

Impact of maternal weight on pregnancy outcomes: a systematic review

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Abstract

Purpose – The nutritional status of a woman before and during pregnancy is important for a healthy pregnancy outcome. The increasing prevalence of maternal overweight and obesity worldwide has become a problem of concern among public health professionals. The purpose of this paper is to review the evidence regarding the impact of maternal weight on pregnancy outcomes to facilitate the provision of evidence-based information to pregnant women during antenatal clinics in Ghana.

Design/methodology/approach – A search was conducted in PubMed, PLOS ONE, Cochrane, Embase and bibliographies for all studies on maternal weight and pregnancy outcomes published from January 2000 to May 2013. The key words used for the search were: “pre-pregnancy BMI”, “gestational weight gain”, “maternal weight”, “pregnancy outcomes” and “birth outcomes”.

Findings – The search yielded 113 papers; out of these, 35 studies were included in the review after exclusion of duplicates and irrelevant papers. Excluded papers included animal studies and human studies that did not meet inclusion criteria.

Research limitations/implications – The review only considered papers published from 2000 to 2013 and might have left out other important papers published before 2000 and after 2013.

Practical implications – The origins of the studies included in the review suggest paucity of studies on maternal weight and pregnancy outcomes in developing countries where there is a double burden of malnutrition. There is the need for more studies to be initiated in this area.

Social implications – Results of this review have revealed that the extremes of maternal weight prior to and during pregnancy increase the risk of maternal and fetal complications.

Originality/value – This paper provides evidential information on the impact of maternal weight on pregnancy outcomes for counseling during antenatal clinics.

Keywords Health, Nutrition, Pregnancy, Obesity, Maternal weight

Paper type Literature review



Introduction

The recent surge in the prevalence of overweight and obesity in women of child-bearing age worldwide is a serious public health challenge, reports from WHO (2015) indicate that about 40 per cent of women worldwide are overweight or obese. This issue is worrying in developing countries where there is the double burden of malnutrition. In

Ghana, from 2008 to 2014, the prevalence of overweight or obesity in women aged 15-49 years increased from 21 to 25 per cent and from 9 to 15 per cent, respectively (Ghana Demographic health survey, 2008 and 2014).

The impact of maternal weight on pregnancy outcomes has attracted widespread attention because these have been proven to be predictors of both short- and long-term, as well as negative and positive outcomes of pregnancy (Rolfes *et al.*, 2009; Forsum *et al.*, 2013). Pre-pregnancy overweight/obesity has been shown to increase the risk of fetal death, preeclampsia, gestational diabetes and pregnancy-induced hypertension (Nohr *et al.*, 2008). On the other hand, an underweight woman has a high risk of having a low-birth-weight infant, as well as increased risk of preterm birth, fetal and infant deaths (Tennant *et al.*, 2011). Low gestational weight gain (GWG) is associated with preterm birth or delivery of small-for-gestational age (SGA) infants whereas high GWG is associated with a greater risk of cesarean section, gestational diabetes and pregnancy-induced hypertension and its complications (Kabali and Werler, 2007).

The ideal weight prior to pregnancy is set between 18.5 kg/m² and 24.9 kg/m²; regardless of all the known effects of maternal weight on pregnancy outcomes, clinical observations in developing countries indicate that it is quite impossible for this to be achieved because most pregnancies are unplanned. Results from studies have also shown that most women do not follow the weight gain pattern proposed by International Organization for Migration (IOM) and as such do not eventually achieve healthy weights during pregnancy (Yekta *et al.*, 2006). Again, overweight or obesity is interpreted as “a sign of good living” in some parts of Africa. This indicates some form of ignorance on the part of lay individuals in such countries, including Ghana. The objective of this systematic review was to gather facts regarding the effects of maternal weight on pregnancy outcomes to facilitate the provision of evidence-based information to pregnant women during antenatal clinics.

Objectives

To examine the effects of maternal weight (Pre-pregnancy body mass index [BMI] and GWG) on pregnancy outcomes:

H1. Maternal weight is an important predictor of pregnancy outcome.

Methods

Inclusion criteria

Studies were selected if they met criteria based on the sample studied, the exposures of interest and outcomes of interest:

- (1) *Population studied:* Studies were included if only pregnant humans of child-bearing age with singleton births or pregnancies were studied.
- (2) *Exposures:*
 - pre-pregnancy BMI (underweight/overweight/obesity/normal); and
 - GWG (inadequate/adequate/excess).
- (3) *Outcomes:*
 - Maternal outcomes included gestational diabetes, preeclampsia, anemia and pregnancy-induced hypertension.

- Fetal outcomes: birth weight, preterm delivery, fetal and infant death and intrauterine growth restrictions.
- There were no restrictions regarding the type of study design

Exclusion criteria

Studies were excluded if pregnant women with multiple pregnancies, pre-existing diabetes or hypertension or any medical condition were used.

Sources of data

- *Electronic databases* included Pubmed, Plosone, Embase and Cochrane.
- Bibliographies of selected papers were also scrutinized for additional studies.
- *Grey literature* includes fact sheets on maternal and child health on World Health Organisation (WHO) website, book chapters focusing on nutrition before and during pregnancy.

Search strategy

A search was conducted in electronic databases (PubMed, Plosone, Cochrane library and Embase), books and WHO website for all relevant papers published on the impact of maternal weight on short-term pregnancy outcomes from the year 2000 to 2013. The key words used for the search were: “pre-pregnancy BMI”, “gestational weight gain”, “maternal weight”, “pregnancy outcomes and birth outcomes”.

Quality assessment

We assessed the quality of included studies by creating a specific quality assessment scale based on the criteria proposed by strengthening the Reporting of Observational Studies in Epidemiology and Yu *et al.* (2013) for the assessment of observational studies. Briefly, quality assessment was based on the following items: type of study, loss of follow-up, statistical method and diagnostic criteria for pre-pregnancy underweight/overweight/obesity, GWG (inadequate/adequate and excess) measurement of fetal and maternal outcomes. According to the score achieved (from 0 to 14), studies were classified as being of high (>10), medium (6-10) or low (<10) quality.

Search results

The initial search in PubMed, EMBASE, Cochrane library and Plosone made available 2,504 references that had the potential to be included in the review. The titles of the studies were reviewed, 2,398 were excluded and the abstracts of the remaining 113 were reviewed, which included five articles obtained from bibliographic search. This led to the elimination of 78 abstracts and acceptance of 35 abstracts which were further reviewed entirely for the work. A summary of the selection process is presented in Figure 1. Out of the 35 studies that were reviewed:

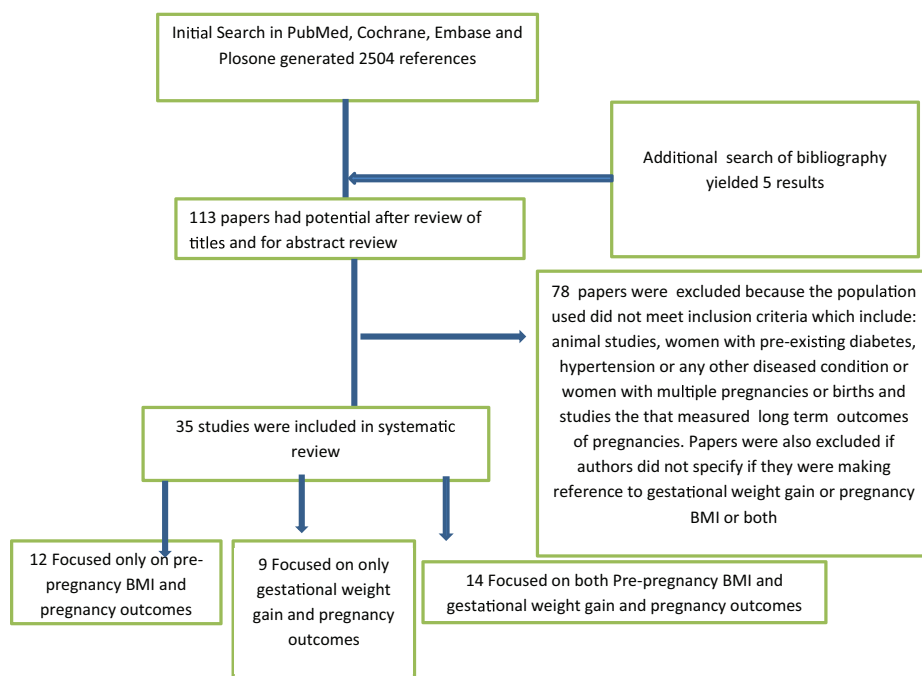


Figure 1.
Selection process for
articles

- 12 focused on pre-pregnancy BMI and pregnancy outcomes;
- 9 focused on GWG and pregnancy outcomes; and
- 14 focused on both pre-pregnancy BMI and GWG and pregnancy outcomes;

Data extraction

Data extraction was conducted based on the following criteria:

- publication details (author, date of publication);
- study design;
- aim or objectives of studies;
- quality assessment score;
- exposures; and
- conclusions.

Study characteristics

In all, 35 studies were used for this systematic review. The studies used were published from 2000 to 2013, and the main subjects or study populations were healthy women with singleton pregnancies with no incidence of pre-pregnancy diabetes or hypertension or any medical condition. A total population of 1,001,718,109 pregnant women were included in the review. The studies were mainly observational (19 cohorts, 6 case-controls, 1 cross-sectional and 9 secondary data analyses). In total, 12 of the studies focused on the effects of pre-pregnancy BMI on pregnancy outcome, 9 of the studies

examined the effects of GWG on birth outcomes and 14 worked on the impact of both pre-pregnancy BMI and GWG. About 90 per cent of the studies focused mainly on obesity and overweight in pregnant women and the effects of these on both maternal and neonatal outcomes. With regards to the countries in which the studies were conducted, majority of the studies were conducted in Asia and America, with only a few in Africa and Europe. Most of the studies that used pre-pregnancy BMI made use of reported recalled BMIs by study subjects and also used already existing data or records from other studies. Summary of the major findings and characteristics of the papers included in the review are presented in [Table I](#).

Effects of pre-pregnancy body mass index on pregnancy outcomes

Twelve studies were identified (ten cohorts and two case controls) which examined relationships between maternal pre-pregnancy BMI and pregnancy outcomes. Most studies (nine) in this category focused on the effects of pre-pregnancy obesity, overweight or super obesity on pregnancy outcomes, whereas the remaining three focused on both pre-pregnancy obesity and normal weight. All but one of the 12 studies found direct relationships which were statistically significant. [Tennant *et al.* \(2011\)](#) in a cohort study investigated the association between early pregnancy BMI and the risk of fetal and infant deaths among English women, with pregnancies not affected by congenital anomalies or pre-gestational diabetes. Results of this study showed that the risk of both fetal death (aOR = 2.32 [95 per cent confidence interval (CI): 1.64-3.28; $p < 0.001$]) and infant death (aOR = 1.97 [1.13-3.45; $p = 0.02$]) was significantly higher for obese women than for overweight (fetal death: aOR $\frac{1}{4}$ 1.34 [0.94-1.89]; $p \frac{1}{4}$ 0.10; infant death: aOR $\frac{1}{4}$ 1.35 [0.79-2.32]; $p \frac{1}{4}$ 0.27) and underweight women (fetal death: aOR = 0.98 [0.42-2.25]; $p = 0.96$; infant death: aOR = 1.89 [0.73-4.88]; $p = 0.19$). When data was further analyzed, the authors found a V-shaped association between BMI and the risk of fetal and infant death, with a minimum risk at 23 kg/m².

In another study, [Meenakshi *et al.* \(2012\)](#) examined maternal and fetal complications in overweight and obese women with singleton pregnancies. The study population was composed of 87 women with BMI (25-29.9 kg/m²), 83 women with BMI (30 kg/m²) and 45 controls with BMI (20-24.9 kg/m²). When compared to women with normal BMI, outcomes, such as gestational hypertension ($p < 0.05$), preeclampsia ($p < 0.001$), preterm delivery ($p < 0.05$), cesarean section ($p < 0.01$), still births ($p < 0.05$), early neonatal deaths ($p < 0.05$) and Apgar score < 7 at 5 min were found to be more common in overweight and obese women. Results of these studies and others used in the review indicate that maternal pre-pregnancy obesity and overweight independently increased the risk of gestational diabetes mellitus (GDM), pregnancy-induced hypertension, preeclampsia and other hypertensive disorders, preterm delivery, cesarean section, stillbirths, infant and fetal deaths, fetal macrosomia, large for gestational age (LGA) infants, post-term delivery and miscarriages ([Yazdani *et al.*, 2012](#); [Marshall *et al.*, 2012](#); [Owens *et al.*, 2010](#); [Bhattacharya *et al.*, 2007](#); [Kosa *et al.*, 2011](#); [El-Gilany and Hammad, 2010](#); [Kalk *et al.*, 2009](#); [Verma and Shrimali, 2012](#)). In addition, [Ahmed *et al.* \(2009\)](#) found an increased risk of anemia (R.R 3.84) among obese women than in non-obese women.

[Kongubol and Phupong \(2011\)](#) on the other hand found no significant risk for GDM and preeclampsia among pregnant obese Thai women. In their study, pregnant women with BMI (≥ 27.5 kg/m²) were compared to pregnant women with normal weight (BMI > 18.5 -23 kg/m²) with respect to maternal and fetal complications. When compared to

Authors	Study design	No. of subjects	Quality assessment score	Exposure	Conclusions
Kongkol and Phupong (2011)	Prospective cohort	240	11 (High)	Pre-pregnancy obesity	Pre-pregnancy obesity increases the risk for gestational diabetes, preeclampsia and fetal macrosomia
Yazdani <i>et al.</i> (2012)	Retrospective cohort	1,000	9 (Medium)	Pre-pregnancy BMI	Increased BMI in the first trimester increases risk for adverse pregnancy outcomes
Verma and Shrimali (2012)	Prospective cohort	784	10 (Medium)	Pre-pregnancy BMI	Maternal underweight, overweight and obesity are associated with adverse maternal and perinatal outcomes
Owens <i>et al.</i> (2010)	Prospective cohort	2,329	9 (Medium)	Pre-pregnancy obesity	Pre-pregnancy obesity increases the risk for adverse obstetric outcomes
Mamun <i>et al.</i> (2011)	Prospective cohort	6,632	12 (High)	Pre-pregnancy BMI and gestational weight gain	Obese women increased their risk for cesarean delivery, macrosomia and pregnancy complications than underweight women who were at risk for pre-term delivery
Kosa <i>et al.</i> (2011)	Retrospective case control	1,214	11 (High)	Pre-pregnancy weight	Pre-term delivery is associated with both pre-pregnancy underweight and overweight
Ota <i>et al.</i> (2011)	Prospective population-based case control	2,989	12 (High)	Pre-pregnancy BMI and gestational weight gain	The risk for the delivery of SGA infants was high among women with low BMI and inadequate GWG
Tennant <i>et al.</i> (2011)	Retrospective cohort	40,932	10 (Medium)	Pre-pregnancy BMI	Pre-pregnancy obesity is significantly associated with infant and fetal death
Adido (2010)	Retrospective analysis of clinical records	1,755	11 (Medium)	Gestational weight gain	Overweight and obesity are related to adverse neonatal and maternal outcomes
Meenakshi <i>et al.</i> (2012)	Prospective cohort	1,115	12 (High)	Pre-pregnancy overweight and obesity	Overweight and obesity are definite risk factors for adverse pregnancy outcomes
Drehmer <i>et al.</i> (2013)	Prospective multicenter cohort study	2,244	12 (High)	Weekly weight gain during the second and third trimesters	Inadequate gestational weight gain in the second trimester significantly increased the risk of small for gestational age infant deliveries, and excessive weight gain in the third trimester resulted in preterm births and cesarean deliveries
Ludwig and Currie (2010)	Retrospective cohort	1,164,750	11 (High)	Pregnancy weight gain	Maternal weight gain is significantly related to birth weight
Davis and Hofferth (2012)	Retrospective study	100,000	11 (High)	Inadequate/low gestational weight gain	Inadequate gestational weight gain increases the odds for infant death

*(continued)*Table I.
Data extraction table

Table I.

Authors	Study design	No. of subjects	Quality assessment score	Exposure	Conclusions
Carreno <i>et al.</i> (2012)	Retrospective study	7,985	11 (Medium)	Excessive early gestational weight gain	Excessive weight gain during pregnancy increases the incidence of gestational diabetes and delivery of large for gestational age babies
Hedderson <i>et al.</i> (2010)	Prospective nested case control	1,145	11 (High)	Gestational weight gain before oral glucose tolerant test	Excessive GWG in the first trimester increases the risk for gestational diabetes, especially among obese and overweight women
Heude <i>et al.</i> (2012)	Prospective cohort	1,884	12 (High)	Pre-pregnancy BMI and net gestational weight gain	High BMI strongly is associated with the delivery of large for gestational age infant
Choi <i>et al.</i> (2011)	Retrospective cohort	2,413	11 (High)	Pre-pregnancy BMI and gestational weight gain	Pre-pregnancy obesity and overweight are associated with increased odds for gestational diabetes and hypertensive disorders
Xinxo <i>et al.</i> (2013)	Retrospective case-control study	300	10 (Medium)	Pre-pregnancy maternal nutritional status and gestational weight gain	The odds for preterm delivery was (2.7 and 4.3) among underweight and obese BMI, respectively
Halloran <i>et al.</i> (2012)	Retrospective study	38,028	11 (High)	Pre-pregnancy BMI and gestational weight gain	High pre-pregnancy BMI and excess GWG increase the risk for post-term delivery
El-Gilany <i>et al.</i> (2010)	Prospective study	787	11 (High)	Pre-pregnancy BMI	Obese and overweight women had a high risk for adverse pregnancy outcomes

normal weight women, obese Thai women were not at increased risk for GDM (RR = 0.9 [95 per cent CI 0.6-1.4]), preeclampsia (RR = 0.7 [95 per cent CI 0.2-3.3]) and fetal macrosomia (RR = 1.4 [95 per cent CI 0.5-4.3]).

Pre-pregnancy underweight was found to increase the risk of intrauterine growth restrictions, anaemia, preterm delivery, low birth weight and delivery of SGA infants (Kosa *et al.*, 2011; El-Gilany and Hammad, 2010; Verma and Shrimali, 2012).

Effects of gestational weight gain and pregnancy outcomes

Nine studies (four cohorts, one case-control, four secondary data analysis and three undeclared study designs) were identified for this category. All the nine studies in this category reported that GWG within the IOM guidelines for the various BMI groups' results in positive outcomes of pregnancy. GWG was found to be directly associated with the birth weight of an infant and every additional kilogram of pregnancy weight gain increased birth weight by 7.35g (Ludwig and Currie, 2010). Using records of women who received antenatal care in a private hospital in Ghana, Addo (2010) found a statistically significant association between excessive weight gain and still birth and macrosomia. Other papers included in this reviewed found that excessive weight in the early stages of pregnancy, especially in the first trimester, increased the risk of gestational diabetes, fetal macrosomia, pregnancy-induced hypertension, stillbirths, postpartum hemorrhage and other hypertensive disorders, especially in women who started pregnancy with normal BMI (Carreno *et al.*, 2012; Stotland and Cheng, 2006; Hedderston *et al.*, 2010; Addo, 2010). Weight gain below the 15lb recommended for obese pregnant women was beneficial in lowering preeclampsia, cesarean delivery and LGA infants but increased risk for SGA infants (Kiel *et al.*, 2007). Using the Brazilian Study of Gestational Diabetes cohort, Drehmer *et al.* (2013) particularly examined the independent effects of weight gain in the second and third trimesters in isolation and reported that the extremes of birth weight were more associated with weight gain in the second trimester, whereas the risk of preterm birth or caesarean section was more associated with excessive weight gain in the third trimester. Thus, inadequate or excessive weight gain in the second trimester increased the risk of delivering SGA or LGA infants, respectively. No relationship was found between insufficient weight gain in the third trimester and adverse obstetric or birth outcomes. Davis *et al.* (2012), in a retrospective study, concluded that maternal weight gain below recommendations increased the odds for infant deaths which resulted from excessively low-birth-weight infants. It is thus beneficial for underweight women to gain appropriate weight during pregnancy (Rode *et al.*, 2007).

Combined effects of pre-pregnancy body mass index and gestational weight gain on pregnancy outcomes

Fourteen studies evaluated the combined effects of pre-pregnancy BMI and GWG on pregnancy outcomes (five cohorts, three case-controls, one cross-sectional and five secondary data analysis). According to Magriples *et al.* (2009), pre-pregnancy BMI is a better predictor of the mode of child birth, either by natural birth or cesarean section, whereas GWG helps in predicting the possible weight of fetus. Fourteen out of the 35 studies included in the review investigated the combined effects of pre-pregnancy BMI and GWG on pregnancy outcomes. Dietz *et al.* (2006) and Xinxo *et al.* (2013) found that excessive weight gain increased the risk of preterm delivery regardless of the

pre-pregnancy BMI. On the other hand, they found that the association between very low GWG and preterm delivery was dependent on the pre-pregnancy BMI, and the strongest association was among overweight and obese women. [Heude et al. \(2013\)](#) and [Halloran et al. \(2012\)](#) also found that regardless of the pre-pregnancy BMI, inadequate weight gain during pregnancy increased the risk of preterm delivery. The risk of preterm delivery was also high among underweight women with low GWG and obese women with high weight gain. Thus, the risk of preterm delivery in underweight or obese women was dependent on their weight gain pattern, as well as normal weight women who do not reach or attain the recommended weight gain. [Wise et al. \(2010\)](#) found that pre-pregnancy BMI $<18 \text{ kg/m}^2$ increased the incidence of spontaneous preterm births (SPTB) and medically indicated preterm births (MPTB) and pre-pregnancy BMI $\geq 30 \text{ kg/m}^2$ increased the risk of MPTB. Again, low weight gain $<0.5 \text{ lb}$ per week was associated with increased risk of SPTB among normal and obese women, and GWG $\geq 1.5 \text{ lb}$ per week was associated with increased risk of SPTB among overweight and obese women. The risk of pregnancy complications, such as gestational diabetes, pregnancy-induced hypertension, cesarean section, fetal macrosomia, neonatal death and over all infant death and LGA infants deliveries, was high among women who gained excessive weight during pregnancy with the strongest relationship in the women with pre-pregnancy BMI $>24.9 \text{ kg/m}^2$ ([Kabali and Werler, 2007](#); [Xinxo et al., 2013](#); [Tabatabaei, 2011](#); [Mamun et al., 2011](#); [Choi et al., 2011](#); [Chen et al., 2009](#); [Nohr et al., 2008](#); [Yekta et al., 2006](#)). Other studies found that women with pre-pregnancy BMI $<18 \text{ kg/m}^2$ and gained inadequate weight during pregnancy had a greater risk of low-birth-weight infants and preterm delivery and SGA infants, especially among those with weight gain less than 10 kg ([Ota et al., 2011](#)).

Discussion

The aim of this review was to summarize available evidence on the impact of maternal weight on pregnancy outcomes. Findings from this review indicate that pre-pregnancy overweight and obesity increased the risk and incidence of gestational diabetes, pregnancy-induced hypertension, preeclampsia, preterm delivery, cesarean section, stillbirths, infant and fetal deaths, fetal macrosomia, LGA infant delivery, post-term delivery and miscarriages. Pre-pregnancy underweight also increased the risk and incidence of intrauterine growth restrictions, anaemia, preterm delivery, low birth weight and delivery of SGA infants.

The 2009 IOM guidelines recommend specific ranges of weight gain for women of varying pre-pregnancy BMIs with the goal of minimizing the negative health consequences of inadequate or excessive weight gain for both mother and fetus. Findings from papers assessing the impact of GWG on pregnancy outcomes revealed that excessive weight gain in the early stages of pregnancy, especially in the first trimester, increased the risk of gestational diabetes, LGA infants, fetal macrosomia, pregnancy-induced hypertension, stillbirths and postpartum hemorrhage.

In addition, inadequate weight gain throughout pregnancy increased the risk of low-birth-weight infants, SGA infants, preterm deliveries and infant deaths. Apart from the identified short-term consequences of maternal weight, there are a number of long-term effects on both mothers and infants that have been identified. These could result from factors related to fetal programming or as a result of these short-term outcomes. For instance, preterm delivery has the potential of increasing the risk of

neurological and respiratory problems, hematological complications, gastrointestinal and metabolic issues and infections (Kamath-Rayne *et al.*, 2013) and the long-term effects of pregnancy-induced hypertension and gestational diabetes increases the risk of cardiovascular complications, renal diseases and cancer for some women (Mustafa *et al.*, 2012).

Pregnancy is a state of increased requirements for macro and micronutrients, the absence, inadequate or excess supply of these lead to adverse outcomes (Imdad *et al.*, 2011). During this period, numerous dynamic changes take place in the life of women which require a lot of care. The fetus is nourished directly by the mother through a placenta during this period, requiring an expectant mother to consume adequate portions of macro and micronutrients (Rolfes *et al.*, 2009). These nutrients when available in their right amounts and at the right stage of pregnancy provide the building blocks for fetal growth and development. Pregnant women require additional energy to gain weight which helps them carry the weight of pregnancy (Byrd – Bredbenner *et al.*, 2013).

The consequences of underweight, overweight and obesity in the absence of pregnancy are well known. While overweight and obesity are closely linked with non-communicable diseases, such as diabetes, dyslipidemia, stroke and hypertension, underweight compromises the immunity of individuals making them increasingly susceptible to infections and diseases. Underweight individuals are also likely to consume too little protein, fat and other nutrients, such as antioxidants, which help support a strong, functioning immune system. Thus, when they contract infections or disease, their bodies are less able to fight them. Again, underweight individuals are likely experience reduced nutrient absorption leading to nutrient deficiencies (Brown, 2008).

In view of this, a pregnant woman who is underweight prior to pregnancy and is unable to gain adequate weight throughout pregnancy is at risk of nutrient deficiencies arising from low intakes and altered absorption. Maternal nutrient deficiency will lead to inadequate supply of nutrients to the growing fetus and increase the risk of undesirable outcomes, such as preterm delivery, low birth weight, intrauterine growth restrictions and delivery of SGA babies (Hans and Edward, 2010).

Furthermore, deficiency in nutrients, such as calcium, can lead to poor bone formation in fetus and also predispose mothers to pregnancy-induced hypertensive disorders and osteoporosis later in life. Iron deficiency which is most common in pregnancies can also result in maternal anemia and in maternal death during delivery. Infants who experience intrauterine growth restrictions are also at risk of developing degenerative diseases, such as hypertension, type 2 diabetes and cardiovascular diseases, as proposed by the thrifty phenotype hypothesis (Black *et al.*, 2008).

Overweight/obesity, either before or during pregnancy, means excess intake of energy beyond what is required to maintain metabolic activities in both the mother and growing fetus. An overweight/obese expectant woman is first of all predisposed to gestational diabetes or insulin resistance, a condition in which body cells become resistant or insensitive to the activities of insulin leading to high blood sugar levels (Hedderson *et al.*, 2010).

Furthermore, the presence of gestational diabetes in any pregnancy increases the risk of hypertensive disorders. Because the fetus depends solely on the mother, these disorders directly affect its health and further result in preterm deliveries, stillbirths and

fetal macrosomia (Kim, 2010). As with maternal underweight, the early intrauterine environment plays a role in programming phenotype, thus affecting health of infants in later life. Maternal overweight and obesity at the time of pregnancy increases the risk for childhood obesity that continues into adolescence and early adulthood, initiating the transgenerational transmission of obesity (Black *et al.*, 2013).

Results obtained in this review are consistent with those of similar systematic reviews (Torloni *et al.*, 2009; Heslehurst *et al.*, 2008; Yu *et al.*, 2013; Monte *et al.*, 2011), which found maternal BMI and weight gain during pregnancy to be directly associated with outcomes. We found that a V- or U-shaped relationship exists between maternal weight and pregnancy outcomes. A low maternal pre-pregnancy BMI or inadequate weight gain results in adverse outcomes as much as high pre-pregnancy BMI or excessive weight gains. Thus, having a healthy pre-pregnancy BMI and gaining weight according to IOM's recommendations seems to be more protective.

Limitations of the study

Majority of the studies included in this study focused on maternal overweight/obesity, indicating that the global incidence of overweight/obesity across all population groups is alarming. We must however not lose sight of the fact that maternal underweight exists especially in developing countries where the double burden of malnutrition menace still exist and has equal implications as overweight/obesity. The year limit reduced the number of studies reviewed and more useful information could be obtained if the year limit is removed.

Conclusion

The evidence presented above show that public health professionals in charge of maternal health have vital roles to play in ensuring that pregnant women under their care experience healthy pregnancies through healthy weight gain. This could be achieved through provision of guidelines for the selection, preparation and cooking of healthy meals and regularly monitoring. Again, environmental factors, such as maternal alcohol consumption, smoking and drug abuse, must be controlled to mitigate their effects on pregnancy. This study supports the importance of preconception counseling and possibly pre-marital nutritional counseling to prepare women nutritionally for conception and lactation.

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