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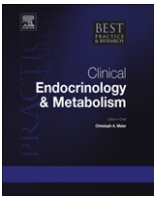

The maternal and fetal impacts of obesity and gestational diabetes on pregnancy outcome

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Obesity has reached pandemic proportions and is of growing concern worldwide. Adverse health outcomes associated with a raised body mass index present the greatest challenge currently facing clinicians across all disciplines.

Obesity is a chronic illness which is associated with metabolic disease, nutritional deficiency, musculoskeletal complications and cancer. These obesity-related health issues extend to pregnancy where they are responsible for producing a variety of medical and obstetric complications resulting in an increased incidence of maternal and fetal adverse outcomes.

Management of diet, gestational diabetes and gestational and inter-gestational weight may improve outcomes in women who are obese during pregnancy. Specific recommendations for the management of obesity in pregnancy have recently been published.

Obesity… why worry?

There is no doubt that obesity (defined as body mass index (BMI) $> 30\ kg/m^2$) is an increasing problem and presents one of the greatest challenges to the practicing clinician, across all disciplines. The incidence of obesity, a modifiable risk factor for metabolic and cardiovascular disease, has increased to pandemic proportions over the past 20 years. In 2005, the World Health Organization

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(WHO) estimated that approximately 1.7 billion adults worldwide were overweight (BMI > 25 kg/m^2) and 400 million obese with a projected increase to 700 million by 2015.[1,2] Alarmingly, 10% of the world's children, under the age of 15 years are obese. In the United States the rate of childhood obesity has stabilized at 17% since 1999, having tripled in the period prior to this from 1980.[3] The problem of obesity has more recently become apparent in the developing world where its incidence has also tripled over the past 20 years. Figures from developed countries estimate that between 24 and 35% of the general adult population are obese, with a further 40% overweight.[1,4] It is interesting that adults of normal BMI are now in the minority, and that the prevalence of obesity in adult women is greater than that in men.

Concern relating to the obesity pandemic is far greater than a cosmetic consideration. This paradoxical condition of chronic, overfed malnutrition is associated with a plethora of medical complications. The association between obesity and the metabolic syndrome/type 2 diabetes mellitus is well established.[5] We also know that the incidence of malignancy, musculoskeletal disorders and chronic respiratory disease are raised in obesity, and as a consequence of associated medical complications death by the age of 50 is increased two to threefold in those who are obese in middle age.[6]

Raised BMI and pregnancy

The increasing prevalence of obesity amongst females of reproductive age is of particular concern with epidemiological data describing an overall incidence of 32.4% in the United States. In women of reproductive age, the prevalence of grade I (BMI 30–34.9 kg/m^2) and grade II (BMI 35–39.9 kg/m^2) obesity has doubled since 1979 and that of grade III (BMI > 40 kg/m^2) obesity has increased threefold over the same period.[1] Data from the Pregnancy Risk Assessment Monitoring System (PRAMS database) shows a pre-pregnancy incidence of obesity in the United States of 20%, which represents an overall increase of 70% over a ten-year period.[7]

At the time of presentation for a booking obstetric visit, 21% of Irish women are obese and 37% overweight (Fig. 1).[8] In 2005, the prevalence of obesity in pregnant women in the United Kingdom at their booking visit was between 16 and 19%.[9] The impact of obesity on pregnancy outcome and parturition is now considered a primary obstetric issue. Numerous studies have shown that a raised pre-pregnancy BMI is associated with a linear increase in adverse maternal and fetal outcomes. Adverse pregnancy outcome in obese mothers is attributed predominantly to impaired glucose

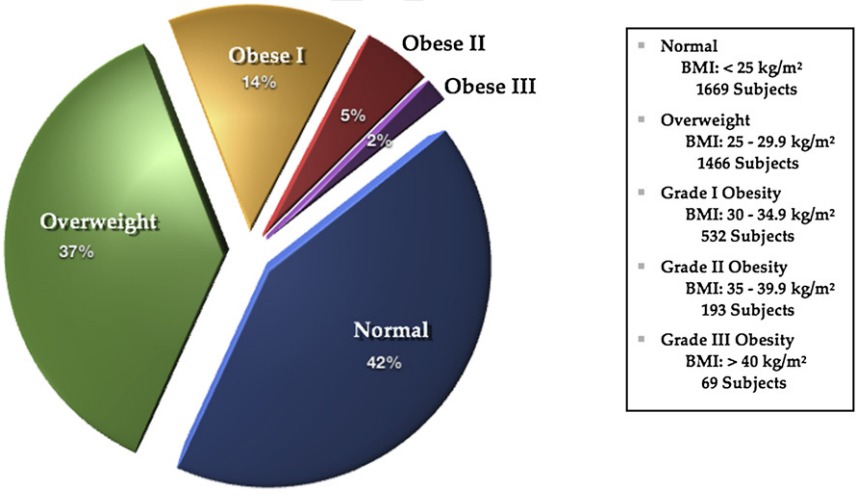

Fig. 1. Body mass index (BMI) measurements in an Irish obstetric population. Measurement of weight and height was taken at booking obstetric visit, prior to 28 weeks gestation. Data from ATLANTIC-DIP prospective observational study.

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homeostasis and unhealthy metabolic status, a mechanism which may also account for the poor outcomes seen in obese and overweight mothers described as "glucose tolerant" when current criteria for the diagnosis of gestational diabetes are used.[10–12]

In this review, we will examine the prevalence, risks and potential mechanisms of short-term and long-term outcomes observed in relation to raised pre-pregnancy BMI and gestational weight gain. We will also discuss the effect of pre-pregnancy care, weight loss and bariatric surgery on these outcomes.

Adverse pregnancy outcome

A raised maternal BMI is associated with greater frequency of complications of pregnancy for both mother and fetus during gestation, parturition and in the immediate postpartum period (Table 1). The majority of studies investigating maternal and neonatal outcomes in obesity have included obese mothers who have gestational diabetes but studies from Ireland and Denmark confirm that obesity is an independent risk factor for adverse pregnancy outcome in glucose tolerant women.[12–15]

Adverse maternal outcomes

When compared with women with a normal BMI, obese mothers have a greater risk of medical diseases during pregnancy.[16] The risk of mothers entering pregnancy with established type 2 diabetes mellitus increases linearly with increasing BMI.[17] Raised pre-pregnancy BMI also produces an additional threefold risk of developing gestational diabetes (GDM).[18,19] Hypertensive disease of pregnancy, including pre-eclamptic toxaemia (PET) occurs in obesity with a frequency two to four times that of mothers with healthy BMI.[20] The association between PET and raised BMI occurs independently of gestational diabetes, and demonstrates a linear rise in risk with increasing BMI, from a doubling of risk in overweight mothers to a fourfold increase in those categorized as grade III obesoty.[8,13] Mechanical complications associated with pregnancy such as pelvic pain and lower back pain are reported more frequently in overweight and obese women during pregnancy.[21] Not only do these women have to bear the burden of the expanding gravid uterus, but also the increased tissue mass of obesity, which of itself

Table 1
Meta-analysis (Heslehurst et al.; Stothard et al.) summary for adverse maternal and fetal pregnancy outcomes in obese and overweight women. Figures expressed as adjusted odds ratios (aOR) with 95% confidence intervals (95% CI). Number of studies analyzed expressed as $n = x$.

Outcome	Overweight versus Healthy BMI aOR (95% CI)	Obese versus Healthy BMI aOR (95% CI)
Delivery		
Total Caesarean	1.483 (1.390–1.581); $n = 14$	2.005 (1.872–2.148); $n = 16$
Elective Caesarean	§	1.240 (0.899–1.710); $n = 3$
Emergency Caesarean	§	1.629 (1.396–1.893); $n = 6$
Failure to Progress	§	2.306 (1.871–2.842); $n = 4$
Birthweight		
SGA	0.933 (0.89–0.978); $n = 14$	0.841 (0.782–0.905); $n = 19$
LGA	1.308 (1.215–1.407); $n = 8$	2.357 (2.293–2.422); $n = 15$
Maternal Outcome		
Haemorrhage	1.420 (1.095–1.842); $n = 3$	1.202 (1.163–1.243); $n = 4$
Infection	§	3.335 (2.738–4.062); $n = 6$
Fetal Outcome		
Neonatal ITU Admission	1.121 (0.979–1.283); $n = 3$	1.377 (1.157–1.639); $n = 4$
Fetal Compromise	2.062 (1.439–2.955); $n = 4$	1.623 (1.545–1.705); $n = 5$
Meconium	§	1.570 (1.422–1.732); $n = 5$
Congenital Abnormality		
Neural Tube Defect	1.20 (1.04–1.38); $n = 8$	1.87 (1.62–2.15); $n = 9$
Cardiovascular Anomaly	1.17 (1.03–1.34); $n = 6$	1.30 (1.12–1.51); $n = 7$
Orofacial Cleft	1.00 (0.87–1.15); $n = 3$	1.20 (1.09–1.40); $n = 3$
Anorectal Atresia	1.19 (0.91–1.71); $n = 1$	1.48 (1.12–1.97); n = 1

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also expands throughout gestation. The combination of these factors contributes to reduced mobility in the overweight and obese cohort during pregnancy and consequently to the risk of developing venous thromboembolism (VTE). Overall, there is a fivefold increase of antenatal venous thrombosis and a doubling of the risk of pulmonary thromboembolism antenatally in women with a BMI $\geq$ 30 kg/m^2 when compared to those with BMI $<$ 25 kg/m^2.[22] Reduced mobility, because of the mechanical complication of pregnancy, increases this risk dramatically. One large case control study described an adjusted odds ratio (aOR) of 62.3 for antenatal venous thromboembolism (VTE) and 40.1 for post-natal VTE in women with BMI $>$ 25 kg/m^2 who were immobilized during pregnancy when compared to women of normal BMI who remained mobile throughout.[23] The impact of obesity on the peripartum period is also important, with a high rate of intrapartum complications. While maternal obesity is not currently an indication for labour induction, obese women are more likely to have induction of labour when compared to their normal BMI counterparts. Labour induction in obesity requires higher oxytocin and prostaglandin doses, failure of progression is more common and the requirement for delivery intervention increases.[24] Trends from the published literature consistently show higher caesarean section rates with increasing BMI.[13,18,25,26] In our population of glucose tolerant women, the aOR for elective caesarean section was 1.7 in overweight mothers and 4.4 in women with grade III obesity when compared to mothers with normal BMI. A similar trend was seen for emergency caesarean section, the aOR rising from 1.4 to 3.5 across the range of BMI categories from overweight to grade III obesity. This progression to emergency caesarean section may be partially explained by the fewer successful instrumental deliveries observed in mothers with raised BMI (aOR 0.66).[8,13] In those proceeding to delivery by caesarean section, obesity carries a risk of failed regional anaesthesia, inadequate analgesia, difficulty with intravenous access and requirement for general anaesthetia, which is in turn complicated by obesity-related difficulty with intubation.[25,27] Operative wounds following caesarean sections are also more likely to get infected and break down, leading to specific recommendations for subcutaneous suturing and antibiotic prophylaxis. Puerperal infections of the respiratory and urinary tract are also more likely with raised BMI.[25] There is also compelling evidence demonstrating increased risk of antepartum and postpartum haemorrhage in obese mothers, which can be reduced with active management of the third stage of labour.[26] A particularly worrying report describes maternal obesity as the greatest risk factor for maternal mortality in the developed world, the recent United Kingdom Confidential Enquiry into Maternal And Child Health (CEMACH) show 50% of maternal deaths occurring in obese women and 15% in women classified as grade III obesity.[28]

Adverse fetal and neonatal outcomes

The risks to the fetus associated with raised maternal BMI have been demonstrated in numerous obstetric populations and analyzed in a recent meta-analysis (Table 1).[16] There is a consistent association between raised pre-pregnancy maternal BMI and fetal macrosomia, regardless of the definition used (birthweight $>$ 4.5 kg, $>$90th percentile or $>$2SD above the mean gestational age adjusted birthweight for the reference population). Additionally, obesity during pregnancy carries the greatest risk for birth of infants large for gestational age (LGA).[29] Fetal macrosomia and LGA are surrogate risk factors for adverse pregnancy outcomes such as shoulder dystocia and fetal birth injury.[16,18,30] Immediate neonatal complications such as hypoglycaemia, hyperbilirubinaemia and respiratory distress syndrome are also associated with raised maternal BMI.[16]

Infants born to overweight and obese mothers require admission to the neonatal intensive care unit more frequently than offspring of normal weight mothers, predominantly due to a higher incidence of preterm birth, meconium aspiration and shoulder dystocia.[12,16,31] Congenital abnormalities are also described more commonly in infants of obese mothers, including neural tube defects, orofacial abnormalities, cardiac defects, limb reduction defects and intestinal tract anomalies such as anorectal atresia and omphalocele.[8,13,32] The most commonly occurring congenital anomalies are neural tube defects (aOR 1.87 obese; 1.2 overweight) followed by cardiovascular anomaly (aOR 1.30 obese; 1.17 overweight). Within these groups spina bifida (aOR 2.2 obese) and cardiac septal anomalies (aOR 1.20) were the most frequent.[32] Not surprisingly there is also an increased risk of stillbirth and perinatal death.[33]

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Long-term outcomes for mother and offspring

Postpartum and long-term maternal outcome

Obesity associated morbidities extend into the immediate postpartum period and beyond. Many obese women can expect numerous obstetric and medical challenges which affect not only their own health, but also the health of their offspring for the future. Breastfeeding is initiated and maintained with significantly poorer success both as a consequence of maternal attitude and mechanical difficulty with infant positioning.[34,35] In future pregnancies, maternal obesity is a risk factor for unsuccessful vaginal birth after caesarean (VBAC). Grade III maternal obesity carries the additional risks of neonatal injury and uterine rupture following trial of labour.[36]

The risk of developing type 2 diabetes in mothers with previous GDM is seven times that following normoglycaemic pregnancy. This risk appears to be highest in the immediate five years following pregnancy.[37,38] Independent of GDM, pre-pregnancy maternal BMI within the overweight and obese range is a risk factor for type 2 diabetes, one study showing an aOR of 2.0 and 2.6 respectively over a period of 10 years.[39] We selected a cohort from the ATLANTIC-DIP prospective observational study of pregnancy outcome in Ireland who during gestation had normal glucose tolerance, impaired glucose tolerance (IGT) or GDM and performed a 75 g oral glucose tolerance test 12 weeks postpartum. Within this cohort, 15.1% of women with abnormal glucose homeostasis (IGT/GDM) during pregnancy had persistence of dysglycaemia, compared with fewer than 1% of women who had a normoglycaemic pregnancy. Those who had GDM were at greatest risk of postpartum disorders of glucose metabolism; 10.6% demonstrated IGT or impaired fasting glucose (IFG) and 6.4% type 2 diabetes.[40] Further research is needed to investigate whether or not women who have persistence of abnormal glucose handling postpartum are in fact dysglycaemic prior to conception. This possibility further highlights the need for education, weight optimization and management of maternal metabolic status prior to conception.

Childhood obesity

The concept that obesity begets obesity is very apparent in the offspring of obese or overweight mothers. The published data correlates childhood obesity directly with maternal rather than paternal BMI.[41] We have previously addressed studies examining neonatal birthweight in relation to maternal BMI which demonstrate a positive correlation. Offspring of obese mothers whose birthweight is appropriate for gestational age have a higher proportion of body fat when compared to offspring born to lean mothers.[18,42] Even more concerning is the finding that children born to obese mothers demonstrate insulin resistance (HOMA-IR) calculated from fetal cord blood. Does this poor neonatal profile translate into a long-term effect?

The current body of evidence would overwhelmingly suggest that this is indeed the case. Higher birthweight is associated with raised BMI throughout childhood and into adulthood. Studies in the United States, the United Kingdom, Sweden and Finland have all demonstrated a doubling of the risk of childhood obesity in both boys and girls born to overweight mothers and this risk is raised fourfold in those born to obese mothers.[43,44] These studies have also shown the long-term effects of maternal obesity on offspring is apparent across a broad age range, from 2 to 18 years.[44]

The accuracy of defining raised a BMI in childhood (>95th percentile for the age-matched child) often provokes controversy, as there is variance within different age-groups, particularly during adolescence. Adiposity, assessed by anthropometric measures or dual emission X-ray absorptiometry (DXA), may more reliably measure childhood obesity.[18,42] These techniques demonstrate higher adiposity in children up to the age of 7 years and also in adults between 18 and 24 years who were born to mothers with raised BMI, and/or exposed to gestational diabetes *in utero*.[45–48]

The association between raised maternal BMI and LGA birthweight or raised neonatal adiposity implies a direct effect on the developing fetus of an adverse uterine environment during pregnancy. It is difficult however to determine whether in the long term, raised BMI and adiposity in the offspring of obese mothers occur directly due to adverse uteroplacental priming of the fetus during the obese pregnancy (*versus* inherited genetic influences), or as a result of the indirect environmental influence of an "over-fed" home.

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Mechanisms of adverse pregnancy outcome in obesity

The mechanisms underlying the adverse pregnancy outcomes in obesity, while poorly understood, are probably initiated by abnormal adipose tissue distribution secondary to excessive weight gain in women who are already obese prior to conception. This in turn, contributes to metabolic and immunologic dysfunction at a time of natural physiological aberrancy. Clinically, obesity is an umbrella term used to describe a broad conglomeration of mechanical, metabolic and inflammatory disease. The adverse pregnancy outcomes of obesity should be viewed as a domino effect, whereby poor maternal metabolic health contributes to an adverse utero-placental environment, and culminates in a plethora of complications which arise as a consequence of each other. When examining the contribution of increased maternal BMI and GDM to adverse pregnancy outcome, few studies have separated these two factors, but those that have show that raised BMI remains a risk factor for adverse maternal and fetal outcome in women who remain normoglycaemic during pregnancy.[8,12,13]

Gestational weight gain

Over the duration of a normal, healthy pregnancy maternal weight gain of approximately 12 kg has, in the past, been accepted as normal.[49] Acceptable gestational weight gain is now more appropriately calculated according to pre-pregnancy BMI.[50] Evidence from smaller cohorts suggests that management of gestational weight gain, within these guidelines, can limit adverse metabolic status during pregnancy and larger studies are ongoing (Fig. 2; Table 2). The gravid uterus accounts for half of gestational weight gain, with expansion of extracellular fluid and maternal fat deposition accounting for the remainder. From early pregnancy onwards, irrespective of pre-pregnancy adiposity or BMI, fat deposition increases. Normal gestational adipose tissue gain, approximately 4 kg, is a mechanism of physiological preconditioning, in anticipation of fetoplacental and maternal demands associated with later gestation and lactation.[44,51] In women of healthy pre-pregnancy BMI, early gestational adipose tissue gains are laid down in the subcutaneous compartments of the breast, trunk and upper thigh, and during later pregnancy a small quantity of fat is stored as visceral adipose tissue.[52,53]

Although there is conflict in published data, greater gain in gestational adiposity probably occurs in mothers who are overweight or obese prior to conception. Excess gestational fat in obese mothers is stored predominantly in the visceral compartment rather than in the subcutaneous compartments.[53,54] In the non-pregnant state, regional preference for visceral adiposity contributes to insulin resistance and metabolic complications of obesity.[55] The predisposition for gestational storage of excess visceral fat in obese and overweight mothers is likely to play a role in the pathogenesis of the homeostatic imbalance which characterizes the obese pregnancy, as visceral adiposity during pregnancy is associated with a higher risk of GDM and gestational hypertension/PET.[44,56]

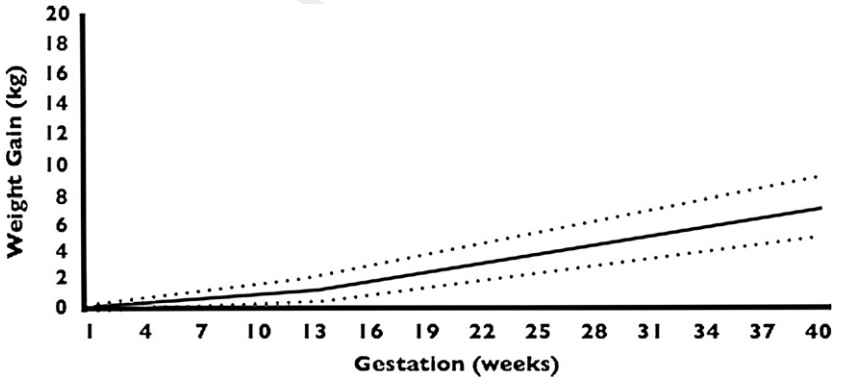

Fig. 2. Institute of Medicine recommendations for gestational weight gain in women who are obese ($\geq$30 kg/m^2) pre-pregnancy.

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Table 2
Recommended weight gain during pregnancy according to pre-gestational BMI.

Pre-Gestational BMI (kg/m^2)	Total Weight Gain Range (kg)	Weight Gain in 2nd and 3rd Trimesters (Mean: kg/week)
Underweight (<18.5)	12.5–18.0	0.51
Healthy BMI (18.5–24.9)	11.5–16.0	0.42
Overweight (25.0–29.9)	7–11.5	0.28
Obese (≥30)	5–9	0.22

The effect of gestational weight gain for women with normal pre-pregnancy BMI, as a contributor to adverse outcomes, including GDM and pre-eclampsia, remains to be proven. Pre-pregnancy raised BMI is a more reliable predictor of poor pregnancy outcome and adverse effects of gestational weight gain in this setting. Visceral gains in adiposity probably reflect adverse fetal and maternal pregnancy outcomes rather than absolute increase in BMI *per se*. The influence of pre-gestational BMI as a factor of gestational weight gain on pregnancy outcomes is shown in a Swedish study of 151,000 women, which demonstrated that gestational BMI increases >3 kg/m^2 in primiparous women were associated with weight retention in the puerperium, independent of pre-pregnancy BMI, and that weight retention was associated with adverse maternal and neonatal outcomes in the second pregnancy of these women.[57]

Maternal metabolism during pregnancy

During healthy pregnancy, maternal metabolism and glucose homeostasis are in a state of dynamic change depending on the trimester. Early pregnancy induces an increase in insulin sensitivity and significant reductions in fasting glucose concentrations. With advancing gestation, fasting and post-prandial glucose concentrations increase and the post-prandial peak of glucose is prolonged. By the third trimester of normal pregnancy, insulin sensitivity has fallen to 50–70% that of pre-pregnancy values. Consequently, the insulin response to oral carbohydrate is elevated and basal insulin production increases, producing an overall 2–3-fold rise in mean insulin concentrations over any 24 h period.[58,59] The naturally insulin resistant state of late pregnancy provides an adaptive mechanism, supplying sufficient fuel to support the placenta and fetal development. A state of normal insulin sensitivity is restored in the immediate puerperium.

Normal, healthy pregnancy also produces a natural state of increased lipid turnover. Basal oxidation of fatty acids increases by approximately 70% during pregnancy and results in relative hyperlipidaemia, when compared with the pre-pregnant state. Serum concentrations of very low density lipoprotein (VLDL) and triglyceride increase threefold in the second and third trimesters. This is accompanied by an initial small reduction in the calculated low density lipoprotein (LDL) which is followed by a continuous rise, throughout the later trimesters. High density lipoprotein (HDL) steadily increases through to the 24th week of pregnancy, declines thereafter until the 32nd week and remains unchanged at this concentration until the postpartum period.[44]

Obesity induces a state of insulin resistance, independent of pregnancy. During gestation, insulin resistance in overweight and obese women is further exaggerated and often falls to 40% that of normal pre-pregnancy values. This profound insulin resistance produces a pathological response, resulting in maternal hyperinsulinaemia, hyperglycaemia and gestational diabetes mellitus.[58–60] Exaggerated hyperlipidaemia also occurs during obese pregnancy. VLDL concentrations are increased compared with normal pregnancy and the appearance and oxidation of small LDL particles is characteristic. Abnormal lipid metabolism during pregnancy in obese mothers indicates endothelial dysfunction which is likely to contribute to vascular complications, including pre-eclampsia.[44,61]

Gestational diabetes mellitus and impaired glucose tolerance

Gestational diabetes (GDM), defined as any degree of glucose intolerance with onset or first recognition during pregnancy, occurs in 7% of all pregnancies in the United States.[62,63] Raised maternal BMI is an established risk factor for gestational diabetes. This is not surprising, given the association

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between raised BMI and both type 2 diabetes and the metabolic syndrome. Compared with lean women, obese mothers carry a fourfold increased risk of developing GDM. Obesity of grade III and above raises this risk to ninefold.[26,64] Clearly, there is a linear association between the incidence of gestational diabetes and BMI. It is estimated that in the absence of obesity, the prevalence of gestational diabetes would fall by approximately 50%.

While many studies have described gestational diabetes as an independent risk factor for adverse maternal and fetal outcome it has not often been investigated independently of raised BMI. Poor maternal and fetal outcomes are not exclusively seen in obese and overweight women with gestational diabetes or impaired glucose tolerance, but also in pregnant women with raised BMI, who have satisfied current criteria for normoglycaemia following a 75 g oral glucose tolerance test (OGTT).[12,13] Obesity, dysregulated metabolism and insulin resistance are inextricably linked in both the pregnant and non-pregnant states. The association of raised BMI with adverse pregnancy outcome is at least partially linked to hyperinsulinaemia, abnormal lipid turnover and an adverse maternal metabolic milieu. The greater prevalence of poor gestational outcomes in pregnant women of apparently "normal" glucose tolerance, who have a BMI raised above the normal reference range, has resulted in recent recommendations advising a lowering in the current diagnostic thresholds for gestational diabetes mellitus and impaired glucose tolerance during pregnancy (Table 3).[11,65]

The Pedersen Hypothesis proposes fetal hyperglycaemia and overnutrition as a mechanism underlying adverse fetal outcome in the setting of poorly controlled maternal diabetes mellitus. Excessive transfer of carbohydrate across the placenta would induce relative fetal hyperglycaemia and compensatory fetal hyperinsulinaemia. Fetal hyperinsulinaemia is now known to produce a twofold effect to cause macrosomia; the metabolic effects of insulin on its putative receptor increases fat and glycogen deposition, and additionally excess insulin acts on the insulin-like growth factor (IGF) receptors to directly stimulate fetal growth. In addition to macrosomia, compensatory fetal hyperinsulinaemia increases the risk of neonatal hypoglycaemia.[30]

Chronic inflammation

Activation of various pro-inflammatory elements of the immune system is reflected by raised serum markers of inflammation in the obese population. Numerous studies show increased circulating pro-inflammatory cytokines.[5,66–68] Additionally, the non-specific marker of inflammation, C-reactive protein (CRP) is raised and the anti-inflammatory adipokine, adiponectin, reduced. These serum markers of inflammation are associated with a poor metabolic profile, type 2 diabetes and gestational diabetes.[15,69,70] Chronic inflammation in obesity probably occurs secondary to excessive deposition of visceral fat rather than subcutaneous fat which is greater during pregnancy in women who are obese prior to conception.[71]

Table 3
Updated recommendations, based on HAPO study findings, for the diagnosis of gestational and type 2 diabetes during pregnancy (see reference[11] for details).

Diagnostic Criteria	
Screening – Booking Obstetric Visit	Fasting Plasma Glucose < 7.0 mmol/L HbA1c $> 6.5\%$
Diagnostic Test	75 g OGTT @ 24–28 weeks gestation
Thresholds	
Fasting Plasma Glucose	$>$ 5.1 mmol/L
1 Hour Plasma Glucose	$>$ 10.0 mmol/L
2 Hour Plasma Glucose	$>$ 8.5 mmol/L
GDM Diagnosis	Single value above recommended threshold
Impaired Fating Glucose	Diagnosis eliminated
Identification of Overt Diabetes	HbA1c $\geq 6.5\%$ at any time in pregnancy. Fasting Plasma Glucose ≥ 7.0 mmol/L. at booking visit Random Plasma Glucose ≥ 11.1 mmol/L at any time during pregnancy if reconfirmed by fasting plasma glucose or HbA1C

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The aetiology of chronic inflammation in obesity remains poorly understood. A raised macrophage population of pro-inflammatory potential (M1 polarized) is observed in both omental and subcutaneous adipose tissue. The proportion of pro-inflammatory adipose tissue macrophages (ATM) in both subcutaneous tissue and omentum tissue correlates with insulin resistance. These macrophages surround and engulf elements of apoptotic adipocytes and consequently contain high quantities of intracellular fat.[72,73]

During pregnancy, serum markers of inflammation are raised in overweight and obese women.[74] Placental tissue examined postpartum from obese mothers also has a higher macrophage population and greater concentrations of pro-inflammatory cytokines.[75] Therefore, the chronic inflammatory process associated with obesity extends to the placenta during pregnancy, with recently described direct, adverse fetal effects.[76]

Many of the adverse pregnancy outcomes linked with maternal obesity have independent associations with chronic inflammation. The relationship between insulin resistance, abnormal glucose homeostasis and chronic inflammation is well established. Compensatory increases in endogenous cortisol release as a stress response to inflammation produces insulin resistance via the glucocorticoid receptor. Direct inflammatory activation will block the insulin signaling pathway resulting in insulin resistance and abnormal glucose homeostasis.[77,78] PET, VTE, preterm labour and respiratory distress syndrome are all associated with raised markers of inflammation both in maternal serum and placental tissue, independently of BMI.[74]

The contribution of chronic inflammation to the pathogenesis of obesity-related adverse pregnancy outcome is a developing area of research interest, and presents an exciting therapeutic target area. Pregnancy always presents the additional challenge of protecting both mother and fetus from the adverse effects both the disorder and the therapy.

Lipid turnover

Lipid turnover and circulating concentrations of lipoproteins are altered to the detriment of the maternal metabolic profile during obese pregnancy. Dysregulated lipid turnover and abnormal fatty acid flux can act independently in contributing to the chronic pro-inflammatory profile of obesity.[72] Elements of the intracellular inflammatory signalling pathway are stimulated directly by raised intracellular concentrations of saturated fatty acids. Upstream along this pathway, abnormal circulating concentrations of saturated fatty acids also bind and activate immune pattern recognition receptors (toll-like receptors), for which bacterial lipopolysaccharide (LPS) is the usual ligand (see Herrera chapter).[77,79,80]

Vitamin D and folate

Serum concentrations of vitamin D are lower in obese and overweight individuals, when compared with their lean counterparts. The prevalence of vitamin D deficiency (52–72 nmol/L) is estimated at twice that of the geographically matched population. It follows, therefore, that obese mothers are at greater risk of vitamin D deficiency when compared to pregnant women of normal BMI. Cord blood from babies born to obese mothers also has a lower mean vitamin D concentration compared to those born of women with normal BMI.[81–83]

Several mechanisms of vitamin D deficiency in obesity are proposed. Dietary deficiency of vitamin D is common and while the diet in obesity is of high calorific value, it has relatively poor nutritional benefit.[5,81] Ironically, obesity may be viewed as a state of overfed malnutrition as a consequence of poor dietary and lifestyle habits. Dietary deficiency of obese or "formerly obese" individuals may occur following gastric bypass or gastric sleeve resection bariatric surgery.[84,85] Vitamin D conversion to 25-hydroxy-vitamin D in the skin is also reduced in obese individuals due to decreased skin exposure to the sun. Vitamin D is a fat soluble vitamin which preferentially deposits in adipose tissue. Once deposited in adipocytes however, it is sequestered and by virtue of a chronic state of irreversible storage and zero bioavailability this fraction becomes functionally useless.[81]

Vitamin D deficiency in pregnancy has been associated with pre-eclampsia, insulin resistance and gestational diabetes mellitus, although cause and effect has not been established. During pregnancy,

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the developing fetus is dependent on maternal skin exposure for activation of vitamin D and therefore, maternal vitamin D deficiency extends to the fetus. There is consequently significant scientific evidence to support the requirement for maternal vitamin D sufficiency in pregnancy for normal development of the fetal brain and skeleton (see chapter by McElduff).[86]

Dietary folate deficiency is also common in women of BMI $\geq$ 27 kg/m^2. Folate deficiency in the general pregnant population is associated with an increased risk for fetal neural tube defect, and this risk is reduced by the use of pre-conceptual folate. Therefore, it is hardly surprising that the prevalence of neonatal neural tube defects is raised in obesity, given the likelihood of folate deficiency.[87,88]

Management of obesity in pregnancy and between pregnancies

The impact of maternal obesity and gestational diabetes extends to the need for greater monitoring and specialist input during the management of pregnancy and labour. The Royal College of Obstetricians and Gynaecologists (RCOG) and the United Kingdom Centre for Maternal and Child Enquiries (CMACE) have published a joint guideline on management of women with obesity in pregnancy.[89,90] A further guideline is currently in progress by the National Institute for Clinical Excellence (NICE). These guidelines place raised maternal BMI as the greatest single risk factor contributing to maternal death and adverse maternal outcome of pregnancy.

Ideally, management of obesity in pregnancy starts with pre-pregnancy care and weight loss. Education and awareness is essential for all women of child-bearing age regarding the risk of adverse outcome associated with obesity in pregnancy. Availability of weight management services to provide advice on weight optimization prior to conception is recommended. While the provision of these services is often limited by lack of funding and resources, recent obesity awareness media campaigns emphasize obesity-related health risks, which may help to improve our ability to address pre-pregnancy weight management in the future, particularly in nulliparous women considering their first pregnancy. Education of already expectant mothers at booking obstetric visit and immediately postnatally should emphasize the need to optimize weight prior to further pregnancy. Following calculation of BMI at booking visit, those $\geq$27 kg/m^2 will enter into an education programme emphasizing the risks of obesity in pregnancy.[90]

Management of obesity in pregnancy predominantly involves risk factor modification and planning of delivery, in an effort to improve maternal and fetal outcomes. Weight loss during pregnancy is not recommended but preventing excessive gestational weight gain may have benefit in terms of reducing primary adverse outcomes such as GDM.[84] Dietary advice and lifestyle modification during pregnancy is aimed at stressing the importance of healthy diet. The major challenge in preventing excessive gestational weight gain is that of over-education of the mother, leading to inappropriate caloric restriction. While prevention of inappropriate gestational weight gain is desirable, this must be balanced with the provision of sufficient bioavailable calories to nourish the fetus and avoid ketonaemia with potential negative neurocognitive fetal impact. Numerous small studies have examined the introduction of low glycaemic index (GI) and high fibre diets with moderate exercise in pregnancy to minimize weight gain and prevent GDM in “at risk” individuals. The results have consistently been promising, showing reductions in the rates of LGA birth and gestational diabetes.[91–93] However, data is available only in cohorts of fewer than 50 patients and sufficient data to recommend introduction of these measures on a larger scale is lacking.[44]

Vitamin supplementation in overweight and obese pregnancy merits special consideration. In an effort to reduce the risk of neural tube defects and skeletal abnormality, supplementation with higher doses of folate (5 mg) and vitamin D (10 μg) should be undertaken pre-pregnancy or in early pregnancy in women of BMI $\geq$ 27 kg/m^2.[90] Recommendations in some European countries extend vitamin D supplementation to the postpartum period, suggesting that supplementation should be commenced in children for the first year of life. Rapid growth and development at this age promotes susceptibility to bone deformities associated with rickets. Children of obese mothers may have insufficient stores of vitamin D, to meet their needs, but the choice of appropriate pharmaceutical preparations of vitamin D for use in this age group is limited (see chapter by McElduff).[94]

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The practical obstetric challenges of obese pregnancy must be addressed as early as possible. Preparation for the possibility of complicated delivery, caesarean section and difficulties associated with regional anaesthesia can be achieved by early consultation between obstetrician and anaesthetist. Thromboprophylaxis with low molecular weight heparin (LMWH) is recommended in the antenatal period for all women of BMI $\geq$ 40 kg/m^2 and in women of BMI $\geq$ 30 kg/m^2 who have two or more additional risk factors for thromboembolism. Early postpartum mobilization is also essential, and postnatal heparin should continue for six weeks postpartum.[90]

It is currently recommended that all women with a BMI greater than 30 kg/m^2 be screened for gestational diabetes mellitus between 24 and 28 weeks gestation by performing a75 g oral glucose tolerance test (OGTT).[89] There is increasing evidence to extend this recommendation to pregnant women of BMI less than 30 kg/m^2.[13] Close liaison with the diabetes service is needed to adequately manage gestational diabetes. Dietary intervention, regular capillary glucose monitoring and introduction of insulin therapy to maintain adequate glycaemic control will minimize complications such as macrosomia and shoulder dystocia.[95] Metformin may provide an alternative to insulin therapy for intensifying glycaemic control in pregnancy. Studies in which this agent has been used show satisfactory safety data and suggest additional benefit in women with polycystic ovarian syndrome (PCOS).[96,97] In obese women with gestational diabetes, further screening with OGTT should be undertaken 6 weeks postpartum. A normal OGTT in the postpartum period however is not completely reassuring as the risk of developing type 2 diabetes in the 5 years following a pregnancy complicated by GDM is almost 8 times that of euglycaemic pregnancy. Therefore, screening for cardiometabolic risk factors and type 2 diabetes should be undertaken on a yearly basis in addition to ongoing weight management and dietary advice.[90]

Regular blood pressure monitoring is undertaken in all pregnancy. Surveillance and monitoring for pre-eclampsia is now recommended in pregnant women of BMI $\geq$ 35 kg/m^2 with one additional risk factor (Table 4) in line with Pre-eclampsia Community Guidelines (PRECOG). Additionally, NICE classifies obesity as a moderate risk factor for pre-eclampsia and recommends instituting aspirin therapy (75 mg daily) at 12 weeks gestation and continuing this to the birth of the baby.[90]

Management of labour is particularly challenging in obese women during pregnancy. Current recommendations state that all mothers of BMI $\geq$ 35 kg/^{2} should give birth in a consultant led obstetric unit with appropriate neonatal services. Home birth is not an option in this cohort due to an unacceptable risk of emergency caesarean section and postpartum haemorrhage (PPH) for the mother and the increased likelihood that neonatal special care or intensive care admission is required. Upon presentation of the obese mother in labour, the midwifery and obstetric team should liaise with the anaesthetic, paediatric and if necessary the diabetes teams. Active management of the third stage of labour is recommended in these women to minimize the risk of PPH. Those proceeding to caesarean section should have suturing of the subcutaneous space and prophylactic antibiotic therapy, in light of a higher incidence of wound breakdown and infection.[90]

Interventional strategies for weight management

Regardless of culture, race, sex or gestational status, instituting successful weight management and weight loss programmes, presents a huge challenge and is met with variable results. Engaging patient adherence in undertaking major dietary and lifestyle changes is very difficult and while initial short-term benefit is seen, the published longer term results show an approximate 45% drop out rate in the first year, weight regain in the majority of patients after six months and in all patients after five years.[5] Pharmaceutical "weight loss" therapy, added to dietary and lifestyle change, has largely been poorly effective, offering an excess weight loss of less than 3 kg when compared to diet and exercise alone. The majority of these agents have in the past been amphetamine-derived and associated with unacceptable, sometimes fatal, side-effects resulting in their withdrawal.[98]

Two questions must be addressed. How then can we achieve pre-pregnancy or inter-pregnancy weight loss in obese and overweight women? Can we reverse the risks associated with adverse outcome in pregnancy associated with obesity in achieving weight loss?

Achieving pre-pregnancy and inter-pregnancy weight optimization will best be achieved by a proper education programme. Lifestyle intervention in the developed world has previously been

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achieved with apparently good success after education of potential and expectant mothers regarding the maternal and fetal risks of smoking during pregnancy.[99] Appropriate education in this regard reduced the percentage prevalence of smoking during pregnancy in the United States by 16% between 1990 and 2002. However, smoking cessation during pregnancy, while difficult, is a short-term intervention and postpartum relapse of smoking is high.[100] Weight optimization requires lifelong alteration of multiple lifestyle and dietary habits to prevent future regain of weight. The commitment required for success is therefore often difficult to meet. Furthermore, significant psychosocial barriers also often exist to instituting behavioural and lifestyle modification in obese subjects. Essentially, effective management if difficult to achieve in the primary care, should promote referral to a multidisciplinary clinical environment involving physician, bariatric surgeon, dietitian, specialist nurse, physiotherapist and psychologist.[5] The promise of pharmacological agents in weight management must also be met with caution. Currently, orlistat, a pancreatic lipase inhibitor, is the only pharmaceutical agent available for treatment of obesity in Europe. At best, with optimal combination of diet and exercise, this agent produces a mean weight loss of approximately 4–5 kg and in fact some studies have shown weight gain following its initiation.[101] Newer agents under development include various gastrointestinal neuroendocrine peptide derivatives and GLP-1 agonists, currently used in the treatment of type 2 diabetes.[98] In phase II clinical trials, GLP-1 agonists produce moderate degrees of weight loss when used at doses higher than currently used in diabetes therapy and imaging studies suggest a weight loss preference for visceral adipose tissue. The use of GLP-1 agonists as weight management agents provides the additional benefit of improved metabolic status and makes them an attractive future choice for this indication.[102] However, the authors advise two points of caution when presenting the option to initiate pharmacotherapy for weight management in obesity. "Diet drugs" may be erroneously viewed by the patient as an "easy option" for weight loss or as an alternative rather than an adjunct to lifestyle and dietary modification. Scientific data points not only to the harmful effects of high calorific intake, but also to those of the constituent elements of an unhealthy diet in contributing to the adverse milieu of obesity.[68,79,80] Therefore, the onus is on the prescriber to ensure that patient is fully aware of ongoing requirement for dietary weight management in addition to the possible facilitatory effects of pharmacotherapy, and consequently to ensure that patient expectations from pharmacotherapy are not unrealistic. Secondly, the effects of weight management drugs on the developing fetus are unknown and in the interests of safety these agents should only be prescribed in non-pregnant women of reproductive age with appropriate contraceptive advice.

The most effective way in achieving weight loss in obese subjects is bariatric surgery.[103] The three methods of surgery in current, mainstream practice are the adjustable laparoscopic gastric band (LAP banding), gastric sleeve resection and gastric bypass surgery. In non-pregnant subjects with grade II obesity and above, gastric bypass surgery is associated with sustained weight loss of 26% body weight and an improvement in metabolic parameters of hyperglycaemia, hypertriglyceridaemia and hypertension.[103–105] Patients with more moderate degrees of obesity, BMI range between 30 and 40 kg/m^2 also show significant weight loss and metabolic benefit from LAP banding.[106] Few studies have investigated the effects of weight loss following bariatric surgery on adverse pregnancy outcome. Recent evidence has shown a benefit in fetal outcomes following maternal inter-gestational weight management surgery, with lower birthweight, less fetal macrosomia and improved neonatal metabolic status.[107] However, concern has been raised regarding the appropriate time period between bariatric surgery and future pregnancy, particularly in light of post-surgical nutritional deficiencies.[85] Raised neonatal birthweight has also been associated with early gestational weight loss, a matter of concern should a woman conceive in the initial 18 months following bariatric surgery.[84]

Summary

In light of the overwhelming body of evidence available, which unquestionably points towards the adverse pregnancy outcomes of obesity and dysglycaemia in pregnancy, we have a responsibility, as physicians, to address the issue with all obese and overweight women of reproductive age. A

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culture of 'political correctness' promoting obesity as an acceptable lifestyle characteristic which is of cosmetic concern only, should be appropriately balanced by education and information reinforcing obesity as a chronic illness carrying unacceptable risks of morbidity and mortality, particularly in the setting of maternal obesity. The authors recommend that the first step in educating the general populace in this regard involves encouraging government departments of health to launch media and public awareness campaigns, similar to that undertaken to inform individuals of the hazards of cigarette smoking. Like all modifiable risk factors of disease, the best approach to obesity in pregnancy is its avoidance.

At risk women of BMI ≥ 30 kg/m^2 (or $\geq$27 kg/m^2 with manifest metabolic disease, hypertension, hyperlipidaemia or any degree of clinically apparent abnormal glucose handing) must be introduced to the clinical importance of weight management prior to gestation and cautiously advised against pregnancy until weight optimization has occurred. This is particularly relevant in those seeking fertility treatment. Screening for metabolic complications of raised BMI should be performed at least yearly by measuring blood pressure and fasting blood levels of lipids and glucose. Women who have had previous gestational diabetes mellitus must be entered into a regular screening programme, testing blood glucose at 6 weeks, 3 and 6 months postpartum and following this with yearly screening for at least five years. Careful planning of pregnancy accompanied by aggressive glycaemic and metabolic management prior to pregnancy is advised in those with a manifest adverse metabolic milieu. Metformin provides weight neutral metabolic and glycaemic control and has an acceptable safety profile during pregnancy. Therefore this is the author's first choice of anti-hyperglycaemic agent, if required for type 2 diabetes prior to conception. It is the author's opinion that treatment with GLP-1 agonists may offer a good option for glycaemic and metabolic control while also aiding weight loss in women of reproductive age, but these agents must be substituted once pregnancy is being planned and should only be given in the setting of active contraception.

The challenge of weight loss involves a long-term patient commitment to a properly designed programme of dietary intervention, lifestyle changes and exercise. A health service-led, structured weight management treatment algorithm is an ideal guide for primary care physicians, further instruction on the time of appropriate referral to the specialist weight management team. If primary care resources are insufficient to provide a structured weight management option, "at risk" women should be referred at the earliest opportunity to specialist care. Treatment within specialist should primarily centre on patient engagement to the weight loss programme and reproductive health education. Currently, no suitable pharmacotherapy for weight management is available. However, a trial of orlistat as a facilitatory agent, in the setting of a patient already losing weight is reasonable. Bariatric surgery may a reasonable option for women ≥ 40 kg/m^2, or in women of BMI ≥ 35 kg/m^2 with metabolic risk factors, meeting the pre-surgical weight loss requirements. However, the authors would caution against becoming pregnant in the initial 18 months following bariatric surgery. Women should be commenced on vitamin D and calcium supplementation following bariatric surgery.

Clinical Practice Points

- Lifestyle and dietary advice to optimize weight for all women pre-conceptually
- Early identification of pregnant women with high BMI ($\geq$27 kg/m^2) as high risk
- Early screening for gestational diabetes mellitus in pregnant women with high BMI
- Appropriate supplementation with Vitamin D and high dose folate in obese pregnancy to avoid adverse fetal outcome
- Careful obstetric planning of delivery and labour in women of BMI ≥ 30 kg/m^2
- Postpartum screening for adverse metabolic outcome in "at risk" women at 6 weeks, 12 weeks and yearly thereafter
- Appropriate contraceptive advice if using pharmacotherapy for obesity
- Post-bariatric surgery, women should wait 18 months prior to conception

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Research Points

- Larger studies required to evaluate pregnancy outcomes in women following bariatric surgery
- Larger studies to investigate effects of gestational weight gain
- Larger studies to compare pre-gestational insulin resistance with incidence of GDM and postpartum persistence of dysglycaemia
- Randomized, controlled, interventional trials are required to: evaluate the effectiveness of weight control programmes pre-gestationally and during pregnancy, and to assess benefit in terms of neonatal and maternal outcomes
- Scientific studies to further investigate the contribution of immunological dysfunction and chronic inflammation to an adverse maternal metabolic profile during pregnancy

References

1. World Health Organization. *Global database on body mass index*. Geneva: WHO, 2009.
2. World Health Organization. *Fact Sheet no. 311*. Geneva: WHO, 2006.
3. Ogden CL, Carroll MD, Curtin LR, Lamb MM & Flegal KM. Prevalence of high body mass index in US children and adolescents, 2007–2008. *JAMA: The Journal of the American Medical Association* 2010 Jan 20; **303**(3)**:** 242–249.
4. Main Report Morgan KMH, Watson D, Perry I, Barry M, Shelley E, Harrington J et al. *SLAN: survey of lifestyle attitudes and nutrition in Ireland*. Dublin: The Stationery Office, 2008.
5. Bessesen DH. Update on obesity. *Journal of Clinical Endocrinology and Metabolism* 2008 Jun 1; **93**(6)**:** 2027–2034.
6. Pischon T, Boeing H, Hoffmann K, Bergmann M, Schulze MB, Overvad K et al. General and abdominal adiposity and risk of death in Europe. *New England Journal of Medicine* 2008 Nov 13; **359**(20)**:** 2105–2120.
7. Huda SS, Brodie LE & Sattar N. Obesity in pregnancy: prevalence and metabolic consequences. *Seminars in Fetal and Neonatal Medicine* 2009 Nov 3**:** 1–7.
8. Dennedy MC, Avalos G, O'Reilly M.W., O'Sullivan E.S., Gaffney G, Dunne F. ATLANTIC-DIP: raised BMI confers adverse fetal and maternal pregnancy outcome in a normoglycaemic cohort of Irish women. 2010. Unpublished data.
9. Heslehurst N, Lang R, Rankin J, Wilkinson JR & Summerbell CD. Obesity in pregnancy: a study of the impact of maternal obesity on NHS maternity services. *BJOG: An International Journal of Obstetrics and Gynaecology* 2007 Mar; **114**(3)**:** 334–342.
10. HAPO Study Group. Hyperglycemia and Adverse Pregnancy Outcome (HAPO) Study: associations with neonatal anthropometrics. *Diabetes* 2009 Feb 1; **58**(2)**:** 453–459.
11. International Association of Diabetes and Pregnancy Study Groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy. Diabetes Care. Mar;33(3):676–682.
12. Jensen DM, Damm P, Sorensen B, Molsted-Pedersen L, Westergaard JG, Ovesen P et al. Pregnancy outcome and prepregnancy body mass index in 2459 glucose-tolerant Danish women. *American Journal of Obstetrics and Gynecology* 2003 Jul; **189**(1)**:** 239–244.
13. Owens LA, O'Sullivan EP, Kirwan B, Avalos G, Gaffney G, Dunne F. Atlantic Dip: the impact of obesity on pregnancy outcome in glucose-tolerant women. Diabetes Care. Mar;33(3):577–579.
14. Nohr EA, Timpson NJ, Andersen CS, Davey Smith G, Olsen J & Sørensen TIA. Severe obesity in young women and reproductive health: the Danish National Birth Cohort. *PLoS ONE* 2009 Jan 1; **4**(12)**:** e8444.
15. Metzger BE, Lowe LP, Dyer AR, Trimble ER, Chaovarindr U, Coustan DR et al. Hyperglycemia and adverse pregnancy outcomes. *New England Journal of Medicine* 2008 May 8; **358**(19)**:** 1991–2002.
16. Heslehurst N, Simpson H, Ells LJ, Rankin J, Wilkinson J, Lang R et al. The impact of maternal BMI status on pregnancy outcomes with immediate short-term obstetric resource implications: a meta-analysis. *Obesity Reviews* 2008 Nov; **9**(6)**:** 635–683.
17. Cundy T, Gamble G, Townend K, Henley PG, MacPherson P & Roberts AB. Perinatal mortality in Type 2 diabetes mellitus. *Diabetic Medicine* 2000 Jan; **17**(1)**:** 33–39.
18. Catalano PM & Ehrenberg HM. The short- and long-term implications of maternal obesity on the mother and her offspring. *BJOG: An International Journal of Obstetrics and Gynaecology* 2006 Oct 1; **113**(10)**:** 1126–1133.
19. Ehrenberg HM, Dierker L, Milluzzi C & Mercer BM. Prevalence of maternal obesity in an urban center. *American Journal of Obstetrics and Gynecology* 2002 Nov; **187**(5)**:** 1189–1193.
20. O'Brien TE, Ray JG & Chan WS. Maternal body mass index and the risk of preeclampsia: a systematic overview. *Epidemiology* 2003 May; **14**(3)**:** 368–374.
21. Jarvie E & Ramsay JE. Obstetric management of obesity in pregnancy. *Seminars in Fetal and Neonatal Medicine* 2010 Feb 10**:** 1–6.
22. Larsen TB, Sorensen HT, Gislum M & Johnsen SP. Maternal smoking, obesity, and risk of venous thromboembolism during pregnancy and the puerperium: a population-based nested case-control study. *Thrombosis Research* 2007; **120**(4)**:** 505–509.
23. Jacobsen AF, Skjeldestad FE & Sandset PM. Ante- and postnatal risk factors of venous thrombosis: a hospital-based case-control study. *Journal of Thrombosis Haemostasis* 2008 Jun; **6**(6)**:** 905–912.
24. Pevzner L, Powers BL, Rayburn WF, Rumney P & Wing DA. Effects of maternal obesity on duration and outcomes of prostaglandin cervical ripening and labor induction. *Obstetrics and Gynecology* 2009 Dec; **114**(6)**:** 1315–1321.

Please cite this article in press as: Dennedy MC, Dunne F, The maternal and fetal impacts of obesity and gestational diabetes on pregnancy outcome, Best Practice & Research Clinical Endocrinology & Metabolism (2010), doi:10.1016/j.beem.2010.06.001

25. Weiss JL, Malone FD, Emig D, Ball RH, Nyberg DA, Comstock CH et al. Obesity, obstetric complications and cesarean delivery rate – a population-based screening study. *American Journal of Obstetrics and Gynecology* 2004 Apr; **190**(4)**:** 1091–1097.
26. Sebire NJ, Jolly M, Harris JP, Wadsworth J, Joffe M, Beard RW et al. Maternal obesity and pregnancy outcome: a study of 287,213 pregnancies in London. *International Journal of Obesity and Related Metabolic Disorders* 2001 Aug; **25**(8)**:** 1175–1182.
27. Saravanakumar K, Rao SG & Cooper GM. The challenges of obesity and obstetric anaesthesia. *Current Opinion in Obstetrics & Gynecology* 2006 Dec; **18**(6)**:** 631–635.
28. C.E.M.A.C.H.. *Saving mother's lives: reviewing maternal deaths to make motherhood safer. 2003–2005*. London: RCOG, 2006.
29. Ananth CV & Wen SW. Trends in fetal growth among singleton gestations in the United States and Canada, 1985 through 1998. *Seminars in Perinatology* 2002 Aug; **26**(4)**:** 260–267.
30. Pedersen J. Diabetes and pregnancy: blood sugar of newborn infants. PhD thesis. Copenhagen: Copenhagen; 1972.
31. Dempsey JC, Ashiny Z, Qiu CF, Miller RS, Sorensen TK & Williams MA. Maternal pre-pregnancy overweight status and obesity as risk factors for cesarean delivery. *Journal of Maternal Fetal and Neonatal Medicine* 2005 Mar; **17**(3)**:** 179–185.
32. Stothard KJ, Tennant PW, Bell R & Rankin J. Maternal overweight and obesity and the risk of congenital anomalies: a systematic review and meta-analysis. *JAMA: The Journal of the American Medical Association.* 2009 Feb 11; **301**(6)**:** 636–650.
33. Chen A, Feresu SA, Fernandez C & Rogan WJ. Maternal obesity and the risk of infant death in the United States. *Epidemiology* 2009 Jan; **20**(1)**:** 74–81.
34. Amir LH & Donath S. A systematic review of maternal obesity and breastfeeding intention, initiation and duration. *BMC Pregnancy and Childbirth* 2007; **7:** 9.
35. Mok E, Multon C, Piguel L, Barroso E, Goua V, Christin P et al. Decreased full breastfeeding, altered practices, perceptions, and infant weight change of prepregnant obese women: a need for extra support. *Pediatrics* 2008 May; **121** (5)**:** e1319–e1324.
36. Hibbard JU, Gilbert S, Landon MB, Hauth JC, Leveno KJ, Spong CY et al. Trial of labor or repeat cesarean delivery in women with morbid obesity and previous cesarean delivery. *Obstetrics and Gynecology* 2006 Jul; **108**(1)**:** 125–133.
37. Bellamy L, Casas JP, Hingorani AD & Williams D. Type 2 diabetes mellitus after gestational diabetes: a systematic review and meta-analysis. *Lancet* 2009 May 23; **373**(9677)**:** 1773–1779.
38. Kim C, Newton KM & Knopp RH. Gestational diabetes and the incidence of type 2 diabetes: a systematic review. *Diabetes Care* 2002 Oct; **25**(10)**:** 1862–1868. **Q3**
39. Lauenborg J, Hansen T, Jensen DM, Vestergaard H, Molsted-Pedersen L, Hornnes P et al. Increasing incidence of diabetes after gestational diabetes: a long-term follow-up in a Danish population. *Diabetes Care* 2004 May; **27**(5)**:** 1194–1199.
40. O'Reilly MW, Avalos G, Dennedy MC, O'Sullivan EP, Gaffney G, Dunne F. ATLANTIC-DIP: Persistence of abnormal glucose tolerance in an Irish cohort with previous gestational diabetes mellitus [Prospectve Observational Study]. 2010. Unpub- **Q4** lished data.
41. Shields BM, Knight BA, Powell RJ, Hattersley AT & Wright DE. Assessing newborn body composition using principal components analysis: differences in the determinants of fat and skeletal size. *BMC Pediatrics* 2006; **6:** 24.
42. Hashimoto K, Wong WW, Thomas AJ, Uvena-Celebrezze J, Huston-Pressley L, Amini SB et al. Estimation of neonatal body composition: isotope dilution versus total-body electrical conductivity. *Biology of the Neonate* 2002; **81**(3)**:** 170–175.
43. Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM. Prevalence of high body mass index in US children and adolescents, 2007–2008. JAMA: The Journal of the American Medical Association. Jan20;303(3):242–249.
44. Nelson SM, Matthews P & Poston L. Maternal metabolism and obesity: modifiable determinants of pregnancy outcome. *Human Reproduction Update* 2009 Dec 4**:** 1–21.
45. Pirkola J, Pouta A, Bloigu A, Hartikainen AL, Laitinen J, Jarvelin MR, et-al. Risks of overweight and abdominal obesity at age 16 years associated with prenatal exposures to maternal prepregnancy overweight and gestational diabetes mellitus. Diabetes Care. May;33(5):1115–1121.
46. Laitinen J, Power C & Jarvelin MR. Family social class, maternal body mass index, childhood body mass index, and age at menarche as predictors of adult obesity. *American Journal of Clinical Nutrition* 2001 Sep; **74**(3)**:** 287–294.
47. Reilly JJ, Armstrong J, Dorosty AR, Emmett PM, Ness A, Rogers I et al. Early life risk factors for obesity in childhood: cohort study. *BMJ: The Journal of the American Medical Association* 2005 Jun 11; **330**(7504)**:** 1357.
48. Koupil I & Toivanen P. Social and early-life determinants of overweight and obesity in 18-year-old Swedish men. *International Journal of Obesity (London)* 2008 Jan; **32**(1)**:** 73–81.
49. Pitkin RM. Nutritional support in obstetrics and gynecology. *Clinical Obstetrics and Gynecology* 1976 Sep; **19**(3)**:** 489–513.
50. *Nutrition during pregnancy*. Washington, DC: Institute of Health, 1990.
51. Lederman SA, Paxton A, Heymsfield SB, Wang J, Thornton J & Pierson Jr.. RN. Body fat and water changes during pregnancy in women with different body weight and weight gain. *Obstetrics and Gynecology* 1997 Oct; **90**(4 Pt 1)**:** 483–488.
52. Taggart NR, Holliday RM, Billewicz WZ, Hytten FE & Thomson AM. Changes in skinfolds during pregnancy. *British Journal of Nutrition* 1967; **21**(2)**:** 439–451.
53. Ehrenberg HM, Huston-Presley L & Catalano PM. The influence of obesity and gestational diabetes mellitus on accretion and the distribution of adipose tissue in pregnancy. *American Journal of Obstetrics and Gynecology* 2003 Oct; **189**(4)**:** 944–948.
54. Kinoshita T & Itoh M. Longitudinal variance of fat mass deposition during pregnancy evaluated by ultrasonography: the ratio of visceral fat to subcutaneous fat in the abdomen. *Gynecologic and Obstetric Investigation* 2006; **61**(2)**:** 115–118.
55. Despres JP, Moorjani S, Lupien PJ, Tremblay A, Nadeau A & Bouchard C. Regional distribution of body fat, plasma lipoproteins, and cardiovascular disease. *Arteriosclerosis* 1990 Jul–Aug; **10**(4)**:** 497–511.
56. Bartha JL, Marin-Segura P, Gonzalez-Gonzalez NL, Wagner F, Aguilar-Diosdado M & Hervias-Vivancos B. Ultrasound evaluation of visceral fat and metabolic risk factors during early pregnancy. *Obesity (Silver Spring)* 2007 Sep; **15**(9)**:** 2233–2239.
57. Villamor E & Cnattingius S. Interpregnancy weight change and risk of adverse pregnancy outcomes: a population-based study. *Lancet* 2006 Sep 30; **368**(9542)**:** 1164–1170.

Please cite this article in press as: Dennedy MC, Dunne F, The maternal and fetal impacts of obesity and gestational diabetes on pregnancy outcome, Best Practice & Research Clinical Endocrinology & Metabolism (2010), doi:10.1016/j.beem.2010.06.001

58. Catalano PM, Tyzbir ED, Roman NM, Amini SB & Sims EA. Longitudinal changes in insulin release and insulin resistance in nonobese pregnant women. *American Journal of Obstetrics and Gynecology* 1991 Dec; **165**(6 Pt 1)**:** 1667–1672.
59. Catalano PM, Tyzbir ED, Wolfe RR, Roman NM, Amini SB & Sims EA. Longitudinal changes in basal hepatic glucose production and suppression during insulin infusion in normal pregnant women. *American Journal of Obstetrics and Gynecology* 1992 Oct; **167**(4 Pt 1)**:** 913–919.
60. Catalano PM, Vargo KM, Bernstein IM & Amini SB. Incidence and risk factors associated with abnormal postpartum glucose tolerance in women with gestational diabetes. *American Journal of Obstetrics and Gynecology* 1991 Oct; **165**(4 Pt 1)**:** 914–919.
61. Ramsay JE, Ferrell WR, Crawford L, Wallace AM, Greer IA & Sattar N. Maternal obesity is associated with dysregulation of metabolic, vascular, and inflammatory pathways. *Journal of Clinical Endocrinology & Metabolism* 2002 Sep; **87**(9)**:** 4231–4237.
62. Metzger BE & Coustan DR. Summary and recommendations of the Fourth International Workshop-Conference on Gestational Diabetes Mellitus. The Organizing Committee. *Diabetes Care* 1998 Aug; **21**(Suppl. 2)**:** B161–B167.
63. Hillier TA, Vesco KK, Pedula KL, Beil TL, Whitlock EP & Pettitt DJ. Screening for gestational diabetes mellitus: a systematic review for the U.S. Preventive Services Task Force. *Annals of Internal Medicine* 2008 May 20; **148**(10)**:** 766–775.
64. Callaway LK, Prins JB, Chang AM & McIntyre HD. The prevalence and impact of overweight and obesity in an Australian obstetric population. *Medical Journal of Australia* 2006 Jan 16; **184**(2)**:** 56–59.
65. McIntyre HD, Chang AM, Callaway LK, Cowley DM, Dyer AR, Radaelli T et al. Hormonal and metabolic factors associated with variations in insulin sensitivity in human pregnancy. *Diabetes Care* 2010 Feb; **33**(2)**:** 356–360.
66. Karelis A. The metabolically healthy but obese individual presents a favorable inflammation profile. *Journal of Clinical Endocrinology & Metabolism* 2005 Apr 5; **90**(7)**:** 4145–4150.
67. Zeyda M, Farmer D, Todoric J, Aszmann O, Speiser M, Györi G et al. Human adipose tissue macrophages are of an anti-inflammatory phenotype but capable of excessive pro-inflammatory mediator production. *International Journal of Obesity and Related Metabolic Disorders* 2007 Sep 26; **31**(9)**:** 1420–1428.
68. Weisberg SP, Hunter D, Huber R, Lemieux J, Slaymaker S, Vaddi K et al. CCR2 modulates inflammatory and metabolic effects of high-fat feeding. *Journal of Clinical Investigation* 2006 Jan 1; **116**(1)**:** 115–124.
69. Karelis AD, Faraj M, Bastard JP, St-Pierre DH, Brochu M, Prud'homme D et al. The metabolically healthy but obese individual presents a favorable inflammation profile. *Journal of Clinical Endocrinology & Metabolism* 2005 Jul 1; **90**(7)**:** 4145–4150.
70. Harman-Boehm I, Bluher M, Redel H, Sion-Vardy N, Ovadia S, Avinoach E et al. Macrophage infiltration into omental versus subcutaneous fat across different populations: effect of regional adiposity and the comorbidities of obesity. *Journal of Clinical Endocrinology & Metabolism* 2007 Jun 1; **92**(6)**:** 2240–2247.
71. Curat CA, Wegner V, Sengenès C, Miranville A, Tonus C, Busse R et al. Macrophages in human visceral adipose tissue: increased accumulation in obesity and a source of resistin and visfatin. *Diabetologia* 2006 Apr 1; **49**(4)**:** 744–747.
72. Wentworth JM, Naselli G, Brown WA, Doyle L, Phipson B, Smyth GK et al. Pro-inflammatory CD11c + CD206+ adipose tissue macrophages are associated with insulin resistance in human obesity. *Diabetes* 2010 Mar 31.
73. Weisberg SP, McCann D, Desai M, Rosenbaum M, Leibel RL & Ferrante Jr.. AW. Obesity is associated with macrophage accumulation in adipose tissue. *Journal of Clinical Investigation* 2003 Dec; **112**(12)**:** 1796–1808.
74. Genc MR, Ford CE. The clinical use of inflammatory markers during pregnancy. Current Opinion in Obstetrics and Gynecology. Apr;22(2):116–121.
75. Challier JC, Basu S, Bintein T, Minium J, Hotmire K, Catalano PM et al. Obesity in pregnancy stimulates macrophage accumulation and inflammation in the placenta. *Placenta* 2008 Mar; **29**(3)**:** 274–281.
76. Mestan K, Yu Y, Matoba N, Cerda S, Demmin B, Pearson C, et-al. Placental inflammatory response is associated with poor neonatal growth: preterm birth cohort study. Pediatrics. Apr;125(4):e891–e898.
77. Shoelson SE, Lee J & Goldfine AB. Inflammation and insulin resistance. *Journal of Clinical Investigation* 2006 Jul 1; **116**(7)**:** 1793–1801.
78. Semple R, Sleigh A, Murgatroyd P, Adams C, Bluck L, Jackson S et al. Postreceptor insulin resistance contributes to human dyslipidemia and hepatic steatosis. *Journal of Clinical Investigation* 2009 Jan 26**:** 1–8.
79. Schenk S, Saberi M & Olefsky JM. Insulin sensitivity: modulation by nutrients and inflammation. *Journal of Clinical Investigation* 2008 Sep 1; **118**(9)**:** 2992–3002.
80. Shi H, Kokoeva MV, Inouye K, Tzameli I, Yin H & Flier JS. TLR4 links innate immunity and fatty acid-induced insulin resistance. *Journal of Clinical Investigation* 2006 Nov; **116**(11)**:** 3015–3025.
81. Holick MF. Vitamin D deficiency. *New England Journal of Medicine* 2007 Jul 19; **357**(3)**:** 266–281.
82. Bodnar LM, Catov JM, Roberts JM & Simhan HN. Prepregnancy obesity predicts poor vitamin D status in mothers and their neonates. *Journal of Nutrition* 2007 Nov; **137**(11)**:** 2437–2442.
83. Bodnar LM, Simhan HN, Powers RW, Frank MP, Cooperstein E & Roberts JM. High prevalence of vitamin D insufficiency in black and white pregnant women residing in the northern United States and their neonates. *Journal of Nutrition* 2007 Feb; **137**(2)**:** 447–452.
84. Guelinckx I, Devlieger R & Vansant G. Reproductive outcome after bariatric surgery: a critical review. *Human Reproduction Update* 2008 Nov 5; **15**(2)**:** 189–201.
85. Signori C, Zalesin KC, Franklin B, Miller WL, McCullough PA. Effect of gastric bypass on vitamin D and secondary hyperparathyroidism. Obesity Surgery. May 5.
86. Lapillonne A. Vitamin D deficiency during pregnancy may impair maternal and fetal outcomes. Medical Hypotheses. Jan; 74(1):71–75.
87. Lumley J, Watson L, Watson M & Bower C. Periconceptional supplementation with folate and/or multivitamins for preventing neural tube defects. *Cochrane Database of Systematic Reviews* 2001; (3). CD001056.
88. Mojtabai R. Body mass index and serum folate in childbearing age women. *European Journal of Epidemiology* 2004; **19**(11)**:** 1029–1036.
89. Fitzsimons KJ, Modder J. Setting maternity care standards for women with obesity in pregnancy. Seminars in Fetal and Neonatal Medicine. Apr;15(2):100–107.

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90. Modder JFKJ. *CMACE/RCOG Joint guideline: management of women with obesity in pregnancy*. London: Centre for Maternal and Child Enquiries (CMACE); Royal College of Obstetricians and Gynaecologists (RCOG, 2010.
91. Moses RG, Luebcke M, Davis WS, Coleman KJ, Tapsell LC, Petocz P et al. Effect of a low-glycemic-index diet during pregnancy on obstetric outcomes. *American Journal of Clinical Nutrition* 2006 Oct; **84**(4)**:** 807–812.
92. Clapp 3rd JF. Maternal carbohydrate intake and pregnancy outcome. *Proceedings of Nutrition Society* 2002 Feb; **61**(1)**:** 45–50.
93. Clapp 3rd JF, Kim H, Burciu B, Schmidt S, Petry K & Lopez B. Continuing regular exercise during pregnancy: effect of exercise volume on fetoplacental growth. *American Journal of Obstetrics and Gynecology* 2002 Jan; **186**(1)**:** 142–147.
94. *Recommendations for a national policy on vitamin D supplementation for infants in Ireland*. Dublin: Food Safety Authority of Ireland, 2007.
95. Horvath K, Koch K, Jeitler K, Matyas E, Bender R, Bastian H et al. Effects of treatment in women with gestational diabetes mellitus: systematic review and meta-analysis. *BMJ: The Journal of the American Medical Association* 2010 Apr 1; **340**(1)**:** c1395.
96. Landon MB, Spong CY, Thom E, Carpenter MW, Ramin SM, Casey B et al. A multicenter, randomized trial of treatment for mild gestational diabetes. *New England Journal of Medicine* 2009 Oct 1; **361**(14)**:** 1339–1348.
97. Rowan JA, Hague WM, Gao W, Battin MR & Moore MP. Metformin versus insulin for the treatment of gestational diabetes. *New England Journal of Medicine* 2008 May 8; **358**(19)**:** 2003–2015.
98. Valentino MA, Lin JE, Waldman SA. Central and Peripheral Molecular Targets for antiobesity pharmacotherapy. Clinical Pharmacology & Therapeutics. May 5.
99. Kim SY, England LJ, Kendrick JS, Dietz PM & Callaghan WM. The contribution of clinic-based interventions to reduce prenatal smoking prevalence among US women. *American Journal of Public Health* 2009 May; **99**(5)**:** 893–898.
100. Atlanta Centres for Disease Control and Prevention. Tobacco Use and Pregnancy, http://www.cdc.gov/reproductivehealth/tobaccousepregnancy/index.htm; 2010. Available from:.
101. Fabricatore AN, Wadden TA, Moore RH, Butryn ML, Gravallese EA, Erondu NE et al. Attrition from randomized controlled trials of pharmacological weight loss agents: a systematic review and analysis. *Obesity Reviews* 2009 May; **10**(3)**:** 333–341.
102. Astrup A, Rossner S, Van Gaal L, Rissanen A, Niskanen L, Al Hakim M et al. Effects of liraglutide in the treatment of obesity: a randomised, double-blind, placebo-controlled study. *Lancet* 2009 Nov 7; **374**(9701)**:** 1606–1616.
103. Sjostrom L, Lindroos AK, Peltonen M, Torgerson J, Bouchard C, Carlsson B et al. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. *New England Journal of Medicine* 2004 Dec 23; **351**(26)**:** 2683–2693.
104. Sjostrom L, Gummesson A, Sjostrom CD, Narbro K, Peltonen M, Wedel H et al. Effects of bariatric surgery on cancer incidence in obese patients in Sweden (Swedish Obese Subjects Study): a prospective, controlled intervention trial. *Lancet Oncology* 2009 Jul; **10**(7)**:** 653–662.
105. Sjostrom L, Narbro K, Sjostrom CD, Karason K, Larsson B, Wedel H et al. Effects of bariatric surgery on mortality in Swedish obese subjects. *New England Journal of Medicine* 2007 Aug 23; **357**(8)**:** 741–752.
106. Dixon JB & O'Brien PE. Health outcomes of severely obese type 2 diabetic subjects 1 year after laparoscopic adjustable gastric banding. *Diabetes Care* 2002 Feb; **25**(2)**:** 358–363.
107. Shah M, Simha V & Garg A. Review: long-term impact of bariatric surgery on body weight, comorbidities, and nutritional status. *Journal of Clinical Endocrinology & Metabolism* 2006 Nov 1; **91**(11)**:** 4223–4231.

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