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ScHARR School of Health and Related Research
Public Health Collaborating Centre

Weight Management in Pregnancy: Economic Modelling

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Contribution of Authors

Jason Madan was lead modeller. Elizabeth Goyder and Jim Chilcott were the senior leads.

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Aims

To investigate the health impact and resource use implications of improved management of weight gain in pregnancy.

Introduction

A number of evaluations have been identified of various interventions aimed at keeping weight gain in pregnancy within a recommended range. These evaluations have been assessed to determine whether the efficacy of the intervention has been established. Policy makers are required to determine not only whether interventions are efficacious, but also whether they represent the best use of scarce health care resources. This requires the total health impact and resource demand of the intervention to be quantified. Weight gain in pregnancy has a number of consequences; these consequences need first to be comprehensively identified.

To do this, a conceptual framework of the impact of weight gain in pregnancy was developed. This framework is shown in figure one. This illustrates the wide range of consequences that may result from changes in pregnancy. Each will have its own contribution to the overall impact of the intervention. Some will have a direct impact on health (e.g. shoulder dystocia) and others will largely transmit their impact through increasing risk for other health issues (e.g. macrosomia, which increases risk of shoulder dystocia, amongst other complications). The issues can also be divided according to time-scale. There may be an immediate impact on well-being, either from the lifestyle changes or the resulting impact on weight. There may be an impact during the pregnancy, particularly in terms of hypertensive and insulin resistance disorders. Whilst there may be direct health consequences, these effects will largely cause an impact by increasing the risks of complications during delivery itself.

There are a number of complications in delivery that have been linked with obesity. These include a higher rate of caesarean deliveries and a greater use of medical procedures generally, including induction, instrumental delivery and the need to use general rather than local anaesthetic for pain relief. There is an increased risk of maternal harm e.g. lacerations or haemorrhage. There is also an increased risk that the neonate will suffer complications, including shoulder dystocia and low 5 minute Apgar scores, that may lead on to health issues. These risks will in part be raised through a greater rate of macrosomia (high birth weight) in pregnancies where weight and weight gain are issues.

There will also be consequences after birth. Complications in labour may lead to health issues for the mother such as prolapse or incontinence. The risks of complications in subsequent pregnancies will be increased. Pregnancy is known to be a life stage at which obesity can develop for the longer term. This will have an impact in terms of an increased risk of diseases such as type 2 diabetes and CVD, and a resulting reduction in life expectancy. There may also be consequences for the child, in terms of an increased risk of obesity and illnesses such as type 2 diabetes in later life.

Given the wide range of health consequences from excessive weight gain in pregnancy, the studies of weight management will not in themselves provide sufficient evidence to inform cost-effectiveness analysis of the intervention. This is partly due to insufficient size, partly due to insufficient follow-up, and partly due to information not being recorded on certain outcomes. Therefore, a number of observational studies have been identified in an attempt to quantify the link between weight gain and the range of consequences given above. This needs to be interpreted carefully, for two reasons. Firstly, these studies provide evidence of associations rather than causality, so that it is not certain that similar effects will be seen from successful weight management interventions. Secondly, the bulk of the literature relates to the role obesity plays in increasing the health risks of pregnancy and childbirth. These risks may not be mitigated by good weight management. Data was sought that related risk to weight gain, ideally stratified by pre-pregnancy BMI.

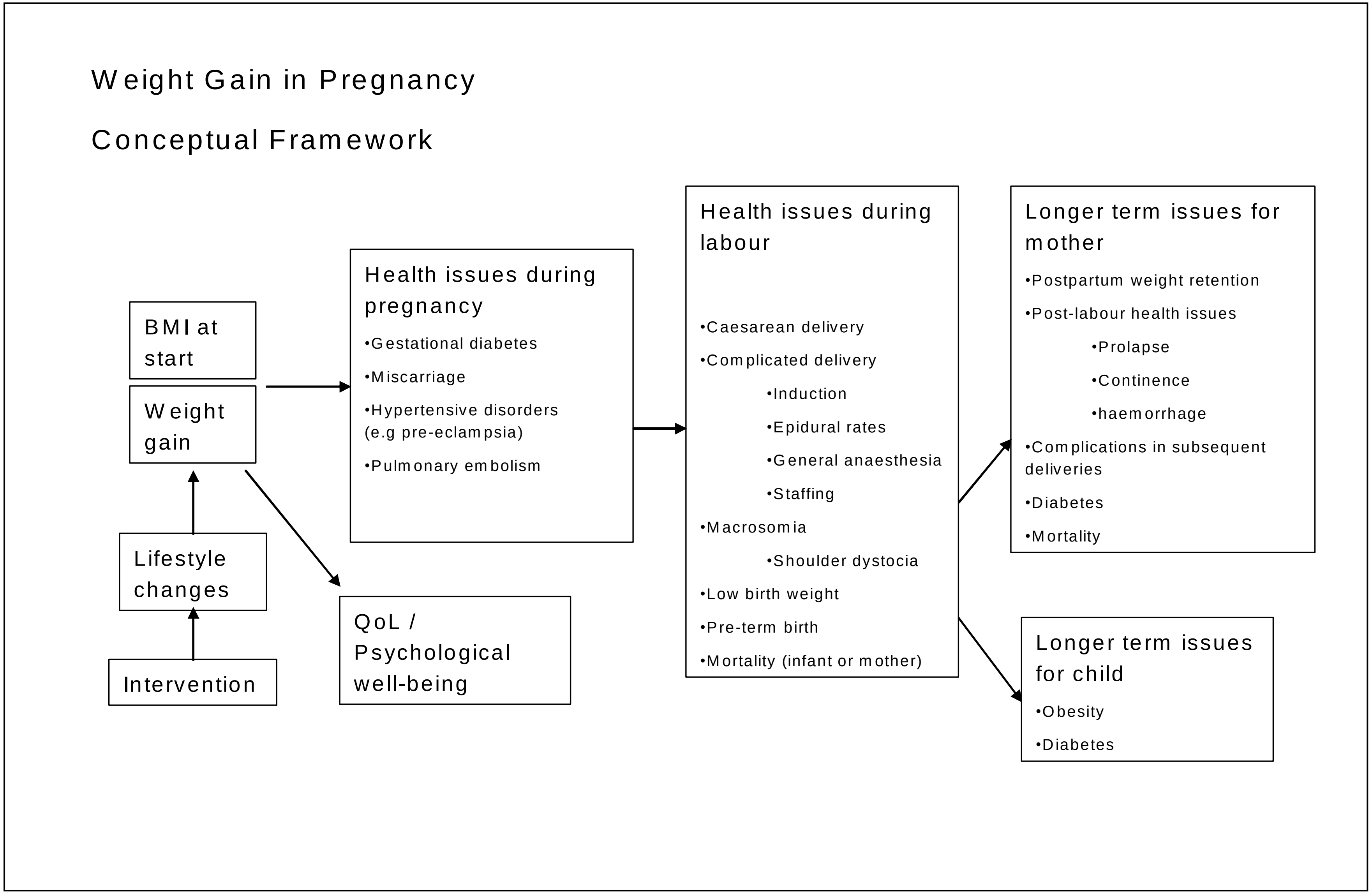


Figure 1: Conceptual framework for the impact of weight management in pregnancy

Consequences of Gestational Weight Gain during Pregnancy and Childbirth

Gestational Diabetes

Gestational diabetes (GDM) is defined as 'glucose intolerance that begins or is first detected during pregnancy'.[1] Whilst it may not have a major direct impact on health, the presence of GDM increases the risks of adverse health events in both mother and foetus. The chief consequence for the foetus where elevated risk occurs is macrosomia (large size). This is discussed further below. The risk of developing type 2 diabetes in later life may also be increased.[2] For the mother, there is an association between GDM and an increased risk that the delivery will not be straightforward (e.g. an increased risk of complications during vaginal delivery, and an increased caesarean rate). This is likely to be due to the increase in prevalence of macrosomia. GDM is also associated with an increased risk of type 2 diabetes. A systematic review found that the proportion of women with GDM who go on to develop type 2 diabetes within five years varied from 20-50%.[3]

The risk of developing GDM varies depending on a number of risk factors, and has been estimated at 1-14%, depending on the population.[4] Ethnicity is a known risk factor, whose influence in GDM matches its influence in type 2 diabetes. There is a strong relationship between pre-pregnancy BMI and GDM; a systematic review reported in 2007 found odds ratios for GDM of 2.14, 3.56 and 8.56 for overweight, obese and severely obese woman respectively compared to normal weight women,[5] with similar rates being reported in a subsequent review published in 2009.[6] Kabiru et al studied the impact of excessive weight gain on pregnancy outcomes. They found a statistically significant relationship between weight gain and GDM rates. Amongst women whose BMI was normal at the first prenatal visit, those who subsequently increased their BMI category by 1 had a 1.5% rate of GDM, whilst those who remained within the normal category had a rate of 0.5%. For women who were overweight at the first visit, the corresponding figures were 3.3% and 1.0%.[7]

Hypertension and Pre-eclampsia

Gestational hypertension is defined as the development of new arterial hypertension after 20 weeks gestation. As with GDM, it does not necessarily have a direct impact on health. However, it can develop into the condition pre-eclampsia. This is a medical condition where hypertension arises in association with proteinuria. It can lead to serious complications in pregnancy – eclampsia and HELLP syndrome

A number of authors have found an association between gestational weight gain and the incidence of pre-eclampsia. Kabiru et al found that, amongst women of normal BMI at the first prenatal visit, an increase of BMI category was associated with an incidence of 3.2%, whilst those women who remained in the normal category had a pre-eclampsia rate of 1.9%. For women who were overweight at the first prenatal visit, the corresponding rates were 3.7% and 2.8%. De Vader et al found an association between weight gain during pregnancy and rates of pre-eclampsia in a population of Missouri women of normal pre-pregnancy BMI. The incidence rate increased from 2% in women who gained 25lb to 8.5% in women who gained 65lb.[8] Kiel et al found similar results in a population of Missouri women who were obese. For women who gained 12lb, rates of pre-eclampsia were 4.5% for women with a pre-pregnancy BMI of 30-35 kg/m2, 7% for women with a pre-pregnancy BMI of 35-40, and 8.5% for women with a pre-pregnancy BMI greater than 40 kg/m2. For women who gained 30lb during their pregnancy, the corresponding rates were 7.5%, 9% and 12%.[9]

Complications of delivery

A number of studies have found a link between gestational weight gain and complications during delivery. There is a consistent association between weight gain and the rate of caesarean delivery. A study of births at John Hopkins University found that each 1kg increase in weight gain was associated with a 4% increase in the odds of a caesarean delivery.[10] Kabiru et al found that women whose BMI category increased during pregnancy had a higher rate of caesarean deliveries. The absolute difference in caesarean rates between the two groups was 4.4% in women whose BMI was in the normal range at the first pre-natal visit, and 1.3% in women who were overweight at the first pre-natal visit. De Vader et al found that, for women of normal pre-pregnancy BMI each 10lb increase in gestational weight gain beyond 25lb was associated with a an increase in the absolute caesarean rate of 2%.[8] Kiel et al found a similar relationship amongst women who were obese pre-pregnancy.[9]

There is also evidence associating weight gain with an increased risk of complications during delivery. Thorsdottir et al report that, in a population of expectant mothers in Iceland, 73% of mothers who gained over 20kg had a normal delivery (as defined by the obstetrician) compared with 80% of mothers who gained 16-20kg.[11] Kabiru et al report that women who increased their BMI category during pregnancy had an increased incidence of a range of complications compared with women who did not. Amongst women who were in the normal BMI category at the first pre-natal visit, the rate of failed induction increased from 4.7% to 9.2%, of serious lacerations from 24.0% to 29.3%, and of operative vaginal delivery from 11.4% to 12.4%. For women who were overweight at the first pre-natal visit, the corresponding rates were 7.9% vs. 10.3%, 26.3% vs. 27.5%, and 8.4% to 11.4%.[7]

To some extent, this increase will be linked with an increased prevalence of macrosomia. Gestational weight gain has been found to predict macrosomia in a number of studies. De Vader et al found that, in women of normal BMI, a 10lb increase in gestational weight gain was associated with an increase in the rate of macrosomia of around 3%.[8] Kiel et al also found a positive correlation between gestational weight gain and macrosomia in obese women.[9]

Shoulder dystocia is a complication of delivery that has been associated with foetal macrosomia, and is one reason why caesarean delivery may be chosen for suspected macrosomia. With elective induction, the rate of shoulder dystocia in vaginal delivery is estimated at 14%.[12] Shoulder dystocia may lead to injury of the brachial plexus, which will be permanent in some cases. Kabiru et al found that an increase in BMI category during pregnancy was associated with an increase in the absolute rate of shoulder dystocia of nearly 1% in both normal and overweight women.[7]

Post-partum consequences of excessive gestational weight gain

As gestational weight gain is associated with an increased risk of complications during pregnancy, it will also be linked with an increased risk of post-partum complications. Kabiru et al found that, for women of normal BMI, a 1 category increase in BMI during pregnancy was associated with a 0.4 percentage-point increase in the rate of post-partum infection, and an increase of more than one BMI category was associated with a 3.2 percentage-point increase. For women who were overweight, the corresponding increases were 2.2 percentage points and 1.2 percentage points.[7] There is evidence that pre-pregnancy BMI is associated with increased rates of post-partum haemorrhage,[13] and it is plausible that a similar link will exist with gestational weight gain. The trauma of delivery in macrosomia may be one reason for such a relationship. Previous delivery of an infant with macrosomia has also been shown to be related to an increased risk of post-partum prolapse.[14]

As well as longer-term trauma from delivery, another possible consequence of gestational weight gain is longer-term weight retention. Nohr et al found a relationship between gestational weight gain and an increase in BMI category when comparing weight pre-pregnancy and 6 month post-partum. For women who gained 10-15kg, the probability of an increase by 1 category was 7% for normal women, 9% for women who were overweight, and 7% for women who were obese. For women who gained over 20kg during their pregnancy, the corresponding figures were 25%, 25% and 26%.[15] It is not certain, however, how long this difference persists. Rooney et al found a positive correlation between weight gain above the recommended range and long-term obesity, but it was not statistically significant.[16]

Gestational weight gain may also have longer-term consequences for the infant. There is limited evidence on this potential link. Oken et al found that women whose gestational weight gain was above the recommended range gave birth to children who had a higher than average BMI at 3 years of age, although the difference was not statistically significant after adjusting for covariates.[17] There is also a possibility of an increased risk of obesity-related conditions for the infant in later life. Boney et al found that gestational diabetes was associated with an increased risk of metabolic syndrome in childhood.[18]

Health and resource cost impacts of events associated with excessive weight gain.

Gestational diabetes

The health impact of GDM is complex, imperfectly understood, and largely indirect. There is an association between gestational diabetes and macrosomia, whose impact is discussed below. GDM is associated with an increased risk of diabetes in both mother and child, although it is not clear whether this is a causal relationship or a correlation driven by a predisposition to diabetic disorders.

If GDM is present, this will increase the health care resources used by the mother during the pregnancy. Kitzmiller et al estimate that the costs of managing GDM were on average $1200 (1996 USD).[19] These costs related to treatment supplies, visits to medical professionals, and foetal surveillance. It does not include the impact on costs of delivery.

Pre-eclampsia

Pre-eclampsia can have serious health consequences. In the intervention arm of the MAGPIE trial of prophylactic magnesium sulphate, 0.8% of pregnancies progressed to eclampsia, and the maternal mortality rate was 0.2%. The infant mortality rate was 13% in pregnancies that progressed to eclampsia.[20] Maternal mortality from eclampsia in the UK has been recorded at 1.8%, with stillbirths and neonatal deaths at 56 per 1000.[21] The costs of pregnancy are generally estimated to be higher in women with pre-eclampsia – in the MAGPIE trial, these were $12,000 US in 2001 prices for countries with high Gross National Income.[20]

Complications of pregnancy

The maternal mortality rate in the UK between 2003 and 2005 was 6.24 per 100,000 maternities, or 5.56 per 100,000 maternities excluding deaths in early pregnancy.[22] The largest contributors to this were thrombosis (1.94 per 1000), eclampsia (0.85 per

100,000), haemorrhage (0.66 per 100,000), amniotic fluid embolism (0.8 per 100,000) and sepsis (0.85 per 100,000). Together, these five factors accounted for 92% of mortality in late pregnancy and labour. For all these events, apart from amniotic fluid embolism, there is evidence linking incidence with obesity. Perinatal mortality (stillbirths, perinatal deaths and neonatal deaths) in the UK in 2006 was 1.7% of all births.[23] The link between perinatal mortality and maternal obesity is less clear, but there is evidence of an association with macrosomia discussed below.

Complications during delivery will increase resource use. NHS average reference costs for delivery are £1,113 for unassisted vaginal delivery, £2,203 for assisted vaginal delivery, and £1,947 for caesarean section.

Macrosomia will be associated with complications and health outcomes during labour. Thorsdottir et al found that women delivering babies weighing more than 4.5kg had a 27.9% rate of delivery complications, compared with 16.5% for the rest of the study population.[11] Spellacy et al found that, in comparison with infants weighing 2.5-3.5kg, infants weighing (4.5-5kg) had an increase in shoulder dystocia of 7 percentage points and an increase in perinatal mortality of 0.5 percentage points.[24] Herbst et al found that there was a probability of 1.2% that dystocia would lead to permanent plexus injury, whose cost of treatment was $55,000 (2005 USD).[12]

If weight gain during pregnancy has an impact on longer-term obesity, this will have consequences for health and well-being. Macran found a relationship between BMI and self-reported quality of life, although this was less pronounced for women of child-bearing age. In women aged 25-34, women who were overweight had a utility of 0.01 less than women of normal BMI, but 0.03 more than those who were obese [25]. Obesity in mother and child may be related to life-expectancy, through incidence of conditions such as diabetes, cardiovascular disorders and bowel cancer. A recent meta-analysis found that obese adults in early middle age had a life expectancy 2 years shorter than those who were overweight, and obese young adults had a life expectancy 3 years shorter than those whose BMI lay within the normal range.[26]

Economic Analyses for Weight Management in Pregnancy

Base Case

Ideally, an economic analysis of the impact of weight gain management in pregnancy would include all the sequelae described above. However, there are a number of issues that arise in attempting this. As mentioned above, the available data is largely associative, and there may be strong medical reasons in some cases to assume that the association would not translate into a benefit from the intervention. Even where a direct causal relationship is possible, the information may not be available at the level required for the economic analysis (costs and QALYs). With these caveats in mind, the information described above was used to calculate the parameters of the economic model as listed in table 1. The derivation of these parameters is described below.

The first step was to select the scale on which the direct impact of the intervention could be represented. This could be the proportion of the population that maintained weight gain within the recommended limits defined by the IOM. However, this is an imprecise measure; a more accurate reflection of the impact of a weight management programme is the reduction in the mean weight gained by the intervention cohort. The calculation of cost-utility was therefore based around this measure.

To do this, it was necessary to estimate the increase in risk, per kg of extra weight gain, of the adverse events described above. It was found that the studies by De Vader et al and by Kiel et al showed a relationship between weight gain and the risk of pre-eclampsia, macrosomia, and caesarean section that was almost linear, as can be seen in the appendix. Regression analysis was used to estimate these relationships. The results are given in the appendix and in the appropriate values in table one. There were issues raised by this process. The first is that the studies mentioned do not include data on women in the overweight BMI category. The increase in risk for this group was assumed to lie between the normal and obese BMI groups. The second issue involved the appropriateness of assumption of a linear relationship between weight gain and risk in women of normal BMI who gained less than 25lb. It seems unlikely that the benefits of restricting weight gain would be as strong within the currently advised range. Therefore, it was assumed that the benefit of weight management would only extend to the at-risk population, defined as those who would otherwise gain over 25lbs (if their pre-pregnancy BMI lay within the normal range) or 15lbs (if their pre-pregnancy BMI lay within the overweight range).

Table 1: List of parameter values for economic model base case

Parameter		Value	Source
Increase in risk of GDM		0.8% per 10kg weight gain	Kabiru et al
Increase in risk of pre-eclampsia			
when pre-pregnancy BMI is:	20-25	3.5% per 10kg weight gain	De Vader et al
(kg/m2)	25-30	3.4% per 10kg weight gain	Interpolation
	30-35	3.3% per 10kg weight gain	Kiel et al
	>35	3.1% per 10kg weight gain	Kiel et al
Increase in caesarean rates		5.4% per 10kg weight gain	Kiel et al
Increase in assisted vaginal delivery rates			
when pre-pregnancy BMI is:	20-25	0.8% per 10kg weight gain	Kabiru et al
(kg/m2)	>25	2.3% per 10kg weight gain	Kabiru et al
Increase in macrosomia rates			
when pre-pregnancy BMI is:	20-25	6.5% per 10kg weight gain	De Vader et al
(kg/m2)	25-30	6.2% per 10kg weight gain	Interpolation
	30-35	6.0% per 10kg weight gain	Kiel et al
	>35	7.5% per 10kg weight gain	Kiel et al
Increase in risk of BMI category change			
post pregnancy:			
20-25	to 25-30	10% per 10kg weight gain	Nohr et al
25-30	to 30-35	7% per 10kg weight gain	Nohr et al
30-35	to >35	14% per 10kg weight gain	Nohr et al
Duration of weight retention change		1 year	NA
BMI related health state utility			
	20-25	0.92	Macran et al
	25-30	0.91	Macran et al
	>30	0.88	Macran et al
Probability of pre-eclampsia leading to eclampsia		0.80%	Douglas et al
Eclampsia mortality rate:	maternal	1.80%	Douglas et al
	infant	0.56%	Douglas et al
Increase in plexus injury rate due to macrosomia		0.08%	Herbst et al
Increase in perinatal mortality due to macrosomia		0.46%	Spellacy et al
QALY impact of maternal death		20.7	Kind et al
QALY impact of infant death		24.7	Kind et al
Cost of medical care in labour:			
Uncomplicated delivery		£1,113	Reference costs
Caesarean delivery		£1,947	Reference costs
Assisted vaginal delivery		£2,203	Reference costs
Cost of medical care in pre-eclampsia pregnancy (including delivery)		£9,952	Simon et al
Cost of GDM management		£1,139	Kitzmiller et al
Cost of treatment - plexus injury		£39,102	Herbst et al

A further complication arose in estimating the relationship between weight gain and the risk of GDM and assisted vaginal delivery. These relationships were estimated using data collected by Kabiru et al, which was presented in terms of BMI category change rather than weight gain. To translate the available data into the measure required, it was assumed that a change in BMI category represented a weight gain of 13 kg (equivalent to a BMI change of 5 kg/m^2 for a woman of height 1.6m). Applying this assumption to the results reported by Kabiru et al gave an increase in risk per kg of weight gain for GDM and assisted vaginal delivery shown in table 1.

All other values given in table 1 are as reported in the previous section, with the exception of the QALY tariffs for maternal and infant death. These were calculated by combining UK life expectancy data with age-related QALY weights reported by Kind et al. Some of the effects described previously have not been included in the base case. This is either because it is not clear that they will be affected causally by weight gain management, or because values in the required format were not found in the literature. These effects are explored in sensitivity analyses, presented below. All long term costs and benefits are discounted at the annual rate of 3.5%, as recommended by NICE.

Impact of weight gain management

From the base case, the impact of a reduction in the amount of weight gained during pregnancy can be estimated. Table 2 gives the health benefits and cost savings resulting from a mean reduction in pregnancy weight gain of 5kg per person at risk for a cohort of 1000 women. As described previously, a woman is defined as 'at risk' if she would gain over 25lb if her pre-pregnancy BMI was in the normal range, or 15lb if her pre-pregnancy BMI was in the overweight range. A study of women in the US suggested that the proportion of women in this group was 48% for the former group, and 70% in the latter group.[27]

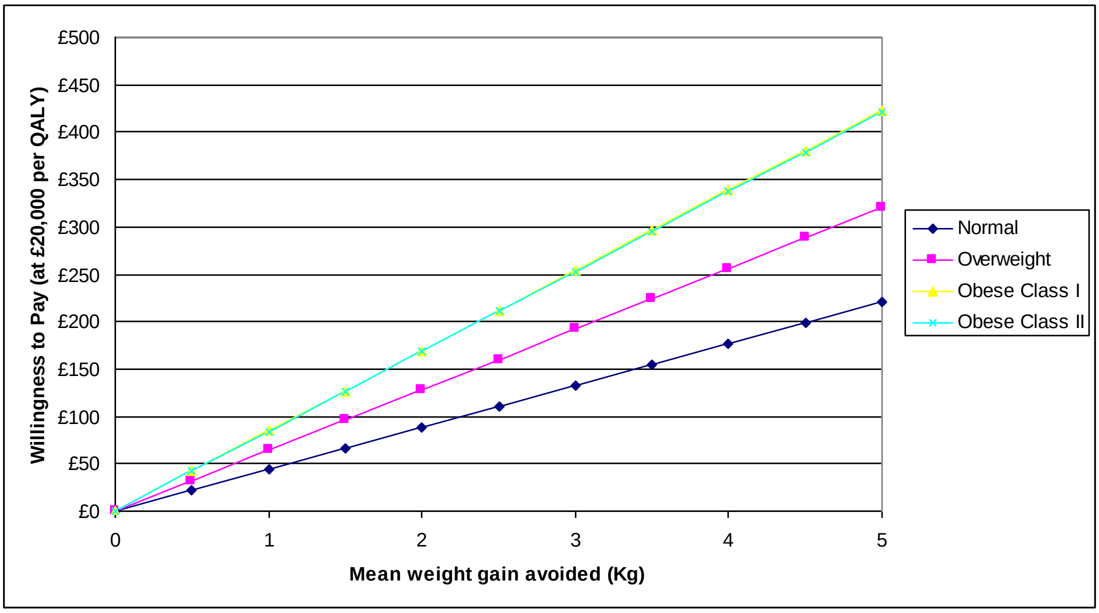
The cost-effectiveness of weight management programmes will depend on the combination of cost and effectiveness. One difficulty is that there are a number of interventions in the literature, and they differ in terms of the resources used. Figure two illustrates the relationship between the effectiveness of an intervention and the maximum cost-per-person for which it would be cost-effective (assuming willingness-to-pay for one QALY of £20,000. This suggests that willingness-to-pay increases with BMI category, and the key driver behind this finding is the increase in the at-risk population in women of higher pre-pregnancy BMI.

Whilst none of the interventions of weight management programmes in pregnancy reported economic evaluations, there are a number of economic evaluations of weight management programmes in general populations. The resource impact of the intervention will differ to some extent between populations, but the latter should give a reasonably informative guide of the former. The NICE guidance document on obesity identified nine economic evaluations of non-pharmaceutical interventions. The cost per participant ranged from around £50 to £600. It was noted that diet-based interventions tended to cost less than exercise-based interventions. Most of the interventions were longer than would be required for weight management during pregnancy (most were between six months and two years), and so weight management during pregnancy should be less costly.

Table 2: Impact of reducing weight gain by 5kg in a cohort of 1000 maternities.

	BMI: Normal 20-25	Overweight 25-30	Obese I 30-35	Obese II >35
QALYs gained				
BASE CASE	13.13	13.26	11.84	12.18
Consisting of:				
maternal deaths (pre-eclampsia)	6.52	6.33	6.15	5.78
infant deaths (pre-eclampsia)	2.42	2.35	2.28	2.14
infant deaths (macrosomia)	3.69	3.52	3.41	4.26
BMI related wellbeing	0.50	1.05	0.00	0.00
SENSITIVITY ANALYSIS				
Two extra years of weight gain delay	0.95	1.99	0.00	0.00
Disutility - complications in labour	1.55	1.93	1.93	1.93
Permanent reduction in obesity	2.40	1.68	3.36	0.00
Diabetes - Maternal	0.52	0.52	0.52	0.52
Diabetes - Child	1.43	1.36	1.32	1.65
Costs saved				
BASE CASE	£187,133	£190,842	£186,391	£177,787
Consisting of:	£0	£0	£0	£0
GDM care avoided	£4,556	£4,556	£4,556	£4,556
Reduction in caesareans	£22,518	£22,518	£22,518	£22,518
Reduction in assisted deliveries	£4,360	£12,535	£12,535	£12,535
Pre-eclampsia costs avoided	£154,683	£150,263	£145,844	£137,005
Brachial plexus treatments avoided	£1,017	£970	£938	£1,173
SENSITIVITY ANALYSIS				
Diabetes costs avoided:				
Mother	£5,600	£5,600	£5,600	£5,600
Child	£15,600	£14,880	£14,400	£18,000

Figure 2: Cost-effective threshold willingness-to-pay per person receiving weight management.



Sensitivity analysis

The base case represents a conservative view of the impact of weigh gain reduction, in particular as it excludes possible longer-term effects for which causal relationships cannot be assumed. We explore the impact of more favourable assumptions through sensitivity analysis. These assumptions were as follows.

Weight retention

The base case assumes that weight management during pregnancy leads to a temporary reduction in post-pregnancy weight gain lasting one year. It may well be that the intervention has a longer-lasting effect. The effect was calculated of extending the duration of the delay in moving to a higher BMI category to three years.

It may also be that some experience a long-term change in their BMI. The impact was calculated, assuming that 20% of those who avoided a post-pregnancy increase in BMI category maintained this benefit indefinitely, and also assuming that this extended their life expectancy by 2 years. Applying discounting and quality of life adjustments, this translated into an increase of 0.24 QALYs for each woman who maintained a permanent reduction in their BMI category.

Diabetes

Reducing the rate of GDM will lead to a reduction in type 2 diabetes in the maternal population. It may also reduce the long-term incidence of diabetes in their children.

The rate of diabetes may also be correlated with the incidence of macrosomia at birth. The impact was modelled of assuming that the reduction of maternal type 2 diabetes will be 20% of the reduction in GDM, and that the reduction of diabetes in their children will be 20% of the reduction in macrosomia. It was assumed that diabetes leads to a reduction in life expectancy of five years [Price et al], which after applying discounting and health-related quality of life translated to 0.65 extra QALYs for the mother and 0.22 extra QALYs for the child. It was also assumed that the lifetime diabetes cost of care, discounted from the age of onset was £17,000 [Clarke et al]. Assuming an age of onset of 55, and further discounting to the time of the pregnancy, reduced this cost to £7,000 for maternal diabetes and £2,400 for subsequent diabetes in the infant.

Quality-of-life impact of complicated labour

Obesity and weight gain during pregnancy are likely to be associated with a range of adverse health consequences as described above. These are not included in the base case due to a lack of utility values for these effects. The impact was modelled of assuming that the mean QALY loss for those undergoing a complicated delivery (caesarean or assisted vaginal delivery) was 0.05.

Table 2 gives the impact of these assumptions on the benefits of reducing pregnancy weight gain by 5 kg in a cohort of 1000 women. The impact on cost-effectiveness will depend on the costs of the intervention, and the degree to which it can reduce weight gain. Table 3 shows the cost-effectiveness of an intervention that costs £100 per participant and reduces mean weight gain by 1kg.

Table 3: Cost-effectiveness of an intervention that reduces mean weight gain by 1kg at a cost of £100 per participant

Cost-Effectiveness: (£ per QALY)	BMI: Normal 20-25	Overweight 25-30	Obese I 30-35	Obese II >35
Base Case alone	£63,445	£39,482	£26,490	£26,454
Base Case plus:				
Extended obesity delay	£59,174	£34,327	£26,490	£26,454
Permanent obesity prevention	£53,643	£35,041	£20,634	£26,454
Both	£50,557	£30,920	£20,634	£26,454
Diabetes averted:				
In mother	£60,619	£37,585	£24,922	£24,930
In Child	£56,145	£34,781	£22,738	£21,997
In Both	£53,838	£33,217	£21,465	£20,809
Disutility - complications in labour	£56,748			
All additional effects	£40,641	£24,253	£15,483	£18,348

Economic analyses of pre-pregnancy weight management

The health economic analysis of programmes to manage weight gain in pregnancy is motivated by the realisation that such programmes require resources that could be used elsewhere. An example of such an alternative would be interventions that target obesity in young women who are of child-bearing age, or even interventions that focus on women who are planning to conceive. Given that the resources involved will be more or less the same (e.g. dietitian time), this raises the question of which group should be given priority. In other words, is it a better use of resources to attempt to reduce obesity in women who are planning to conceive, or to manage weight once they are pregnant?

To answer this question fully would require an in-depth analysis of the impact of obesity on well-being and resource use in women who bear children, and a full review of the effectiveness of obesity management programmes in women of child-bearing age. We are not aware of any analysis in the literature that had estimated the cost-effectiveness of obesity management in this population, and presented results which could be compared with those given in tables 2 and 3. Whilst such an analysis is beyond the scope of this work, it is possible to use the model developed here, in combination with additional information from the literature, to gain some insight into the comparison.

There are health benefits that apply to anyone who manages to reduce excessive weight. The analysis presented in this report illustrates the additional benefits related to the impact of obesity on the risk of complications during pregnancy, in labour, and beyond. Information on this impact can be gleaned for pre-eclampsia, macrosomia and caesarean delivery by comparing the absolute event rates reported for obese women by Kiel et al and for women of normal BMI by De Vader et al. Chu et al report that the odds ratio of GDM, compared with women of normal BMI, is 3.56 for women of obese BMI and 8.56 for women of obese class 2 BMI.[28] This information, combined with the absolute rates of GDM reported by Kabiru et al for women whose BMI is in the normal or overweight category, can be used to estimate incidence rates for obese women.

A number of studies have found that obesity is related to an increased rate of complications during labour, resulting in an increase in morbidity, mortality and resource use.[29] The NHS reference cost for assisted delivery, given in table 1, is considerably higher than for non-assisted delivery. Kabiru et al report that the rate of operative delivery for both normal and overweight BMI category women is 11.4%. Cedergren et al found that this increases for obese women – the odds ratio was found to be 1.16 for Obese class I women and 1.34 for obese class 2 women.[30] Obese women are also more likely to require caesareans during labour (as opposed to elective caesareans). Doherty et al found that the rate of caesarean deliveries carried out during labour was 6.9% for women in the normal BMI category, 9.8% in the overweight category, and 12.7% in the obese category.[31] Non-elective caesarean delivery is likely to be associated with higher costs; the NHS reference cost for caesareans with complications is £2,981, whereas the standard caesarean cost (as reported in table 1) is £1,947.

The information described in the previous two paragraphs was used to derive the absolute rate of the events per BMI category. The relevant figures are listed in table 4. It shows the association between increasing BMI and increasing risk of adverse events in pregnancy and labour. The information can therefore be used to value the consequences of a reduction in BMI category prior to the pregnancy, as was done for weight management in pregnancy. The calculation is documented in table 5.

Table 4: Absolute rate of events in pregnancy / labour by BMI category

	Normal	Overweight	Obese	Obese II
Pre-eclampsia	2.5%	3.8%	5.0%	7.0%
Macrosomia	7.5%	9.3%	11.0%	13.0%
Caesarean without complications	10.1%	12.2%	14.3%	15.3%
GDM	1.5%	3.3%	5.1%	11.5%
Caesarean with complications	6.9%	9.8%	12.7%	15.7%
Assisted delivery	11.4%	11.4%	14.1%	15.9%

Table 5: Impact of reduction in BMI by one category prior to pregnancy

	Normal	Overweight	Obese	Obese II
Average Costs				
Pre-eclampsia	£220.98	£331.46	£441.95	£618.73
Macrosomia	£2.35	£2.89	£3.44	£4.07
Caesarean without complications	£84.23	£101.75	£119.26	£127.60
GDM	£17.09	£37.59	£58.57	£131.35
diabetes - child	£36.00	£44.40	£52.80	£62.40
Caesarean with complications	£128.89	£183.06	£237.24	£293.28
	£124.26	£124.26	£153.74	£173.79
Total	£613.79	£825.42	£1,067.00	£1,411.21
Average QALYs lost				
pre-eclampsia	0.00010	0.00015	0.00020	0.00029
macrosomia	0.00852	0.01051	0.01250	0.01477
diabetes - child	0.00330	0.00407	0.00484	0.00572
Total	0.01192	0.01473	0.01754	0.02078
costs saved through single category reduction		£211.62	£241.58	£344.22
QALYs gained through single category reduction		0.0028	0.0028	0.0032
WTP (at £20,000 per QALY)		£267.81	£297.77	£408.90

The results presented in table 5 are almost certainly an underestimate of the benefits to be gained by reducing weight before pregnancy, as they represent only a sample of the effects where obesity is a risk factor, and exclude the benefits not specific to childbearing. However, they will need to be reduced in line with the proportion of participants who do not go on to become pregnant. Nevertheless, they indicate that there are significant benefits to weight reduction pre-pregnancy in addition to the general benefits of reducing excess weight. It may well be that it is both easier, and more acceptable to clinicians and participants, to reduce weight pre-pregnancy, in which case this should be prioritised over the perhaps more challenging goal of weight management during pregnancy.

Conclusions

There is considerable uncertainty around all aspects of the economics of weight management in pregnancy; the direct costs of the interventions are poorly described and uncertain, the effectiveness of interventions in terms of limiting excessive weight gain is uncertain, and the range and degree of benefits from doing so are subject to strong assumptions. The modelling presented in this report suggests that there remains a meaningful possibility that many weight management interventions during pregnancy are not cost-effective.

While the results of Table 3 would suggest that interventions aimed at women with a pre-pregnancy BMI of between 30 and 35 might be somewhat more cost effective than the same intervention aimed at either overweight or severely obese women, the differences are not great and are not supported by later work by Nohr et al (2009). This work was published after the modelling for this report was carried out.

Separate economic models were constructed for weight management during pregnancy (WMIP) and weight management after childbirth (WMAC). This was because of differences in the structure of the underlying decision problems and differences in the interventions being considered. The models have been designed to be as consistent as possible given the constraints of the guidance development process. The model for WMIP presented in this report was essentially a short-term model whilst the model for WMAC gave fuller consideration to long-term effects. The WMIP model included long-term effects and cost savings associated with type 2 diabetes subsequent to gestational diabetes, whilst the WMAC model included costs and effects (including both morbidity and mortality effects) of BMI changes over 15 years following pregnancy. The fundamental issue in the economics of WMIP interventions is the absence of strong evidence of effect; the economic aspects are secondary to this concern.

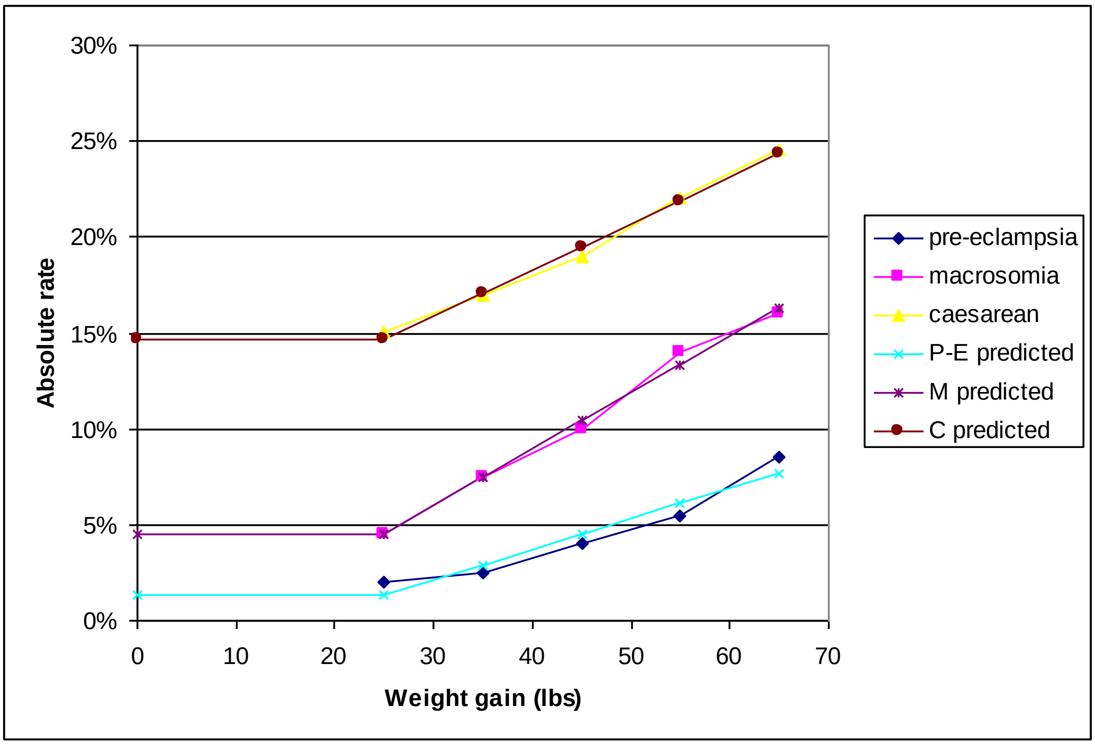
Further research on the effectiveness of weight management interventions during pregnancy should also collect economic evidence, ensuring that interventions are sufficiently well described and costed and that information on cost saving associated with clinical outcomes are collected. Further research is also required on the long term effectiveness of interventions either by collecting long term follow-up of outcomes from specific intervention studies or by defining and validating short term surrogate outcomes for long term effects.

Appendix: Impact of weight gain on complications of pregnancy and labour

Weight gain and pregnancy outcomes in women of normal pre-pregnancy weight (source De Vader et al)

Weight gain (lb)	Pre-eclampsia	Macrosomia	Caesarean delivery
25	2%	4.5%	15%
35	2.5%	7.5%	17%
45	4%	10%	19%
55	5.5%	14%	22%
65	8.5%	16%	24.5%

Risk – weight gain model for women of normal BMI:

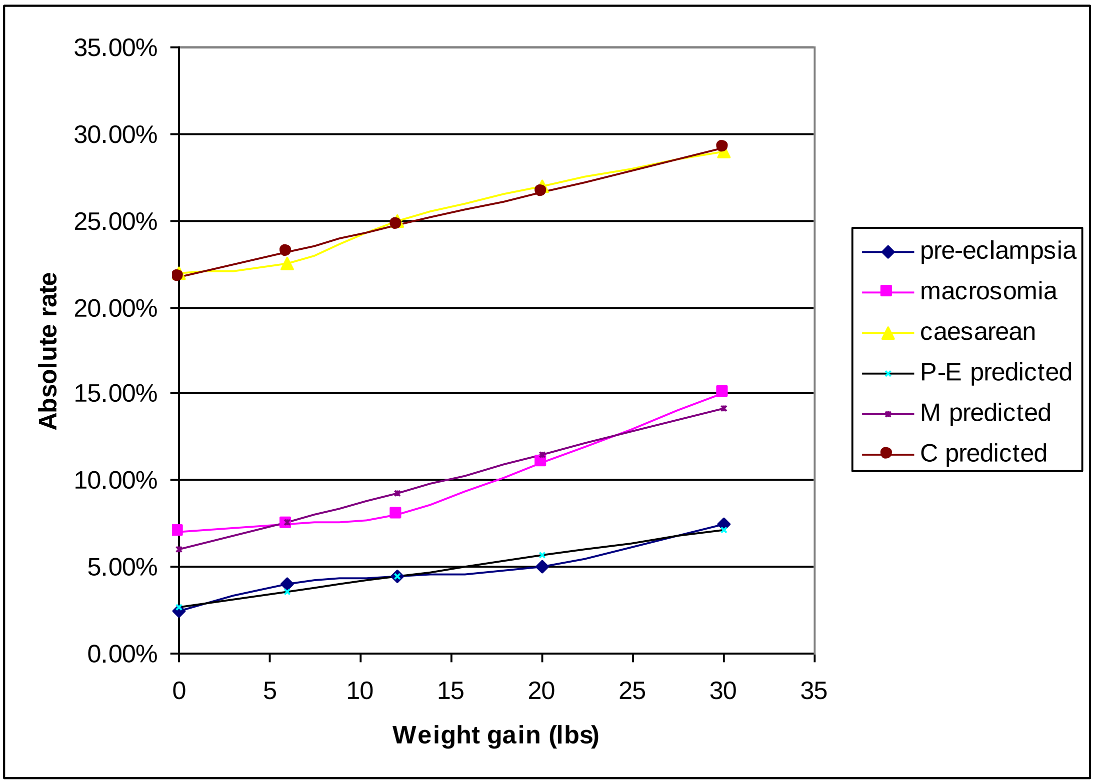


Weight gain and pregnancy outcomes in women of above-normal pre-pregnancy weight (source Kiel et al)

Obese class I women BMI 30-35 N =70,536

Weight (lb)	Pre-eclampsia	LGA >4kg	caesarean
0	2.5%	7%	22%
6	4%	7.5%	22.5%
12	4.5%	8%	25%
20	5%	11%	27%
30	7.5%	15%	29%
>35	10%	19%	34%

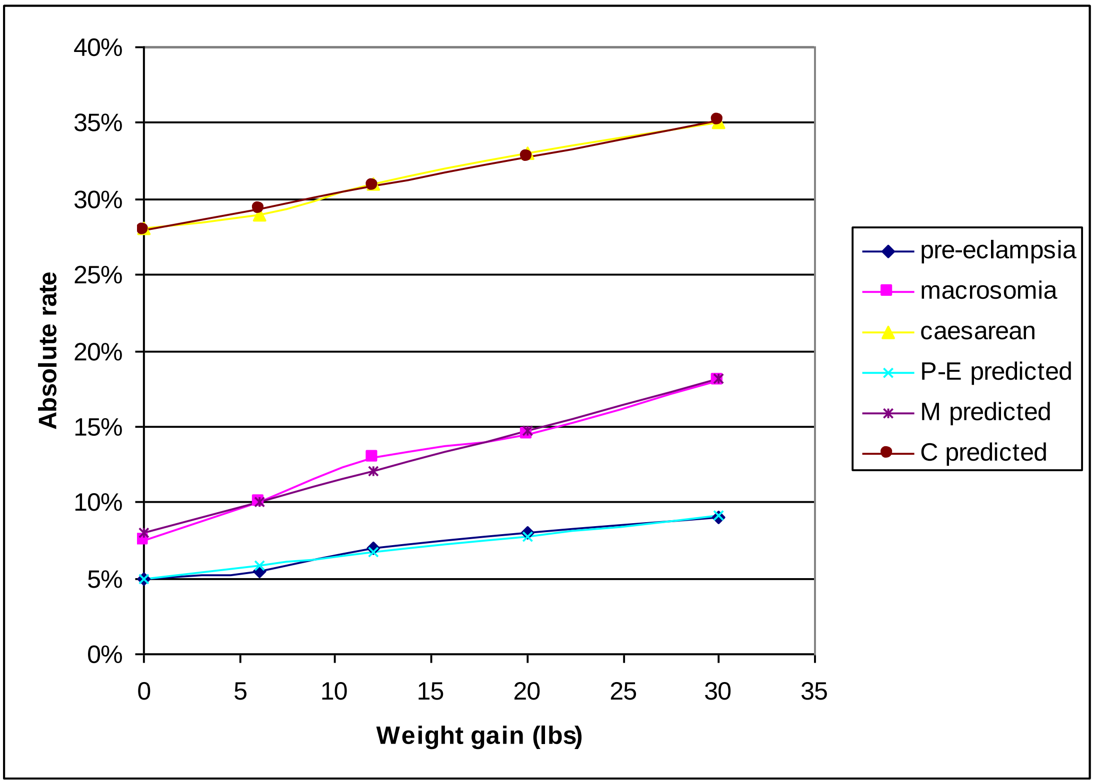
Weight gain – risk model for women in obese class I



Obese class 2 women 35-40 N = 30,609

Weight (lb)	Pre-eclampsia	LGA	caesarean
0	5%	7.5%	28%
6	5.5%	10%	29%
12	7%	13%	31%
20	8%	14.5%	33%
30	9%	18%	35%
>35	13%	23%	39%

Weight gain and risk model for obese class 2 women.



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