous abortion, pregnancy terminated before 24 weeks or stillbirth	5/789 0.6%	26/5641 0.5%	2/547 0.4%	1/181 0.5%	1/79 1%
Admission to special care baby unit	86/789 10.9%	540/5641 9.6%	67/547 12.2%	20/181 11%	16/79 20%