REVIEW ARTICLE

Obesity in pregnancy: risks and management

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Summary: Maternal obesity is now considered one of the most commonly occurring risk factors seen in obstetric practice. Compared with women with a healthy pre-pregnancy weight, women with obesity are at increased risk of miscarriage, gestational diabetes, preeclampsia, venous thromboembolism, induced labour, caesarean section, anaesthetic complications and wound infections, and they are less likely to initiate or maintain breastfeeding. Babies of obese mothers are at increased risk of stillbirth, congenital anomalies, prematurity, macrosomia and neonatal death. Intrauterine exposure to obesity is also associated with an increased risk of developing obesity and metabolic disorders in childhood. This article reviews the prevalence of obesity in pregnancy and the associated maternal and fetal complications. Recommendations and suggestions for pre-conception, antenatal and postnatal care of women with obesity are presented, and current research in the UK and future research priorities are considered.

Keywords: body mass index, complications, management, obesity, pregnancy, risk

CONTEXT OF THIS REVIEW

Maternal obesity is now considered one of the most commonly occurring risk factors seen in obstetric practice, and obstetricians are increasingly faced with caring for women who are obese. Such patients pose particular management problems relating both to increased risks of specific complications, and to medical, surgical and technical challenges in providing safe maternity care. It is therefore not surprising that obesity is associated with increased rates of maternal and perinatal morbidity and mortality. Despite these problems, there remains a lack of awareness of both the range and severity of the problems associated with obesity in pregnancy.

BACKGROUND

Obesity is a condition in which excess body fat has accumulated to such an extent that health may be adversely affected.[1] The worldwide prevalence of obesity has increased markedly over the past few decades and the World Health Organization (WHO) has described this trend as a 'global epidemic' posing a serious threat to public health.[1] Obesity carries considerable human cost; it is associated both with an increased risk of mortality from all causes and with specific increased risks of coronary heart disease, stroke, type 2 diabetes, some types of cancer, respiratory problems and musculoskeletal disorders.[2]

In 1993, the prevalence of obesity in the general population in England was 13% in men and 16% in women.[3] In 2006, 13 years later, this had increased to 24% in both men and women.[4] This reflects similar trends seen in other developed countries. The increased prevalence of obesity in women of child-bearing age is of particular concern as obesity in pregnancy carries additional risks for the mother and baby.[5]

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BODY MASS INDEX AS A MEASURE OF OBESITY

Body mass index (BMI) offers a useful measure of obesity and is a simple index of weight-for-height used to classify underweight, overweight and obese adults. BMI is calculated by dividing a person's weight in kilograms by the square of their height in metres (kg/m^2). Table 1 shows a widely accepted classification published by both the WHO[1] and the National Institute for Health and Clinical Excellence (NICE).[6] The classification has been based largely on the association between BMI and mortality, and it therefore allows the identification of individuals or groups at increased risk.

The main advantage of BMI as a measure of obesity is that it can be calculated easily; however, it is important to recognize that it does have certain limitations. The distribution of adipose tissue in an individual, rather than the absolute amount, appears to affect the risk of adverse health outcomes. In particular, abdominal obesity, which is associated with increased insulin resistance, is more strongly associated with morbidity and mortality compared with the accumulation of fat around the hips and thighs, and BMI is not able to account for this. Waist circumference has therefore been used as a better measure of visceral adiposity and its associated risk.[7] BMI is also unable to distinguish between muscle and fat mass, and two individuals with the same BMI could have very different body compositions. Across different populations, a given BMI may not correspond to the same degree of 'fatness' and the BMI range considered to be healthy may vary between populations. Despite these significant limitations, BMI is still considered the most useful population-level measure of obesity.

Table 1 **Classification of weight status according to BMI[1,6]**

BMI (kg/m^2)	Classification
<18.5	Underweight
18.5–24.9	Normal[1]/healthy[6]
25.0–29.9	Overweight
30.0–34.9	Obese I
35.0–39.9	Obese II
≥40	Obese III

BMI = body mass index

PREVALENCE OF OBESITY IN PREGNANCY

Obesity in pregnancy is usually defined as a maternal BMI ≥30 at the antenatal booking visit. There are currently no national-level data in the UK on the prevalence of obesity in pregnancy. A few observational studies have reported the prevalence rates of obesity in local maternity populations and, at present, these are the best indicators of maternal obesity prevalence in the UK. In the North East of England, BMI recorded at the booking visit in 36,821 pregnancies showed a significant increase in the prevalence of obesity from 9.9% to 16% ($P < 0.01$) between 1990 and 2004.[8] In Glasgow, a comparison of booking BMI between two randomly selected groups of women who booked for antenatal care in 1990 and in 2002–2004 also showed an increase in obesity prevalence from 9.4% to 18% ($P = 0.003$).[9] Sebire *et al.*[10] retrospectively analysed data from 287,213 completed singleton pregnancies in the north-west Thames region between 1989 and 1997 and found the overall prevalence of women with a BMI ≥30 to be 10.9%. The change in prevalence over time was not reported in this study.

Demographic predictors of maternal obesity in early pregnancy have been described. After adjustment for potential confounders, the study of 36,821 pregnancies in the north-east of England found that women classed as obese at booking were significantly older, more parous and lived in more deprived areas than women whose weight was classed within the healthy BMI range.[8] The association between maternal obesity and levels of deprivation has also been reported by Kanagalingam *et al.*[9] This is considered to reflect, at least in part, a suboptimal diet.

PREGNANCY COMPLICATIONS ASSOCIATED WITH MATERNAL OBESITY

There are a number of studies that have investigated the association between BMI and pregnancy outcomes, and the study design and findings of some of these studies are shown in Table 2. Many studies have used different BMI ranges or values to define obesity in pregnancy. Overall, however, it is clear that higher pre-pregnancy BMI is associated with an increased risk of a number of pregnancy complications and adverse pregnancy outcomes.

Obstetric complications

Gestational diabetes

A retrospective UK study of 287,213 pregnancies between 1989 and 1997 showed that after adjusting for ethnic group, parity, maternal age and history of hypertension, women with a BMI ≥30 were more likely to develop gestational diabetes than women with a BMI of 20.0–24.9 (odds ratio [OR] 3.6, 99% confidence interval [CI] 3.25–3.98).[10] These findings were similar to a later Australian study of 14,230 pregnancies, which showed that the odds (corrected for maternal age, parity, ethnicity, educational and smoking status) of developing gestational diabetes were 2.95 times higher (95% CI 2.05–4.25) in obese women (BMI 30.01–40.00) compared with normal-weight (BMI 20.01–25.00) women.[11]

Gestational diabetes milletus (GDM) increases the long-term risk of developing type 2 diabetes. Data from an observational cohort study of 330 Danish women with diet-treated GDM showed that 41% of these women developed diabetes during a median of 10 years follow-up.[12] This reflected a doubling of the risk compared with an earlier cohort of 241 women with GDM, which was followed by the same research group 10 years previously. The authors attributed the increased incidence of diabetes to a substantial increase in BMI among women with GDM.

Preeclampsia

The majority of observational studies since 1996 have shown a direct correlation between maternal BMI and risk of preeclampsia.[13] A Swedish cohort study of 805,275 pregnancies to women delivering between 1992 and 2001 found that 2.8% of women with a BMI of 29.1–35.0 had preeclampsia compared to 1.4% of women with a BMI of 19.8–26.0 (adjusted OR 2.62, 95% CI 2.49–2.76).[14] This difference was more marked in the Australian study reported by Callaway *et al.*[11], where the prevalence of pregnancy-induced hypertension/preeclampsia in normal-weight and obese women (see above) was 2.4% and 9.1%, respectively (adjusted OR 3.00, 95% CI 2.40–3.74). Duckitt and Harrington[15] reported a systematic review of risk factors for preeclampsia. A raised booking BMI, as defined for each included study, compared with a healthy BMI was associated with a 50% increase in the risk of preeclampsia, while a booking BMI >35 doubled the preeclampsia risk. One cohort study included in the review reported that a pre-pregnancy BMI >35 increased the risk of preeclampsia four-fold compared with women with a pre-pregnancy BMI of 19–27. The increased overall risk associated with raised prepregnancy BMI appeared to persist even after adjustment for confounding factors, such as maternal age and chronic hypertension.

Waist circumference is also associated with an increased risk of hypertensive complications. A non-pregnant waist circumference ≥80 cm has been associated with an OR for pregnancy-induced hypertension of 1.8 (95% CI 1.1–2.9) and for preeclampsia of 2.7 (95% CI 1.1–6.8) in a cohort of over 1000 unselected pregnancies.[7]

Venous thromboembolism

There is a significant association between BMI and risk of venous thromboembolism (VTE). Perhaps most striking is the fact that 57% of women with a known BMI dying from VTE in pregnancy in the UK are obese.[16] A retrospective case-control study in Denmark of 129 women with deep vein thrombosis or pulmonary embolism during pregnancy or the puerperium and 258 controls (pregnant women with no VTE) showed a significant association between VTE and obesity defined as BMI ≥30 (adjusted OR 5.3, 95% CI 2.1–13.5).[17] The United Kingdom Obstetric Surveillance System (UKOSS), recently reported that

Table 2 **Studies reporting specific risks associated with maternal obesity**

Complication	First author and study design	Risk of complication (odds ratio 95% confidence interval, unless otherwise stated)
Antenatal		
Miscarriage	Lashen[26] Nested case-control study of 1644 obese and 3288 age-matched normal weight controls. UK	OR of early miscarriage for obese 1.2 (1.01–1.46) and recurrent early miscarriage 3.5 (1.03–12.01)
	Mulders[27] Meta-analysis of outcomes associated with ovulation induction with gonadotrophins. Obese versus non-obese	Pooled OR of spontaneous miscarriage for obese 3.05 (1.45–6.44)
Fetal anomalies	Anderson[39] Population-based case-control study of 477 infants with birth defects and 497 controls (live infants without abnormalities). Obese versus normal weight. USA	AOR of anencephaly for obese 2.3 (1.2–4.3), spina bifida 2.8 (1.7–4.5), isolated hydrocephaly 2.7 (1.5–5.0)
	Callaway[11] Observational study of 14,230 singleton pregnancies. Overweight, obese and morbidly obese versus normal weight. Australia	AOR of birth defects for overweight 1.26 (0.85–1.87) NS, obese 1.58 (1.02–2.46), morbidly obese 3.41 (1.67–6.94)
	Cedergren[30] Case-control study of 6801 women who had infants with cardiovascular defect and 812,457 controls (all delivered women). Obese and morbidly obese (>35) versus normal weight. Sweden	AOR of cardiovascular defects for obese 1.18 (1.09–1.27), morbidly obese 1.41 (1.22–1.64). AOR of severe types of cardiovascular defects for obese 1.23 (1.05–1.44), morbidly obese 1.69 (1.27–2.26)
	Rasmussen[40] Meta-analysis of 12 studies (4 cohort and 8 case-control), including 8962 women. Overweight, obese and severely obese versus normal-weight women	OR of neural tube defect-affected pregnancy for overweight 1.22 (0.99–1.49), obese 1.70 (1.34–2.15) and severely obese 3.11 (1.75–5.46)
	Watkins[29] Case-control study of approximately 40,000 births per year between 1993 and1997. Obese women versus normal-weight women. USA	OR of spina bifida for obese 3.5 (1.2–10.3), omphalocele 3.3 (1.0–10.3), heart defects 2.0 (1.2–3.4)
Gestational diabetes mellitus	Bianco[41] Retrospective cohort study of 11,926 singleton pregnancies resulting in live births. BMI ≥35 versus BMI 19–27. USA	OR of GDM for BMI ≥35 3.2 (2.5–4.2)
	Callaway[11] See above	AOR of GDM for overweight 1.78 (1.25–2.52), obese 2.95 (2.05–4.25), morbidly obese 7.44 (4.42–12.54)
	Sebire[10] Retrospective observational study of 287,213 completed singleton pregnancies. Overweight and obese versus normal weight. UK	AOR of GDM for overweight 1.68 (99% CI 1.53–1.84), obese 3.6 (3.25–3.98)
Hypertension and preeclampsia	Bianco[41] See above	OR of pregnancy induced hypertension for BMI ≥35 3.6 (2.7–4.8)
	Callaway[11] See above	AOR of hypertensive disorders of pregnancy for overweight 1.74 (1.45–2.15), obese 3.00 (2.40–3.74)], morbidly obese 4.87 (3.27–7.24)
	Cedergren[14] Population-based cohort study of 12,698 women with BMI 35.1–40.0 and 3480 women with morbid obesity (BMI >40), compared with 535,900 normal-weight women (BMI 19.8–26.0). Sweden	AOR of pre-eclampsia for BMI 35–40 3.90 (3.54, 4.30), morbidly obese 4.82 (4.04–5.74)
	O'Brien[13] Systematic overview of 13 cohort studies, including nearly 1.4 million women	Risk of preeclampsia typically doubled with each 5–7 kg/m^2 increase in prepregnancy body mass index
	Sattar[7] Prospective observational study of 1142 singleton pregnancies. Waist circumference ≥80 cms versus ≤80 cms, and BMI ≥25 versus ≤25 cm. UK	OR of pregnancy-induced hypertension for women with waist circumference ≥80 cm 1.8 (1.1–2.9), BMI ≥25 2.0 (1.2–3.4) OR of preeclampsia for women with waist circumference ≥80 cm 2.7 (1.1–6.8), BMI ≥25 1.9 (0.7–4.8)
	Sebire[10] See above	AOR of preeclampsia for overweight 1.44 (99% CI 1.28–1.62), obese 2.14 (1.85–2.47)
Venous thromboembolism	Jacobsen[20] Hospital-based case-control study of 559 cases with no prior VTE and 1229 controls. Cases were women with objectively verified VTE during pregnancy or postpartum. Norway	AOR for antenatal VTE: BMI ≥25 with no immobilization 1.8 (1.3–2.4), BMI ≥25 with immobilization 62.3 (11.5–337.6) AOR for postpartum VTE: BMI ≥25 with no antenatal immobilization 2.4 (1.7–3.3), BMI ≥25 with immobilization 40.1 (8.0–201.5)
	Larsen[17] Population-based case-control study including 129 VTE cases and 258 controls. Overweight and obese versus normal weight. Denmark	AOR of VTE during pregnancy for overweight 1.6 (0.6–4.4), obese 9.7 (3.1–30.8)
Maternal death	CEMACH[16] Confidential enquiry into all maternal deaths in the UK between 2003 and 2005. UK	Of women with a known BMI, 31.3% who died of causes directly related to their pregnancy had a BMI ≥30. Of women dying of indirect causes (not due to direct obstetric causes), 25.0% had a BMI ≥30
Intrapartum		
Failure to progress in labour	Bianco[41] See above	OR of failure to progress for BMI ≥35 2.6 (2.0–3.5)
Induction of labour	Sebire[10] See above	AOR of induction of labour for overweight 1.27 (99% CI 1.123–1.30), obese 1.70 (1.64–1.76)
	Usha Kiran[35] Population-based observational study including 8350 singleton uncomplicated pregnancies with cephalic presentation of ≥37 weeks. Obese (BMI ≥30) versus normal weight (BMI <29). UK	OR of postdates for obese 1.4 (1.2–1.7), induction of labour 1.6 (1.3–1.9)
Shoulder dystocia	Cedergren[14] See above	AOR of shoulder dystocia for morbidly obese 3.14 (1.86–5.31)
	Usha Kiran[35] See above	OR of shoulder dystocia for obese 2.9 (1.4–5.8)

(Continued)

Table 2 **Continued**

Complication	First author and study design	Risk of complication (odds ratio 95% confidence interval, unless otherwise stated)
Caesarean	Bianco[41] See above	AOR of caesarean for BMI ≥35 2.3 (1.9–2.8)
	Callaway[11] See above	AOR of caesarean for overweight 1.50 (1.36–1.66), obese 2.02 (1.79–2.28), and morbidly obese 2.54 (1.94–3.32)
	Chu[22] Meta-analysis including 33 studies. Overweight, obese and severely obese versus normal weight	OR of caesarean for overweight 1.46 (1.34–1.60), obese 2.05 (1.86–2.27) and severely obese 2.89 (2.28–3.79)
	Sebire[10] See above	AOR of emergency caesarean section for overweight 1.30 (99% CI 1.25–1.34), obese 1.83 (1.74–1.93)
	Usha Kiran[35] See above	OR of emergency caesarean for obese 2.0 (1.2–3.5)
Macrosomia	Cedergren[14] See above	AOR of large for gestational age for BMI 35–40 3.11 (2.96–3.27), morbidly obese 3.82 (3.50–4.16)
	Sebire[10] See above	AOR of birth weight above 90th centile for overweight 1.57 (99% CI 1.50–1.64), obese 2.36 (2.23–2.50)
	Usha Kiran[35] See above	OR of macrosomia for obese 2.1 (1.6–2.6)
Prematurity	Callaway[11] See above	AOR of prematurity (<34 weeks) for overweight 1.22 (0.90–1.64), obese 1.16 (0.81–1.67), morbidly obese 2.13 (1.13–4.01)
Stillbirth	Cedergren[14] See above	AOR of stillbirth for BMI 35–40 1.99 (1.57–2.51), morbidly obese 2.79 (1.94–4.02)
	Chu[28] Meta-analysis including nine studies (6 cohort, 3 case-control). Overweight and obese versus normal weight	OR of stillbirth for overweight 1.47 (1.08–1.94), obese 2.07 (1.59–2.74)
	Kristensen[42] Cohort study of 24,505 singleton pregnancies (112 stillbirths, 75 neonatal deaths) (Denmark). Obese versus normal weight. Denmark	AOR of stillbirth for obese 3.1 (1.6–5.9)
	Sebire[10] See above	AOR of stillbirth for overweight 1.10 (99% CI 0.94–1.28), obese 1.40 (1.14–1.71)
Postnatal		
Low APGAR scores	Sebire[10] See above	AOR of a low APGAR score for overweight 1.16 (99% CI 1.06–1.28), obese 1.45 (1.28–1.64)
Admission to neonatal intensive care units	Bianco[41] See above	OR of admissions for BMI ≥35 1.2 (1.0–1.3)
	Callaway[11] See above	AOR of admissions for overweight 0.92 (0.73–1.16), obese 1.25 (0.97–1.62), morbidly obese 2.77 (1.81–4.25)
	Sebire[10] See above	AOR of admissions for overweight 1.22 (99% CI 1.16–1.28), obese 1.34 (1.25–1.44)
	Usha Kiran[35] See above	OR of admissions for obese 1.5 (1.09–2.3)
Neonatal death	Cedergren[14] See above	AOR of early neonatal death for BMI 35.1–40 2.09 (1.50–2.91), morbidly obese 3.41 (2.07–5.63)
	Kristensen[42] See above	AOR of neonatal death for obese 2.7 (1.2–6.1)
	Shah[43] Population-based observational study of 30,167 (181 stillbirths and 78 neonatal deaths) singleton pregnancies. Obese versus BMI < 29. UK	OR of early neonatal death for obese 1.66 (1.0–2.75)
Postpartum haemorrhage	Sebire[10] See above	AOR of postpartum haemorrhage section for overweight 1.16 (99% CI 1.12–1.21), obese 1.39 (1.32–1.46)
	Usha Kiran[35] See above	OR of blood loss >500 mL for obese 1.5 (1.2–1.8)
Urine, uterine and wound infection	Sebire[10] See above	AOR of genital tract infection for overweight 1.24 (99% CI 1.09–1.41), obese 1.30 (1.07–1.56) AOR of urinary tract infection for overweight 1.17 (1.04–1.33), obese 1.39 (1.18–1.63) AOR of wound infection for overweight 1.27 (1.09–1.48), obese 2.24 (1.91–2.64)
	Usha Kiran[35] See above	OR of urinary tract infections for obese 1.9 (1.1–3.4)
Venous thromboembolism	Larsen[17] See above	AOR of postpartum VTE for overweight 1.3 (0.5–3.3), obese 2.8 (0.8–9.8)
Reduced breastfeeding success	Sebire[10] See above	AOR of breastfeeding at discharge for overweight 0.86 (99% CI 0.84–0.88), obese 0.58 (0.56–0.60)

OR = odds ratio; AOR = adjusted odds ratio; NS = non-significant; BMI = body mass index; CI = confidence interval; VTE = venous thromboembolism; GDM = gestational diabetes mellitus; CEMACH = Confidential Enquiry into Maternal and Child Health

a BMI ≥30 was associated with an adjusted OR of 2.65 (95% CI 1.09–6.45) for antenatal pulmonary thromboembolism (PTE).[18] This association is not surprising given the associated problems of reduced mobility, co-morbid conditions that predispose to thrombosis, such as preeclampsia, and an increased frequency of operative delivery, especially when superimposed upon the doubling of risk of VTE seen in non-pregnant women with a BMI ≥30, possibly related to higher levels of coagulation factors VIII and IX.[19] In non-pregnant women, the risk of VTE is exaggerated by concomitant use of oestrogen-containing hormonal contraception. Women with a BMI ≥25 using such contraception have been shown to have a 10-fold risk of thrombosis,[19] and similar interactions are likely to be present in pregnancy when oestrogen levels are known to be increased. The interaction of obesity with other risk factors is also highlighted by the large case-control study of Jacobsen *et al.*[20] which reported an adjusted OR of 1.8 (95% CI 1.3–2.4) for VTE in pregnant women with a BMI ≥25, increasing to an adjusted OR of 62.3 (95% CI 11.5–337.6) where BMI and immobility were combined.

Labour and delivery

Observational studies have shown that obesity is associated with a higher incidence of intrapartum complications. The pregnancy, delivery and nutrition study found that women with a BMI $\geq$30 were more likely than women with a BMI $\leq$26 to have their labour induced and to receive oxytocin.[21] Furthermore, after adjusting for a number of potential confounders including labour induction and oxytocin use, labour progression from four to 10 cm was slower in obese women compared with those with a BMI $\leq$26 (7.9 versus 6.2 median hours, $P < 0.001$). These data suggest that obesity is associated with inefficient uterine activity in labour. The authors also found that primary emergency caesarean section rates were higher for obese women compared with women with a healthy BMI (27% versus 19%, $P < 0.04$), with the majority of the deliveries occurring during the first stage of labour for failure to progress in labour and fetal distress.

Many studies have reported a positive association between maternal BMI or weight and caesarean section. Recently, a meta-analysis of 33 cohort studies calculated the risk of a caesarean delivery for women identified by the authors as normal, overweight and obese.[22] Although there were small variations between studies in the BMI ranges used to define normal and overweight, all but one of the studies defined obesity as a maternal BMI $\geq$30. The OR of a caesarean section was 1.46 (95% CI 1.34–1.60) and 2.05 (95% CI 1.86–2.27), respectively, among overweight and obese women compared with women with a normal weight. Chu *et al.*[22] also performed a separate meta-analysis of 12 studies, which included only women without co-morbidities. The odds of a caesarean section remained higher in overweight (OR 1.41, 95% CI 1.17–1.69) and obese women (OR 1.75, 95% CI 1.41–2.23) without complications, compared with women with a healthy BMI.

Anaesthesia

Obese pregnant women have an increased risk of dysfunctional labour and caesarean section delivery as discussed above, which are associated with increased requirements for anaesthesia. However, they are also at higher risk of anaesthesia-related morbidity. Obese women have a higher epidural failure rate in the intrapartum period than women with a BMI $<$25.[23] There is an increased risk of aspiration under general anaesthesia due to increased gastric volume; difficult endotracheal intubation due to suboptimal laryngoscopic views; difficulty in achieving regional analgesia/anaesthesia due to impalpable bony landmarks; and postoperative hypoxaemia and atelectasis.[24] Obese women are more likely to have co-morbidites such as hypertension, ischaemic heart disease and heart failure, adding to the risks associated with anaesthesia.

Maternal death

There is evidence that obesity is associated with a higher risk of maternal death. In the triennium 2003–2005, 28% of all women who died in the UK were classified as obese.[25] These deaths in obese women are associated with many causes of direct and indirect death, including preeclampsia and pulmonary embolism.

Fetal and neonatal complications

Fertility and miscarriage

A Danish case-control study of 1644 obese women (BMI $\geq$30) and 3288 age-matched controls (BMI 19.0–24.9) showed that obese women had a higher incidence of first trimester miscarriage (OR 1.2, 95% CI 1.01–1.46) and recurrent first trimester miscarriage (OR 3.5, 95% CI 1.03–12.01).[26] Compared with women with a healthy BMI, women with obesity also have more fertility problems, largely associated with ovulation disturbance and polycystic ovarian syndrome, and often require assisted reproductive techniques to achieve pregnancy. A systematic review and meta-analysis of 13 studies, examining the predictors of ovulation induction outcome in women with normo-gonadotrophic anovulatory infertility, reported that the most clinically useful predictors of poor treatment outcome were obesity and insulin resistance, with a pooled OR for spontaneous miscarriage of 3.05 (95% CI 1.45–6.44) in obese versus non-obese women.[27]

Stillbirth

A recent meta-analysis of six cohort studies and three case-control studies found a doubling in the risk of stillbirth among obese women (unadjusted OR 2.07, 95% CI 1.59–2.74) compared with women with a healthy BMI.[28] There was one retrospective UK-based cohort study included in this meta-analysis, which analysed 287,213 pregnancies from 1989 to 1997.[10] Women with a BMI $\geq$30 had a stillbirth rate of 6.9/1000 total births compared with 4/1000 total births in women with a BMI of 20–25 (adjusted OR 1.40, 99% CI 1.14–1.71, OR adjusted for ethnicity, parity, maternal age, history of hypertension, gestational diabetes, preeclampsia, emergency caesarean section and smoking).

Congenital anomalies

Women who are obese are at increased risk of fetal anomaly (Table 2). Several large case-control studies have shown up to a three-fold risk of spina bifida, omphalocele and heart defects in babies of obese mothers.[29,30] Prepregnancy and early pregnancy folic acid supplementation is clearly a logical intervention but the increased incidence of neural tube defects in obese women has persisted in populations where flour has been fortified with folic acid. The biological basis for these abnormalities is not clear but may be linked to insulin resistance, diabetes or specific nutritional deficits. Interestingly, a recent large population-based case-control study reported that mothers of babies with gastroschisis were less likely to be obese than those with healthy babies.[31] The same study confirmed an association between maternal obesity and spina bifida, heart defects, anorectal atresia, hypospadias, limb reduction defects, diaphragmatic hernia and omphalocele.

Macrosomia

Maternal obesity is associated with an increased risk of fetal macrosomia. Data from a study of 350,311 pregnancies showed that nearly a fifth of women with a BMI $\geq$30 had fetal macrosomia defined as birthweight $\geq$4 kg (OR 1.97, 95% CI 1.88–2.06), or defined as birthweight $\geq$90th centile for gestational age (OR 2.08, 95% CI 1.97–2.17).[32] The increased incidence of macrosomia was independent of whether the mother also had pre-existing or gestational diabetes. In turn,

macrosomia is a risk factor for operative delivery, a low Apgar score at one minute and a low umbilical arterial pH level, as well as shoulder dystocia and significant injuries to the baby, including fractures and nerve palsies. It should be noted that maternal obesity is not an independent risk factor for shoulder dystocia.[33] Thus, it is macrosomia rather than maternal obesity that is the main risk factor for shoulder dystocia. The overall morbidity for macrosomic babies is increased to around 8%.[34]

Postpartum complications

Following delivery, obese women have an increased risk of postpartum haemorrhage. Several studies have also shown an increased incidence of genital tract infection, urinary tract infection and wound infection (Table 2).[10,35] Interestingly, Jacobsen *et al.*[20] reported that postpartum infection substantially increased the risk of VTE both after caesarean and vaginal delivery. Thus, obese women with postpartum infection may be particularly predisposed to VTE.

Maternal obesity is linked to reduced breastfeeding rates, both in terms of breastfeeding initiation and duration.[36] Possible reasons include physical issues such as difficulty with correct positioning of the baby, psychosocial issues, or endocrine issues such as a lower prolactin response to suckling.[37] Women with obesity may therefore benefit from extra support for breastfeeding. This support should be provided in the antenatal period, the immediate puerperium and after discharge from hospital.

Associated childhood morbidity

Children of obese mothers are at increased risk of longer-term morbidity. Boney *et al.*[38] followed a cohort of 84 large-for-gestational-age (LGA) and 95 appropriate-for-gestational-age (AGA) babies from birth to ages six, seven, nine and 11 years to examine the development of the metabolic syndrome, defined as two or more of the following four components: obesity, hypertension, glucose intolerance and dyslipidaemia. The prevalence of the metabolic syndrome at any time up to 11 years was 50% for LGA offspring of mothers with gestational diabetes, 29% for LGA offspring of non-diabetic mothers, 21% for AGA offspring of GDM mothers and 18% for AGA offspring of women without GDM. Interestingly, babies of any birth weight with intrauterine exposure to maternal obesity had a similar risk of developing the metabolic syndrome in later life as LGA babies (hazard ratio: 1.8 [95% CI 1.0–3.2] and 2.2 [95% CI 1.3–3.8], respectively).

MANAGEMENT OF WOMEN WITH OBESITY IN PREGNANCY

Current guidelines

There is currently no specific national evidence-based guideline for the clinical management of obesity in pregnancy, although the American College of Obstetricians and Gynaecologists (ACOG) has published a Committee Opinion paper on Obesity in Pregnancy, which includes suggested interventions.[44] There are a number of existing guidelines on other aspects of maternity care, which include information relevant to obese pregnant women.[45–53] The published literature includes suggested management strategies for pregnant obese women and some of these are summarized in Table 3.

Specific recommendations

Folate supplementation

During pregnancy, fetal growth is linked to an increase in the total number of rapidly dividing cells, which leads to increased requirements for folate. Maternal folate deficiency in pregnancy is associated with fetal congenital malformations,[54] and supplementing the diet with folic acid 400 μg daily if there is doubt about adequate dietary intake has been recommended for many years.[45] Studies have linked maternal obesity with an increased risk of neural tube defects; although the mechanism

Table 3 **Suggested recommendations for the clinical care of obese women before, during and after pregnancy (modified from Yu *et al.*[59] and Ramsay *et al.*[34])**

Prepregnancy
Counsel for prepregnancy weight loss through lifestyle modification, including diet and regular exercise
Encourage folate supplementation and consider higher dose of 5 mg a day
Antenatal
Booking
Weigh all mothers and calculate BMI to identify individuals at risk
Advise on risks of obesity in pregnancy
Discuss recommended weight gain during pregnancy according to pre-pregnancy BMI
Refer to dietician for dietary advice
Suggest regular moderate-intensity activity, unless contraindicated
Recommend detailed anomaly scan and serum screening for congenital abnormality
Diabetes
Consider screening for GDM
Hypertension
Consider screening for preeclampsia by uterine artery Doppler if facilities permit
Recommend low dose aspirin as prophylaxis against preeclampsia
Provide regular antenatal visits with blood pressure checks
Thromboembolism
Assess thrombosis risk and provide thromboprophylaxis with adequate dose of anticoagulant for an appropriate duration if required
Anaesthetic review
Consider anaesthetic review before delivery
Regional anaesthesia usually preferred unless contraindicated
Anticipation of problems and effective preparation in terms of equipment, monitoring and personnel
General anaesthesia, if required, should be delivered with tracheal intubation and controlled ventilation
General
Plan delivery to allow optimum management by experienced obstetricians
Postpartum
Postoperative care that includes close monitoring, early mobilization and physiotherapy; a high-dependency setting may be appropriate
Consider prophylactic postpartum antibiotics if vaginal delivery is complicated and provide perioperative antibiotics for caesarean delivery
Judicious use of neuraxial, oral and intravenous opioids for postoperative pain
Encourage breastfeeding and provide specific support
Encourage weight loss and increased physical exercise prior to next pregnancy
Assess thrombosis risk postpartum and ensure good hydration and early mobilization after any operative delivery and specific antithrombotic interventions including graduated elastic compression stockings and/or pharmacological thromboprophylaxis if indicated
Consider extended thromboprophylaxis after discharge
Arrange postnatal review at six weeks to discuss any problems and potential for future intervention

BMI = body mass index; GDM = gestational diabetes milletus

for this association remains unknown, obese women have been found to have lower levels of serum folate than non-obese women of child-bearing age.[55] Data from the National Health and Nutrition Examination Survey (NHANES) in the USA showed that women with a BMI $\geq$27 were less likely to use nutritional supplements and were less likely to receive folate through diet than women with a BMI $<$27. Interestingly, the inverse association between BMI and serum folate level persisted after controlling for folic acid intake.[55] A large case-control study found that a daily intake of at least 400 μg of folic acid reduced the risk of neural tube defect-affected pregnancy by 40% in women weighing $<$70 kg, with no risk reduction observed in women weighing $\geq$70 kg.[56] These findings indicate that higher daily doses of folate in obese women may be required to reduce the risk of neural tube defects.

Weight loss before conception through dietary modification

A weight loss of 4.5 kg between two pregnancies has been shown to reduce the risk of developing gestational diabetes by up to 40%.[57] A 10% weight loss over six months is suggested to be an ideal amount, which is safe and possible to sustain in the long term. Although weight loss regimens in the first trimester of pregnancy may increase the risk of fetal neural tube defects, weight loss prior to pregnancy does not appear to carry this risk.[58]

Care following bariatric surgery

Bariatric surgery includes purely restrictive procedures (adjustable gastric banding) and malabsorptive procedures that may also restrict the stomach volume (Roux-en-Y bypass and biliopancreatic diversion). The number of women undergoing bariatric surgery for the treatment of morbid obesity has increased over recent years. Although there were early concerns that pregnancies following bariatric surgery may be associated with increased risk of poor perinatal outcomes and late surgical complications, data from recent studies do not support these concerns.

A recent systematic review of 75 studies, comprising 28 case reports, 26 case series, 18 cohort studies and three matched cohort studies, aimed to assess associations between different types of bariatric surgery and pregnancy outcomes.[60] The reviewed evidence indicated that risks for maternal complications, such as gestational diabetes, preeclampsia and pregnancy-induced hypertension, appeared generally to be lower in women who had undergone bariatric surgery compared with obese women who had not had surgery. Similar findings were reported for all types of bariatric surgery with regard to neonatal complications including premature delivery, low birthweight and macrosomia. Nutritional deficiencies during pregnancy following laparoscopic adjustable gastric banding or gastric bypass procedures appear uncommon when adequate supplementation is maintained.[60,61] Severe nutritional deficiencies requiring parenteral nutrition have been reported in approximately 20% of pregnancies following biliopancreatic diversion.[60] Although most studies have attributed deficiencies to non-adherence with supplementation, parenteral nutrition has also been reported for women taking supplements and for those in whom adherence was unclear.[62–64] These findings emphasize the importance of careful nutritional monitoring during pregnancy.

To minimize potential risks, the ACOG has recommended that women who have had bariatric surgery should delay conception for 18 months after surgery to avoid conceiving during the period of rapid weight loss, be monitored by their surgeon during pregnancy as adjustment of gastric bands may be necessary and receive nutritional supplementation as necessary to avoid deficiencies of iron, folate, calcium and vitamin B_{12}.[44]

It is also recognized that women who have undergone bariatric surgery may be prone to dumping syndrome following an oral glucose tolerance test. Dumping syndrome is thought to arise due to malabsorption, osmotic fluid shifts and postprandial hyperinsulinaemic hypoglycaemia, and may result in a number of symptoms, including flushing, palpitations, syncope, abdominal bloating, diarrhoea and sometimes even altered consciousness.[65] To avoid these symptoms, an oral glucose tolerance test is not recommended for women who have had bariatric surgery. Instead, home blood glucose monitoring for a period of at least one week has been suggested for the purpose of screening for gestational diabetes in these women.[66,67]

Regular moderate-intensity physical activity

Exercise has been found to be helpful in improving glycaemic control in women with GDM and may play a role in its prevention.[68] In 2006, the Royal College of Obstetricians and Gynaecologists (RCOG) produced a statement on exercise in pregnancy which stated that, in most cases, aerobic exercise is safe for both mother and fetus during pregnancy, and women should therefore be encouraged to initiate or continue exercise to derive the health benefits associated with such activities.[49] Recently, a Cochrane Review assessed aerobic exercise during pregnancy.[69] Regular aerobic exercise during pregnancy appeared to improve maternal fitness. There were some data to suggest beneficial effects on fetal growth and the need for more high-quality trials in this area was highlighted.

Measurement of weight and height at first antenatal appointment and during pregnancy

The NICE Antenatal Care guideline published in 2008 recommends that maternal height and weight should be recorded for all women at the initial booking visit to allow the calculation of BMI.[53] Semi-structured interviews of health professionals in the North East Government Office Region of England suggested that self-reported rather than measured height and weight may be used at some community booking visits due to lack of availability of appropriate equipment.[70] However, self-reported height is often overestimated and self-reported weight underestimated, particularly in obese women,[71] which may lead to inaccurate risk assessment during pregnancy. A USA study of 97 overweight and obese (BMI $>$27.3) non-pregnant women found that the mean weight discrepancy between measured and self-reported weight of those in Obesity Class I (BMI 30–35), Class II (BMI 35–40) and Class III (BMI $>$40) was -1.56 ± 5.77, -6.52 ± 10.23 and -5.15 ± 9.86 kg, respectively.[72] The extent of inaccurate reporting of weight in obese women highlights the importance of obtaining and documenting measured weight and height in pregnancy.

The NICE Antenatal Care Guideline recommends that repeated weight measurements during pregnancy should occur only in circumstances where clinical management is

likely to be influenced.[53] Maternal obesity is an example of one such circumstance as maternal weight throughout pregnancy determines the need for specific additional interventions and specialist equipment. There are also a number of studies that have shown an association between pregnancy weight gain and specific outcomes.

Weight gain during pregnancy

The most widely adopted recommendations relating to pregnancy weight gain are those published by the Institute of Medicine (IOM) in 1990.[45] These recommendations advise a gain of 12.5–18 kg for underweight women (BMI <19.8), 11.5–16 kg for women with a healthy BMI (19.8–26.0), 7–11 kg for overweight women (BMI 26.0–29.0) and at least 7 kg for obese women (BMI ≥29.0), although it has been recognized in the guideline that many obese women with good pregnancy outcomes gain less weight than this recommended minimum.[45] Since the publication of the guidelines, several studies have examined the association between early pregnancy BMI, gestational weight gain and outcomes.

A prospective population-based cohort study of 245,526 singleton term pregnancies examined the effects of pregnancy weight gain within different BMI categories on obstetric and fetal outcomes.[73] Women were grouped into three weight gain categories: <8 kg (low weight gain), 8–16 kg and ≥16 kg (high weight gain). Obese women with low pregnancy weight gain had a decreased risk of preeclampsia (adjusted OR 0.52, 95% CI 0.42–0.62), caesarean section (adjusted OR 0.81, 95% CI 0.73–0.90), instrumental delivery (adjusted OR 0.75, 95% CI 0.63–0.88) and LGA babies (adjusted OR 0.66, 95% CI 0.59–0.75). High pregnancy weight gain was strongly associated with the birth of an LGA infant, with this being more pronounced in the lower BMI categories. However, it is important to note that the risk of SGA infants was increased among women with low gestational weight gain in all BMI categories, although the odds decreased with increasing BMI.

A follow-on publication by the same author suggested optimal gestational weight gain for each maternal BMI category.[74] The optimal gain for underweight, normal weight, overweight and obese women was suggested to be 4–10 kg, 2–10 kg, <9 kg and <6 kg, respectively. These weight gain ranges were associated with the lowest risk of overall adverse maternal and perinatal outcome, and are lower than the IOM recommendations.

In a population-based cohort study of 120,251 pregnant obese women delivering full-term, live singleton infants, Kiel *et al.*[75] examined the risk of four pregnancy outcomes (preeclampsia, caesarean section, LGA and SGA) by obesity class and total gestational weight gain. The risk of the first three outcomes decreased with decreasing weight gain, although there was an increased risk of SGA babies across all BMI categories. The authors suggested that the overall minimal risk for mother and baby should be taken as the point where there was an equal risk of LGA and SGA babies, which corresponded with a weight gain of 10–25 lb (4.5–9 kg) for Class I obese (BMI 30–34.9) women, and a weight gain of 0–9 lb (0–4 kg) for Class II obese (BMI 35–39.9) and Class III obese (BMI ≥40) women.

It is clear that careful weight management during pregnancy can help minimize the risks of adverse outcomes associated with maternal obesity, although it is important to be aware of the potential risk of increasing the incidence of SGA babies. Achieving appropriate weight management can be challenging for both the woman and the health professional. Several intervention studies have attempted to prevent excessive gestational weight gain using behavioural programmes.[76–80] Inconsistent results have been reported, with some studies showing no effect in obese women compared to significantly lower weight gain in normal-weight women.[77,79]

CURRENT UK RESEARCH

In 2006, the North East Maternal Obesity Research Group completed a scoping study of routine data collection practice in all maternity units in north-east England.[81] More recently, this group carried out a qualitative study of the impact of maternal obesity on National Health Service (NHS) maternity services.[70] Maternity health professionals from different disciplines discussed issues relating to health service provision for obese pregnant women, additional care and cost implications to service providers, policies and guidelines, difficulties encountered in day-to-day care, available multidisciplinary services, and provision of patient information and advice. This group has now completed a survey of all maternity units in England to establish current data collection practice with regard to maternal obesity. Other projects include a retrospective observational study investigating the prevalence of maternal obesity and associated demographic factors in a sample of NHS Trusts in England,[8] and a cost analysis of the additional care and complications associated with obesity in pregnancy.

Evidence for the association of increased maternal BMI with adverse pregnancy outcome has been derived mainly from populations with moderate obesity (BMI 30–40). The risk of pregnancy complications in women with an even higher BMI is likely to be even greater, but to date there have been few published data on women with extreme obesity. UKOSS was established in 2005 to describe the epidemiology of a variety of uncommon disorders in pregnancy. In 2007, UKOSS commenced a surveillance programme to investigate: (1) the prevalence of extreme obesity in pregnancy in the UK; (2) the risk of adverse outcomes attributable to this degree of obesity; and (3) any adverse outcomes relating to inadequate weight capacity equipment. Until November 2008, maternity units in the UK notified UKOSS of all women with a BMI >50 or a weight >140 kg at any point during pregnancy. Preliminary analysis of the data suggests that the prevalence of extreme obesity (BMI >50) is approaching one in every thousand women giving birth.[82] The results from this study are anticipated to provide valuable information about the risks associated with a maternal BMI >50 and will support maternity services to structure more effectively the care they provide for women with extreme obesity.

The Confidential Enquiry into Maternal and Child Health (CEMACH) commenced a national Obesity in Pregnancy project in 2008 that will run until 2010. This project was initiated in response to a number of factors, including: (1) growing evidence that obesity is clearly associated with increased morbidity and mortality for both mother and baby; (2) national and regional prevalence rates are currently unknown; and (3) there is no national clinical guideline available in the UK with regard to clinical care and provision of services for women with obesity in pregnancy. The project comprises three phases, as shown in Box 1.

Box 1 Phases of the CEMACH Obesity in Pregnancy Project

Phase 1 – A national survey investigating how well maternity units are equipped to care for women with obesity

Phase 2 – The development of national standards of care based on evidence and consensus expert opinion

Phase 3 – A national audit of care provided women with a BMI $\geq$35

The CEMACH project will assess current service provision for women with obesity in pregnancy, provide national and regional prevalence rates of severe obesity (BMI $\geq$35) in pregnancy in the UK, and identify any gaps that may exist in the provision of care for these women. Recommendations based on the project's findings will be made available to health-care providers, commissioners and policy makers, with the aim of improving care and service provision for women with obesity in pregnancy.

Further research on the risks associated with maternal obesity is planned at the Tommy's Centre for Maternal and Fetal Health Research in Edinburgh, which is currently being established.[83] An antenatal clinic has been set up to provide a research base for mothers with obesity. The clinic aims to improve the pregnancy outcomes of these women using an approach of clinical assessment, communication and consultation with other specialists involved in their care throughout pregnancy and prior to delivery.

AREAS FOR FUTURE RESEARCH

The current available evidence supports the development of specific management strategies to decrease maternal and fetal risks in pregnancies complicated by maternal obesity. However, ongoing research in specific areas is required. The RCOG 53rd Study Group on Obesity and Reproductive Health reported that while there is a good body of observational evidence showing a positive association between maternal BMI and risk of pregnancy-related complications, there is now a clear need for prospective randomized studies in obese pregnant women to assess the effects of diet, physical activity and lifestyle changes on maternal, fetal and neonatal outcomes.[84] The group also highlighted a need for further clarification on optimal weight gain in pregnancy for different subsets of the population, with the recognition that weight gain is partly dependent upon maternal BMI at the start of pregnancy. Other potential areas identified for future research included: optimal methods of assessing body fat in women; determination of the optimal gestation of screening obese women for gestational diabetes and whether early detection and management improves outcomes; and investigation of the clinical benefit of low-dose aspirin during pregnancy for women with severe obesity.

CONCLUSIONS

Obesity is a major risk factor for pregnancy complications and carries with it huge social and financial costs. There is a clear need to establish national and regional prevalence rates of maternal obesity so that maternity services can be appropriately organized to ensure suitable care is provided for 'at-risk' women. National Clinical Care Guidelines for health professionals are needed to minimize and manage the risks associated with obesity in pregnancy. Although further research is required, there now appears to be sufficient evidence for maternity services to implement strategies to reduce the risks related to pregnancies in women with obesity. National consensus standards of care are now being developed and will soon be available to guide clinical management.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTORSHIP

All authors contributed to the conception and design of this paper, the acquisition and interpretation of the data presented and drafting and revising it critically for important intellectual content and for final approval.

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