Chapter 3

Pregnancy Weight Gain: The Short Term and the Long Term

Ruth Mielke

Additional information is available at the end of the chapter

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Abstract

Achieving adequate pregnancy weight gain is critical to optimize infant and maternal outcomes. Extremes of pregnancy weight gain—excessive and inadequate—can jeopardize the health of the mother and her baby. Excessive pregnancy weight gain is associated with increased risk of pregnancy complications, cesarean delivery, and an overly large infant. In the longer term, women with excessive gain during pregnancy are prone to retain pregnancy weight and are at risk for life-long obesity and diabetes. Inadequate gain is associated with negative infant outcomes such as low birth weight, growth restriction, and increased risk for cardiovascular disease as an adult. Worldwide, more women are entering pregnancy overweight or obese. This trend is a more recent phenomenon even in developing countries. Some countries or regions have guidelines for pregnancy weight gain but others do not. The 2009 United States Institute of Medicine Guidelines are presented and discussed for the general population or women during pregnancy as well as for less clear-cut cases, such as twins and women with extreme obesity. Midwives and health workers need to be comfortable discussing guidelines for pregnancy weight gain in their settings—whether in a classroom, home, or clinic.

Keywords: pregnancy weight gain, gestational weight gain, postpartum weight retention, prepregnancy body mass index, postpartum weight retention

1. Introduction

Achieving adequate pregnancy weight gain (PWG) is critical to optimize infant and maternal outcomes [1]. In developed countries, excessive pregnancy weight gain (PWG) is more likely [2–6] while women in lower-resource countries are more likely to experience inadequate PWG [7–9]. Inadequate PWG is mainly associated with poorer infant outcomes, preterm

birth, suboptimal infant birth weight [10–12], and greater risk of infant death [13]. Excessive PWG is also associated with negative infant outcomes (e.g., excessive infant birth weights [11, 14]), but in mothers, it increases the likelihood of delivery complications including cesarean delivery [14–16], postpartum weight retention [11, 17], and subsequent obesity [18–20]. In the longer term, inadequate and excessive PWG appear to alter the fetal intrauterine environment, resulting in obesity in childhood [21–23], adolescence [24, 25], and type 2 diabetes, and atherogenic profiles in adulthood [26, 27]. Therefore, optimizing PWG improves not only maternal health but that of the next generation.

2. Pregnancy weight gain: physiology and composition

Pregnancy boasts an astounding array of physiologic and developmental changes that support the fetus from conception to birth. Physiologic changes include those necessary for fetal sustenance and growth; adequate oxygenation of the maternal/fetal dyad during pregnancy; and future provision for newborn nutrition via lactation after delivery. Throughout pregnancy, the mother's metabolism adjusts based on hormonal changes of pregnancy, fetal requirements, her nutritional intake, and her level of physical activity. These changes are reflected in pregnancy weight gain (PWG), which includes gains in maternal and fetal fat mass and fat-free mass (protein, skeletal tissue), as well as the placenta and amniotic fluid [1, 28]. A complete review of pregnancy physiology is beyond the scope of this chapter. However, it is important for midwives and health-care workers to understand how aspects of pregnancy physiology affect PWG.

The appearance of pregnancy-associated hormones and concurrent increases in existing hormones have multi-factorial influences on PWG. Referred to as the hormone of pregnancy, human chorionic gonadotropin (hCG) can be detected within days of embryo implantation. Serum concentrations of hCG rise steeply and peak about 60 days after conception—about 7 weeks after the first day of the last menstrual period (LMP) [29].

The dramatic surge of hCG in early pregnancy along with increases in other maternal hormones such as estrogen and progesterone are believed to contribute to the common experience of "morning sickness" which often starts at the fifth week after the last menstrual period (LMP), peaks at 8–12 weeks, and resolves by 16–18 weeks in only a small number of women in whom the symptoms persist past 20 weeks of gestation. Such vomiting (emesis) can result in small weight loss in the first half of pregnancy. As long as the mother is not dehydrated and has not lost more than 5% of her initial body weight, non-pharmacologic relief measures should be offered and she can be reassured that hyperemesis will not negatively impact the pregnancy outcome if her pregnancy weight gain normalizes. Such measures include ginger, chamomile, vitamin B6, and/or acupuncture [30]. One study showed that nausea and vomiting in pregnancy minimized the risk of excessive PWG, particularly in women with high prepregnancy body mass indices (BMIs) [31]. However, if the mother has severe nausea and vomiting (hyperemesis gravidarum) resulting in electrolyte imbalance, dehydration, and weight loss greater than 5% of her prepregnancy weight, she will require medical treatment inclusive of intravenous fluids [32]. Severe nausea may also be a sign of other illnesses, such as gastroenteritis (stomach bugs), migraines, or gallbladder or pancreas disease [33].

Within a week of conception, the placenta begins to secrete another new hormone, human placental lactogen (hPL), thought to influence several metabolic processes associated with PWG. hPL blunts maternal insulin actions to ensure that sufficient protein and other energy sources are available to the fetus. The rate of HPL secretion parallels placental growth resulting in increasing insulin resistance making increased nutrition available to the fetus as the pregnancy progresses. In addition, hPL promotes maternal lipolysis which increases the circulating levels of free fatty acids to accommodate fetal nutritional and maternal metabolic needs [33, 34]. If a lipid panel (cholesterol, triglycerides, and other lipid fractions) is done for some reason during pregnancy, midwives and health-care workers should expect that levels will be elevated. This is evidence of the increased availability of energy being made available to the fetus during pregnancy!

Increased levels of progesterone and estrogen, both steroid hormones, contribute and respond to changes in PWG. Both hormones are initially synthesized by the corpus luteum of the ovary until about 7–9 gestational weeks when a "luteal-placental" shift occurs and the placenta takes over their production [35]. Increased hormone levels of estrogen influence carbohydrate, lipid, and bone metabolism [29] and promote growth of the uterus and breast tissue. High levels of progesterone ("pro-gestation") maintain the pregnancy by keeping the distended uterus in a quiescent state and suppress the mother's immune response to the fetus so that it is not rejected. Progesterone and estrogen contribute to the decrease in maternal vascular resistance to accommodate the notable increase (40–50% above her baseline) of maternal blood volume for better transit of nutrients and oxygen [33, 35]. Increased maternal blood volume contributes to PWG as does increased extracellular volume (edema).

Pyrosis (heartburn) affects 50–80% of women in late pregnancy. It occurs when progesterone relaxes the lower esophageal sphincter (opening) and a burning sensation occurs as the acidic content of the mother's stomach irritates the esophagus [33]. In some cultures it is believed that mothers with heartburn in pregnancy will have infants with thick heads of hair! Nonpharmacologic approaches for women with heartburn include advice to eat smaller, more frequent meals, avoid trigger foods (e.g., high in fat or spicy foods), and avoid eating too close to bedtime or at times that they plan to be recumbent. The first-line pharmacologic approach is oral antacids containing cations of sodium bicarbonate (baking soda), calcium carbonate (TUMS), or magnesium salts which are widely available in stores and clinics. Antacids that contain calcium or magnesium are recommended as calcium is often needed and magnesium may reduce the incidence of preeclampsia [36]. If these do not work, women may also be given more targeted agents like H2 receptor agonists (cimetidine or ranitidine) or proton-pump inhibitors (omeprazole) by their midwife or clinic [33, 36]. Although no woman wants to experience heartburn in pregnancy, she can be reassured that it may stimulate more healthy eating behaviors and therefore may limit the possibility of excessive PWG.

Pregnancy is a teachable moment in which women are more likely to adopt risk-reducing behaviors and to pursue learning about their health and its effects on the growth and development of the fetus [37–39]. Midwives and other health-care workers are well positioned to provide accurate advice and counseling on PWG that can positively impact the outcome of the pregnancy. In a study of Hispanic women in Los Angeles, 18.8% of the women did not recall any discussions about PWG with health-care providers during pregnancy. Among those who had such discussions, only 42% reported receiving weight gain advice within the Institute of Medicine (IOM)

guidelines [1], 16.5% below guidelines, and 10% above. The other women (13.5%) who reported having the discussion did not recall the recommended weight gain amount. Compared with women who received accurate advice on PWG, women who reported advice below IOM guidelines were 1.7 times more likely to gain less than the recommended amount and those who reported advice above IOM guidelines were 2.0 times more likely to gain excessive PWG [40]. This demonstrates that (1) health-care workers must be knowledgeable on PWG recommendations, (2) accurate PWG information should be a routine part of pregnancy care, and (3) when accurate advice is given, women are more likely to gain appropriately during pregnancy.

2.1. Composition of pregnancy weight gain

Pregnancy weight gain is the sum of maternal, placental, and fetal components. Over the course of pregnancy, protein, fat, water, and minerals are deposited in the fetus, placenta, amniotic fluid, uterus, mammary gland (breasts), blood, and adipose (fat) tissue. The products of conception (placenta, fetus, amniotic fluid) comprise approximately one-third of the total pregnancy weight gain [28] (**Table 1**).

2.1.1. Body water

Total body water accumulation is highly variable during pregnancy. Healthy women accumulate an additional 7–8 L of water which is distributed in the fetus (32%), blood (17%), amniotic fluid (10%), uterus (10%), breasts (4%), and in women with no edema or just mild leg swelling (20%) throughout the maternal tissues. Visible leg edema or noted changes like rings being too tight occur in 50–85% of women during pregnancy. However, some women accumulate much more water by the end of pregnancy. This can be as much as more than 3–4 L over typical water accumulation. Overweight women have greater generalized edema than underweight women [28] as do some women with hypertensive disorders (chronic/gestational hypertension and preeclampsia) during pregnancy. Previous definitions of preeclampsia included excessive edema in the diagnosis [41] but this is not current practice [42]. In of itself, excessive edema can be uncomfortable and unsightly, but in the absence of complications, it does not warrant the use of a diuretic (water pill).

2.1.2. Protein

The normally nourished body has little capacity to store protein [28]. Therefore, additional protein accumulated occurs predominantly in late pregnancy when the fetal needs are greatest [29]. In contrast to water accumulation, which is mostly maternal during pregnancy, protein is accumulated predominantly in the fetus (42%) and less so in the uterus (17%), blood (14%), placenta (10%), and breasts (8%) [28]. A Cochrane review of studies of protein and energy intake in pregnancy concluded that dietary advice was effective to increase pregnant women's energy and protein intake and that balanced energy/protein supplementation improves fetal growth and therefore may reduce the risk of perinatal death. However, high-protein or balanced-protein supplementation alone was not beneficial and could be harmful to the fetus [43]. Other factors that require increased demand for protein such as infections and mild-to-moderate energy deficits (common in developing countries) should also be appropriately considered in assessing protein and energy needs [44] (Appendix A).

2.1.3. Fat

Fat accumulation in pregnancy supports the production of steroid hormones (estrogen and progesterone) and provides energy for the mother and her baby. Most of the fat accumulated (approximately 3.3 kg) goes to maternal stores, providing an energy reserve of approximately 30,000 kcal. Maternal fat stores are gained primarily between the 10th and 30th weeks of gestation before fetal energy demands are at their peak [29] and are stored more as visceral rather than subcutaneous fat [45]. Women with appropriate access to food during pregnancy will notice that their hips, back, and lower body feel fuller or more rounded, even before there is abdominal evidence of the pregnancy. If the mother gains within recommendations for her prepregnancy BMI, fat accumulation is inversely related to BMI. Therefore, obese women gain significantly less fat than underweight and normal-weight women. However, in the context of excessive gain, this results in additional visceral fat accumulation which portends higher risk of life-long obesity and other co-morbidities.

2.1.4. Placenta

Pregnancy weight gain is influenced not only by changes in maternal physiology and metabolism but also by placental metabolism. When blood flow is persistently reduced on both sides (fetal and maternal) of the placental exchange, growth restriction results due to decreased oxygen and nutrient access by the fetus. In such cases, the placenta mobilizes some nutrients from maternal stores [46]. Conversely, when there is a surplus of nutrients as in the case of maternal diabetes, excessive PWG, or maternal obesity, fetal overgrowth is more likely.

Tissues and fluids	Weight gained (g)	Weight gained (lb)
Fetus	3400	7.5
Placenta	650	1.4
Amniotic fluid	800	1.8
Uterus	970	2.1
Mammary glands	405	0.9
Blood	1450	3.2
No edema or leg edema only	7675	–
Extracellular extravascular fluid	1480	3.3
Maternal fat stores	3345	7.4
Total weight gained (no edema)	**12,500**	**27.6**
Generalized edema	7675	–
Extracellular extravascular fluid	4697	10.4
Maternal fat stores	2128	4.7
Total weight gained (edema)	**14,500**	**32.0**

Source: Adapted from Hyttena and Chamberlain [28]. Table 7.11, Analysis of weight gain; p. 195.

Table 1. Tissues and fluids and weight gained by 40 weeks of gestation.

However, it is unlikely that varying levels of blood flow and nutrients alone are responsible for fetal undergrowth or overgrowth. It has been recently postulated that the placenta has independent nutrient sensor functions [47]. According to this hypothesis the maternal supply of nutrients and oxygen are actively regulated by placental nutrient transporters. Therefore, beyond passive filtering of available maternal substrate, the placenta has an active role up- or down regulating transport proteins according to the maternal environment.

2.1.5. Fetus

As noted previously, the fetus demands most of the later pregnancy maternal intake of protein. The rapid rate of fetal growth during the last half of gestation dictates changes in basal metabolism, protein, and mineral accumulations. About 60% of the increase in mother's basal metabolic rate (BMR) occurs during the last half of gestation, when the fetal tissue synthesis is the greatest [29]. As there is no evidence that pregnant women store protein early in gestation for later fetal demands, the increased requirements of late pregnancy must be met by increased maternal intake.

The term fetus has more body fat than most other mammalian species. At birth the human fetus has approximately 12–16% body fat while laboratory animals may have just 1–2% body fat at birth. After 30 weeks of gestation, a small loss of maternal body fat occurs while fetal fat mass increases. During this period, 94% of all fat deposition in the fetus occurs [46].

2.2. Pregnancy weight gain recommendations

Midwives and other health workers must be familiar with PWG recommendations specific to their region and know how to apply these based on their assessment of the mother's prepregnancy weight category. In the United States, pregnancy weight gain guidelines were first established by the Institute of Medicine in 1990 [48] and were revised in 2009 due to the increasing prevalence of obesity and new knowledge regarding pregnancy [1]. A key change in the revised guidelines was the use of World Health Organization (WHO) body mass index (BMI) categories instead of categories based on tables used by the US-based Metropolitan Life Insurance Company. One significant result of the application of the WHO BMI categories was that fewer women are categorized as underweight prior to pregnancy (**Table 2**). This is important as the prior underweight BMI cut-off (<19.8) inappropriately classified younger adolescents as underweight when their prepregnancy BMI was actually appropriate for their age [49, 50].

Another significant change was the addition of a specific and narrower range of recommended gain for women who are obese at the onset of pregnancy (**Table 3**). **Table 3** presents the application of the WHO BMI categories, recommended PWG, and rates of PWG for second and third trimesters.

In many cultures, mothers are encouraged to "eat for two" starting in early pregnancy. However, for all but very underweight women, the first trimester through the first half of pregnancy does not require greater food intake but should be focused on the avoidance of harmful substances (e.g., alcohol and nicotine) and more attention to the quality of maternal nutrition rather than increasing the quantity of food. Additional energy intake is recommended

BMI category	IOM 1990 (kg/m^2)	IOM 2009 (kg/m^2)
Underweight	<19.8	<18.5
Normal weight	19.8–26	18.5–24.9
Overweight	26.1–29	25–29.9
Obese class I	>29	30–34.9
Obese class II	–	35–39.9

Table 2. Comparison of Institute of Medicine (IOM) and World Health Organization (WHO) BMI categories.

	Total weight Pregnancy weight Gain		Rates of weight gain 2nd and 3rd trimester1	
Prepregnancy BMI (kg/m^2)	**Range (kg)**	**Range (lbs)**	**Mean (kg/week)**	**Mean (lb/week)**
Underweight <18.5	12.5–18	28–40	0.51	1
Normal 18.5–24.9	11.5–16	25–35	0.42	1
Overweight 25.0–29.9	7–11.5	15–25	0.28	0.6
Obese >30	5–9	11–20	0.22	0.5

Calculations assume a 1.1–4.4 lbs/0.50–2 kg weight gain in the first trimester.

Adapted from Institute of Medicine [47]. Table S-1 New Recommendations for Total and Rate of Weight Gain during Pregnancy, by Prepregnancy BMI.

Table 3. Institute of Medicine recommended weight gains for pregnancy 1.

more so in the second and third trimesters when greater than 90% of fetal growth occurs. Approximately an additional 340 and 450 kcal are recommended during the second and third trimesters, respectively [51]. However, in well-nourished women, optimal weight gain and outcome of pregnancy can be attained over a very wide range of energy intakes. Many women sustain a pregnancy with a successful outcome on less than the recommended energy intake [29]. This probably reflects different adaptive strategies (reduced physical activity, more effective use of nutrients, etc.) that can be used to meet the additional energy demands of pregnancy.

2.2.1. Global considerations

Worldwide, pregnancy weight gain guidelines may differ from the 2009 IOM guidelines or in some cases, countries may not have PWG guidelines. Although adverse effects are associated with extremes of PWG, there are no WHO guidelines at global or European levels, nor consensus on recommended weight gain in obese women [52]. In 2016, WHO European Region Member States (n = 53) were queried to assess whether there were recommendations in place on appropriate PWG. Two-thirds of the countries (36 countries) reported having national recommendations on appropriate pregnancy weight gain; one-fifth (12 countries) did not have PWG recommendations; and five countries did not respond. Of the 36 countries with recommendations, two-thirds

reported recommendations based on prepregnancy BMI for singleton pregnancies, with 21 of those countries using WHO BMI categories. Thirteen countries based their recommendations on the 2009 IOM ones, with four of the thirteen countries modifying guidelines based on IOM guidance. Six countries reported not using WHO BMI categories. Furthermore, three countries said they have different recommendations for each obese class [52].

Some countries utilize prenatal weight gain grids/charts to show the mother how much she should gain based on her weight category and her trends of PWG. The Rosso and Mardones chart is used in most Chilean prenatal clinics, attended by the majority of the country's middle- and low-income women. Other Latin American countries, that is, Argentina, Brazil, Ecuador, Panama, and Uruguay, have also been using this weight gain chart in their prenatal care programs [53, 54]. The Rosso and Mardones chart categorizes maternal nutritional status early in pregnancy based on weight/height, expressed either as the percentage of standard weight (PSW) or body mass index (BMI). The chart shows the desired trend of desirable gestational weight gains for each of these categories. Similar style grids are used in publically funded clinics in many areas of the United States [55, 56] (Appendix B). The graphical depiction of maternal nutritional status and trending PWG patterns are useful for workers and patients with varying literacy levels.

2.2.2. Asian women

There is increased attention to pregnancy weight gain guidelines that account for ethnic characteristics and population-based differences. For instance, even with typically lower BMIs, many Asian groups have a higher proportion of body fat (more often in the waist area [central obesity]) and therefore have greater risk of type 2 diabetes and cardiovascular disease than European groups. In 2004, WHO experts discussed this issue and recommended lower BMI cut-offs for Asians in that there is a different correlation between BMI, body fat deposition, and health risk than Europeans [57]. The WHO Asian BMI classification (underweight, <18.5; normal weight, 18.5 to <23; overweight, 23 to <27.5; obese, ≥27.5) narrows the range of normal weight and substantially lowers the thresholds for overweight and obese BMI categories, thereby identifying a larger proportion of persons who in actuality are at a higher risk for cardiovascular disease and type 2 diabetes (**Table 3**).

The WHO Asian BMI categories subsequently spurred interest in studying whether there should also be PWG recommendations specific for Asian women [6, 58–61]. Multi-ethnic Asian (Chinese, Malay, Indian) women in Singapore (n = 1529) were studied to assess PWG ranges for optimal infant outcomes (size of infant appropriate for gestational age [AGA] vs. large or small for gestational age [LGA or SGA]) and maternal outcomes (cesarean vs. vaginal delivery). Outcomes for underweight women were best when they gained more weight as per the IOM guidelines (12.9–23.9 kg vs. 12.5–18 kg) and less weight if overweight (2.6–14.0 kg vs. 7–11.5 kg) or obese (−5.0 to 7.0 kg vs. 5–9 kg). Of note, the optimum range for Singaporean women in the obese category suggested that even weight loss during pregnancy was associated with optimum maternal and fetal outcomes.

In this chapter, the IOM 2009 guideline for PWG is used because it is considered to be applicable to various racial and ethnic groups. However, researchers realize that much further study needs to be done as there are body composition characteristics unique to different racial and ethnic groups which many necessitate recommendations specific to certain groups.

2.2.3. Total pregnancy weight gain

Total PWG is the amount of weight a woman gains between conception and the onset of labor [1]. Obtaining an accurately measured weight at both conception and the onset of labor can be difficult if the woman was unsure when conception occurred or due to the lack of awareness of her weight prior to pregnancy. Further, discrepancies between weight reported on a home scale as compared to a clinic or hospital scale are well known. Some women may not have a home scale and because of limited access to health facilities may have little idea of their weight.

However, total PWG is best defined as final pregnancy weight minus her prepregnancy weight. Initial weight can be a prepregnancy weight that is (1) reported by the woman, (2) measured in the clinic, (3) identified from the woman's medical charts at the date closest to conception, or (4) measured at the first prenatal/study visit. The determination of the final pregnancy weight can also be problematic. Hospital emergency departments/birth facilities may not routinely weigh women as part of the labor admission process. However, the woman's self-reported weight is more accurate than estimation by the health-care workers and so should be considered [62, 63].

2.2.4. Body mass index

Body mass index (BMI) is but one measure of body composition—specifically fat composition. Other methods to assess body fat composition (e.g., skin fold thickness, underwater weighing, magnetic resonance imaging, dual energy X-ray absorptiometry [DEXA], and ultrasound) are less used in pregnancy because they are either not practical, potentially harmful, or confounded by pregnancy changes such as increases in total body water by 5–8 L [28, 64].

At present, BMI is the most commonly used method of assessing body fat composition worldwide. The BMI categories recommended by the WHO indicate degrees of thinness and fatness and in so doing identify individuals and/or populations at risk for cardiovascular disease, type 2 diabetes, and other related health conditions [65]. For policy purposes, BMI categories are applied to population data to inform and initiate policy, to facilitate prevention programs, and to measure the effect of interventions. BMI categories are also used to identify high-risk individuals for screening; identify individuals for absolute risk assessment; determine the type and intensity of treatment; and monitor individuals for effects of treatment over time [57] (**Table 4**).

Midwives and health-care workers must see that accurate assessment of the mother's prepregnancy BMI is a key starting point on the road map to positive perinatal outcomes: a healthy weight-term infant, avoidance of pregnancy complications (hypertension and diabetes), increased likelihood of vaginal delivery, optimization of breastfeeding, and reduction of postpartum weight retention and subsequent life-long obesity.

Determination of the mother's prepregnancy BMI is body mass category based on her height and weight. As discussed earlier, assessment of the woman's prepregnancy weight is determined based on the best available reported or measured weight; e.g., first prenatal visit especially if in first trimester, or most recent clinic weight prior to the pregnancy. There are many BMI calculators that are easily available to midwives and health-care workers. Body mass index is based on a mathematical computation using the woman's height. The formula is $kg/m^2 = BMI$ where kg is a person's weight in kilograms and m^2 is their height in meters squared. This can

Classification	BMI (kg/m²)	
	Principal cut-off points	**Asian cut-off points**
Underweight	**<18.50**	**<18.50**
Severe thinness	<16.00	<16.00
Moderate thinness	16.00–16.99	16.00–16.99
Mild thinness	17.00–18.49	17.00–18.49
Normal range	**18.50–24.99**	**18.50–23.00**
Overweight	**≥25.00**	**>23.00–27.5**
Pre-obese	25.00–29.99	
Obese	**≥30.00**	**>27.5**
Obese class I	30.00–34.99	
Obese class II	35.00–39.99	
Obese class III	≥40.00	

Source: Adapted from Organization WH [56, 64].

Table 4. International classification of adult body mass index.

also be determined by using printed body mass index tables (Appendix C) to using one of the many free smartphone apps.

2.3. Recommendations in special populations

The 1990 IOM recommendations included considerations for "special populations." For instance, women of shorter stature were advised to gain at the lower end of the range for their prepregnant BMI based on their greater risk for emergent cesarean delivery. However, subsequent analyses did not report that this risk was modified by lower PWG.

Other special populations mentioned in the 1990 guidelines were pregnant adolescents, various racial or ethnic groups, and pregnancies with multiple fetuses. The 2009 IOM guidelines obviated the concern of recommending too high PWG in the developmentally normal, slim adolescent by use of the WHO BMI cut-offs in which such adolescents are now classified as normal weight rather than underweight. The 2009 guidelines have provisional guidelines for women with multiple (twins, triplets, etc.) gestations but were not able to address the extremes of prepregnancy BMI such as very high (super obese) or very low prepregnancy BMI categories.

2.3.1. Twin pregnancy

Recommended PWG in twin pregnancies is higher than in singleton (single fetus), pregnancies and consistent with singleton pregnancy, is inversely related to prepregnancy BMI category. In other words, a normal-weight woman expecting twins should be advised to gain more than

her overweight counterpart expecting twins, but her recommendation is greater than if she was only expecting one baby The IOM was unable to conduct the same level of analysis for women with twins as it did for women with singletons (single fetuses), so the following provisional guidelines were proffered: normal-weight women should gain 17–25 kg (37–54 lbs), overweight women, 14–23 kg (31–50 lbs), and obese women, 11–19 kg (25–42 lbs) during the term [1]. There was insufficient information with which one can develop even a provisional guideline for underweight women with multiple fetuses.

2.3.2. Prepregnancy extreme obesity

Obesity at the onset of pregnancy is associated with the increased risk of pregnancy complications (gestational diabetes, hypertension, cesarean delivery) and poorer neonatal outcomes (stillbirth, congenital anomalies) [66, 67]. Since 2006, the increase in adult obesity in developed countries has slowed, but more women in developing countries are obese at the onset of pregnancy [68, 69]. The estimated prevalence of obesity exceeded 50% in women in Kuwait, Kiribati, Federated States of Micronesia, Libya, Qatar, Tonga, and Samoa [70]. Further, there are more women worldwide who are in a BMI category of extreme obesity (≥40 kg/m^2).

Although the 2009 IOM guideline improved upon the 1990 ones in that there was a specific recommendation for obese women (5–9 kg), it was not stratified by the severity of obesity (**Table 3**). This is problematic in that pregnancy and newborn complications increase further in higher categories of obesity [71, 72]. Retrospective studies of pregnant women with severe obesity have been conducted to assess the relationship between degrees of PWG with perinatal outcomes [71–73]. A review of 10 such studies included nearly 740,000 obese women from three countries (United States, Sweden, and Germany). For the outcomes of small for gestational age, large for gestational age, and cesarean delivery, the authors concluded that that PWG guidelines may need modification for the severity of obesity as the lowest combined risk was with weight gain of 5–9 kg in women with class I obesity, from 1 to less than 5 kg for class II obesity, and no gestational weight gain for women with class III obesity [74]. Another review and meta-analysis of 18 studies reported that women in higher obese categories who gained less than the IOM guidelines were less likely to have gestational hypertension, preeclampsia, cesarean delivery, and fewer large for gestational age infants than obese women who gained within the guidelines [75]. In summary, it appears that women in more severely obese categories can safely gain less than the IOM guidelines or even gain minimally overall.

For obese women, it is not uncommon to see weight loss in the first trimester and even up to mid-pregnancy. Besides nausea (with or without vomiting) which may blunt appetite and decrease weight, the "teachable moment" of pregnancy spurs many women to choose food more carefully as they shift their attention to nutritional needs of their growing baby. Weight loss during pregnancy can be alarming to the mother and her family, but the midwife or health worker can provide reassurance that as long as she is well hydrated, some weight loss will not harm her baby. In fact, some obese women improve their nutritional habits enough that they gain well within the guidelines and then after the birth of the infant find themselves to weigh slightly less than they were at the beginning of the pregnancy!

2.3.3. Prepregnancy underweight

Maternal underweight (low BMI) at the onset and during pregnancy is a key determinant of poor fetal outcomes. The prevalence of low BMI is higher in developing nations with suboptimal access to food and greater risk for diarrheal diseases but is also present in developed nations in women with eating disorders or dependence on alcohol or other substances. One such negative outcome is intrauterine growth restriction (IUGR) or low birth weight (LBW, less than 2500 g). IUGR and LBW occur as a result of maternal, placental, and fetal factors [76].

Intrauterine growth restriction is associated with increased perinatal morbidity and mortality, and newborns with low birth weight have increased risk for the development of adult metabolic syndrome. One of the most cited examples of the long-term outcomes of maternal undernutrition is the Dutch Famine Birth Cohort Study [77]. In the winter of 1944/1945 the Nazi occupation turned a once prosperous country to one plagued by famine. Official food rations were below 1000 calories/day resulting in inadequate PWG and low birth weight infants. The offspring have been followed over subsequent decades. As middle-aged adults they were more likely to be obese [78] and have atherogenic lipid profiles [79]. This is explained using the fetal origin hypothesis [27], also referred to as the "thrifty phenotype" hypothesis, in which fetal reprogramming necessary to survive low food availability ended up being a longer-term disadvantage when food was more abundant.

Resting metabolic rate varies among pregnant women. Overweight women enter pregnancy with ample fat stores and their resting metabolism increases in an attempt to diminish further accumulation of fat stores [80]. Conversely, underweight women with limited food supply and the demands of hard physical labor frequently enter pregnancy with minimal maternal fat reserves. Their only option is to reduce their resting metabolic rate to conserve energy for their fetus [81, 82]. This permits delivery of a viable infant who may or may not be growth restricted, depending on the severity of the situation. Such strategies enable women to sustain a pregnancy under a wide range of conditions, including suboptimal nutrition. However, at some point, the physiological capacity of the body to adjust its metabolism and accommodate fetal growth will be compromised; nutrients are preferentially diverted to the mother at the expense of fetal growth.

Health workers may want to consider the positive deviance approach based on the premise that solutions to a community's problem may exist within the community [83]. Positive deviance refers to the uncommon yet healthy practices that permit some persons to thrive while similarly positioned neighbors do not. One example was when program planners in Vietnam observed that mothers who fed their children less typical foods like shrimp and greens from the rice paddies instead of rice only were able to protect them from malnutrition [84]. A similar approach could be taken in communities in which access to sufficient energy, nutrient, and protein stores during pregnancy is suboptimal. There may prove to be "positive deviants" or women who have identified less common but effective means of optimizing pregnancy weight.

3. Influences on pregnancy weight gain

Midwives and health workers must consider that there are factors that influence PWG that are modifiable and those which are not modifiable. Further, modifiable factors such as food intake and physical activity are intertwined and are influenced by body habitus and age. It is also critical to be aware that appropriate PWG decreases the risk of pregnancy-related diseases such as gestational hypertension and gestational diabetes.

3.1. Prepregnancy body mass index

Achieving a normal prepregnancy BMI has a significant influence on appropriate PWG [1]. High (obese and overweight) prepregnancy BMI is a recurring key determinant of excessive gain among White [85–88], Black [89], Hispanic [90–93], and multiethnic women [2, 3, 94]. Specifically, overweight BMI has been the most commonly reported determinant of excessive PWG in all ethnicities [2, 4, 31, 88].

As noted previously, more women in developing countries are overweight or obese at the onset of pregnancy [68, 69] and therefore are more likely to have excessive PWG. Globally, the impact of excessive PWG may pose an even greater threat to maternal and infant long-term health in resource-poor settings undergoing various phases of the nutrition transition [95]. The nutrition transition is marked by shifts in diet from traditional foods to a more Western-type diet along with decreasing physical activity that propagates obesity and nutrition-related non-communicable diseases, such as cardiovascular disease and diabetes. As reproductive-age women in these settings were previously exposed to undernutrition and are now becoming overweight/obese, excessive PWG may further lead toward the heightened risk of maternal and offspring obesity and nutrition-related diseases [69].

Conversely, underweight BMI has been implicated in the increased risk of inadequate gain [31] but with less frequency in developed countries. Even with the "globesity epidemic," there are countries like India in which 42% of mothers are underweight and give birth to 20% of the world's babies. In poor-resource areas, women begin pregnancy with low BMI and gain little weight during pregnancy [7].

3.2. Maternal age

Adolescents and younger women [4, 31, 91, 96] are more likely to gain excessively. Though related to concurrent maturation, it is of concern because of the risk of postpartum weight retention and the potential for young women to move to a high BMI category by the next pregnancy [97]. There is less consistency in older women. Deputy et al. [31] reported that inadequate PWG was more likely in multi-ethnic women 35 and older while Puerto Rican women over 30 years of age were at 2.5 times greater risk for excessive PWG than younger women [90].

3.3. Parity

Even one pregnancy changes the fatness of a woman's body. One arm of the CARDIA study showed that White and Black women with a single pregnancy had pregnancy-related increased adiposity as compared to women who remained nulliparous [98]. Parity has a significant relationship to PWG independent of other known influences. In women from England, parity contributed most greatly to PWG followed by birth weight and BMI [85]. Adolescent primiparas gained 5.28 pounds more than multiparas [99]; had twice the likelihood of excessive PWG than multiparas [96]; and large multiethnic studies have also reported primiparity versus subsequent births as a covariate for excessive PWG [2, 3, 100].

3.4. Hypertension and gestational diabetes

A relationship between hypertension in pregnancy and excessive PWG has been observed in women of diverse ethnicities [3, 99, 101, 102]. Midwives and health workers must be aware of both modifiable and non-modifiable factors associated with pregnancy-related hypertension. Compared to White women, Black women consistently have more pregnancy-related hypertension independent of other factors [103–105]. In Hispanics, findings are less consistent: from reports of lower risk [106] to differential risk, higher risk for certain types of hypertension (e.g., preeclampsia but not gestational hypertension) [107]. In all ethnicities, pregnancy-related hypertension is more common in primiparas [102] and in women with a family history of hypertension [108].

High prepregnancy BMI and excessive PWG are modifiable factors that appear to have independent as well as synergistic influences on hypertension in pregnancy. Women with excessive PWG had a three-fold risk of hypertension and four-fold risk of preeclampsia compared to women who gained appropriately [109], and women with obese BMI had 2.5-fold higher odds of having pregnancy-related hypertension with excessive PWG compared to those who gained adequately [110].

Increased risk for gestational diabetes mellitus is associated with excessive PWG in early pregnancy [111]. However, once diagnosed with gestational diabetes, women may be more likely to gain inadequately [92, 93] or adequately [90] overall due to dietary and exercise modifications. Therefore, the diagnosis of gestational diabetes is really an opportunity to optimize pregnancy health through monitoring dietary intake and being more intentional to add physical activity as a means of controlling blood-sugar levels.

4. Postpartum effects of excessive pregnancy weight gain

Excessive PWG in women of all prepregnancy BMI categories exerts negative effects on the mother and her infant. Women with excessive gain are at greater risk for cesarean delivery [14–16] and more likely to have pregnancy complications [15]. Infants of women with excessive PWG are more likely to be overweight by 7 years of age [22] and to be obese by adolescence [25]. If this adolescent is female, then she begins pregnancy in a high BMI and is already

at greater risk for excessive PWG. After delivery, women with excessive PWG are more prone to postpartum weight retention [11, 17] and more likely to become overweight or obese by the next pregnancy [19, 112, 113].

Postpartum weight retention is defined as the weight change from preconception to the first year postpartum. Postpartum weight retention includes PWG, the early postpartum weight loss (from delivery to 6 weeks of postpartum), and late postpartum loss (subsequent weight changes in the postpartum year [114]. Early postpartum weight loss is from the combined weight of the infant, placenta, amniotic fluid, and water accumulated during pregnancy. Depending on the size of the infant and amount of water accumulated, the loss will be about 7 kg (15 lb). However, with an average PWG of 12–14 kg, 4–6 kg is the maternal fat gain, often referred to as "baby fat." Therefore, late postpartum weight loss requires loss of maternal fat that was acquired to support the pregnancy. With excessive PWG, there is even greater fat deposition and the mother has yet more weight to lose.

The pattern of postpartum weight changes was examined in multi-ethnic women (n = 985) aged 18–41 years with 2 consecutive births between 1980 and 1990 [18]. Early postpartum weight change (6 weeks of postpartum) was similar in all four groups. However, the underweight and normal-weight groups lost more late postpartum weight even though their average PWG was greater. The higher (overweight and obese) BMI groups gained less during pregnancy but had diminished weight loss in the later postpartum period. This demonstrated that early postpartum loss is simply a reversal of physiological processes of pregnancy but late postpartum loss requires an alteration in maternal fat stores.

Another multi-ethnic study of young women aged 14–25 years (n = 427) reported that nearly two-thirds had excessive PWG. Of those, 33% of the young women moved to a higher BMI category in the first-year postpartum resulting in 68% being overweight or obese [97].

Excessive PWG is the single greatest contributor to postpartum weight retention and subsequent life-long obesity and related co-morbidities [19, 113]. However, this is further compounded by acculturation/globalization, for example, acquisition of Western patterns of eating and more sedentary work [68, 69, 115]; ethnicity, as women of color are less likely to lose postpartum weight or to gain weight in the postpartum period [116, 117]; short interpregnancy interval [118]; and lower socioeconomic status [119].

Obviously, diminishing postpartum weight retention is greatly dependent on gaining appropriately during pregnancy and not "eating for two." Health workers and midwives should prepare pregnant women for exclusive breastfeeding for at least 6 months not only for the well-known health benefits to the baby but for the increased metabolic expenditure needed for lactation [120]. In women who exclusively breastfed for even 6 months, postpartum weight retention was eliminated in women with average PWG and any weight gain was reduced in all but women with BMI ≥35 kg/m^2 [121]. Each additional week of breastfeeding resulted in an additional postpartum loss or 1.5 lb [97]. In the longer term, breastfeeding has effects on the mother's health beyond postpartum. Middle-aged women who never breastfed were compared to those who breastfed for even 3 months and had waist circumferences of 6.5 cm greater, 28% more central obesity, and therefore greater risk for cardiovascular disease [122].

Therefore, beyond the direct positive effect on postpartum weight retention, and the benefits to the infant, breastfeeding positively influences the mother's trajectory of cardiovascular risk.

5. Conclusions

Achieving appropriate pregnancy weight gain is necessary to optimize maternal, infant, and population health but it is not easily done. Promoting healthy weight gain during pregnancy is an investment in both the mother's longevity and the next generation. As health workers, we see the individual and societal outcomes when women gain too much or too little in pregnancy. Women who gain too much suffer the health consequences from obesity and its associated morbidities. Women who gain suboptimally have infants with more susceptibility to disease and death. The platform of excessive pregnancy weight gain is that up to 50% of women in certain countries start pregnancy overweight or obese. Though the first wave of obesity seen in developed countries is slowing, the developing countries have now taken the globesity baton as they transition to Western eating and more sedentary lifestyles. Women who are young, in their first pregnancy, and who start pregnancy with a high body mass index are much more likely to gain excessively and their more complicated pregnancies come at a cost to their health in the short term and long term. Women who do not have proper access to food and start pregnancy undernourished may ultimately not be able to supply the necessary nutrients for optimal growth and development of their infant.

During pregnancy, it is customary for women to solicit and process advice. Pregnancy weight gain is a topic in which women must receive advice that is based on evidence. As health workers we are the source of this evidence, whether from a local ministry of health or from a weight gain guideline that is recognized as applicable to women of your area. Basic pregnancy weight gain guidelines are as follows: women who are underweight or normal weight need to gain more pregnancy weight than do overweight and obese women. Overweight and obese women do not need additional fat stores as do women in lower BMI categories. Most of the weight gained in pregnancy should be from mid-pregnancy to term as this is the period of fetal growth. In early pregnancy, some women may not gain any weight or may even lose some weight. This is acceptable as long as there are no signs of dehydration or disease. All women need a balance of energy and protein in the second and third trimesters for the rapidly developing fetus. Avoiding excessive gain will dramatically lessen the chance of retaining weight during postpartum and ending up in a high BMI category by the next pregnancy. Exclusive breastfeeding for at least 6 months benefits the infant, increases maternal metabolism and has protective effects for cardiovascular disease in middle age. Pregnancy weight gain is important in the short term and in the long term.

Conflict of interest

I have no financial interests to disclose.

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Notes/thanks/other declarations

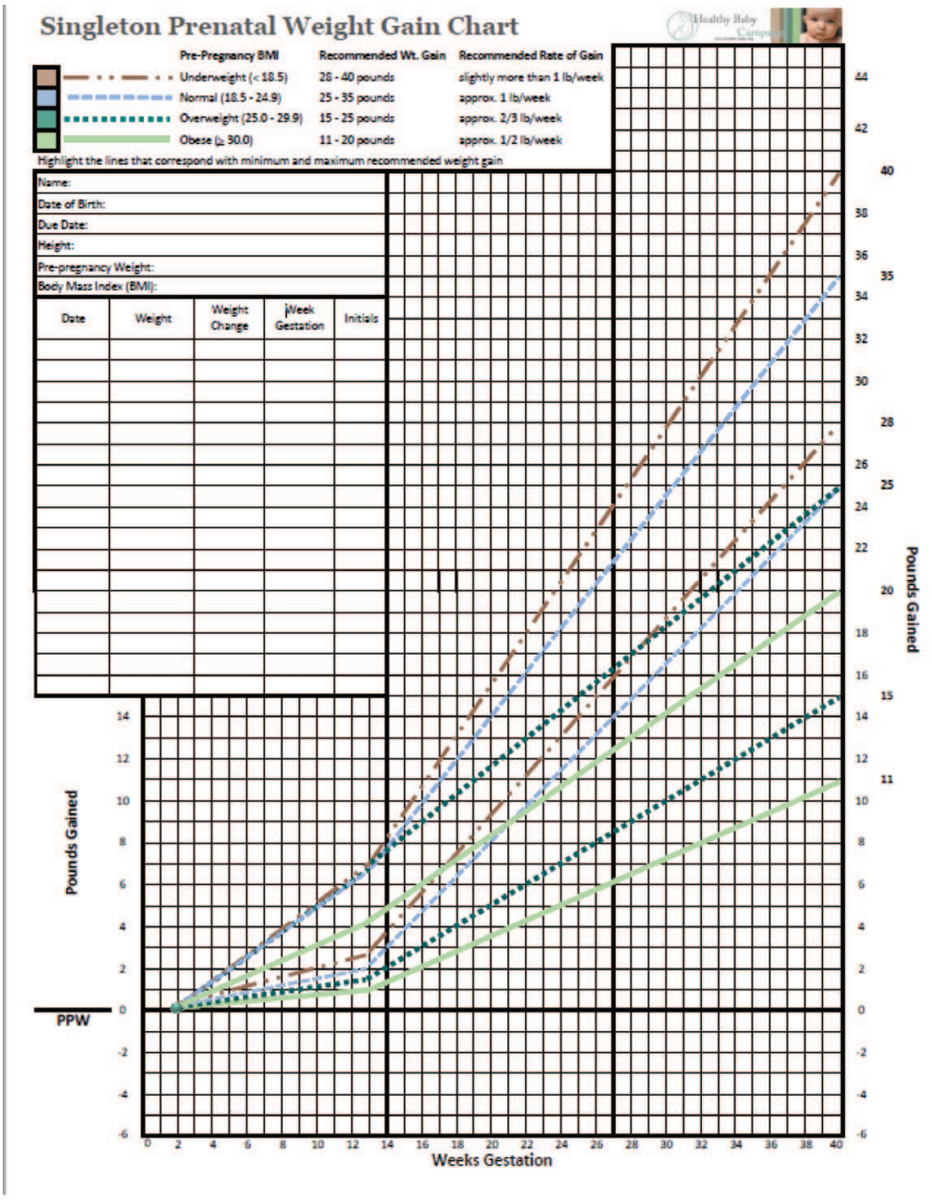
I must recognize the army of doctors, midwives and health workers who strive to make birth safer for the women and babies of the world. Thank you for doing much with little and for your joy in this wonderful work that we are blessed to do!

A. Appendix

Nutritional Interventions for a Positive Pregnancy		
Dietary interventions	Counselling about healthy eating and keeping physically active during pregnancy is recommended for pregnant women to stay healthy and to prevent excessive weight gain during pregnancy. Note: A healthy diet contains adequate energy, protein, vitamins and minerals, obtained through the consumption of a variety of foods, including green and orange vegetables, meat, fish, beans, nuts, whole grains and fruit.	Recommended
	In undernourished populations, nutrition education on increasing daily energy and protein intake is recommended for pregnant women to reduce the risk of low-birth-weight neonates.	Context-specific recommendation
	In undernourished populations, balanced energy and protein dietary supplementation is recommended for pregnant women to reduce the risk of stillbirths and small-for-gestational-age neonates.	Context-specific recommendation
	In undernourished populations, high-protein supplementation is not recommended for pregnant women to improve maternal and perinatal outcomes.	Not recommended
Iron and folic acid supplements	Daily oral iron and folic acid supplementation with 30 mg to 60 mg of elemental iron and 400 g (0.4 mg) of folic acid is recommended for pregnant women to prevent maternal anemia, puerperal sepsis, low birth weight, and preterm birth.	Recommended
	Intermittent oral iron and folic acid supplementation with 120 mg of elemental iron and 2800 g (2.8 mg) of folic acid once weekly is recommended for pregnant women to improve maternal and neonatal outcomes if daily iron is not acceptable due to side-effects, and in populations with an anemia prevalence among pregnant women of less than 20%.	Context-specific recommendation
Calcium supplements	In populations with low dietary calcium intake, daily calcium supplementation (1.5–2.0 g oral elemental calcium) is recommended for pregnant women to reduce the risk of pre-eclampsia.	Context-specific recommendation
Vitamin A supplements	Vitamin A supplementation is only recommended for pregnant women in areas where vitamin A deficiency is a severe public health problem to prevent night blindness.	Context-specific Recommendation

Adapted from: World Health Organization. WHO recommendations on antenatal care for a positive pregnancy experience. Geneva, Switzerland: WHO Press; 2016. p. 14 *Summary list of WHO recommendations on antenatal care (ANC) for a positive pregnancy* experience.

B. Appendix



Colorado Department of Health Care Policy and Financing. Prenatal Plus Program 2018 [Available from: https://www.colorado.gov/pacific/hcpf/prenatal-plus-program].

Colorado Department of Health Care Policy and Financing [54].

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C. Appendix

BMI Chart:

American Institute for Cancer Research; "Heal Well Guide 2013"

Height	Weight	Weight in Pounds (without clothes)												
4'11"	*94<*	*99*	*104*	*109*	*114*	*119*	*124*	*128*	*133*	*138*	*143*	*148*	*173*	*198*
5'	97	102	107	112	118	123	128	133	138	143	148	153	179	204
5'1"	100	106	111	116	122	127	132	137	143	148	153	158	185	211
5'2"	104	109	115	120	126	131	136	142	147	153	158	164	191	218
5'3"	107	113	118	124	130	135	141	146	152	158	163	169	197	225
5'4"	110	116	122	128	134	140	145	151	157	163	169	174	204	232
5'5"	114	120	126	132	138	144	150	156	162	168	174	180	210	240
5'6"	118	124	130	136	142	148	155	161	167	173	179	186	216	247
5'7"	121	127	134	140	146	153	159	166	172	178	185	191	223	255
5'8"	125	131	138	144	151	158	164	171	177	184	190	197	230	262
5'9"	128	135	142	149	155	162	169	176	182	189	196	203	236	270
5'10"	132	139	146	153	160	167	174	181	188	195	202	207	243	278
5'11"	136	143	150	157	165	172	179	186	193	200	208	215	250	286
6'	140	147	154	162	169	177	184	191	199	206	213	221	258	294
6'1"	144	151	159	166	174	182	189	197	204	212	219	227	265	302
6'2"	148	155	163	171	179	186	194	202	210	218	225	233	272	311
BMI	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**35**	**40**

Author details

Ruth Mielke

Address all correspondence to: ruthmielke@fullerton.edu

California State University, Fullerton, Fullerton, California, United States

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