Taiwanese Journal of Obstetrics & Gynecology 54 (2015) 421–425

Contents lists available at ScienceDirect

Taiwanese Journal of Obstetrics & Gynecology

journal homepage: www.tjog-online.com

Original Article

Gestational weight gain and risks for adverse perinatal outcomes: A retrospective cohort study based on the 2009 Institute of Medicine guidelines

Tai-Ho Hung [a, b, *], Szu-Fu Chen [c], Jenn-Jeih Hsu [a], T'sang-T'ang Hsieh [a]

[a] Department of Obstetrics and Gynecology, Taipei Chang Gung Memorial Hospital, Taipei, Taiwan
[b] Department of Chinese Medicine, College of Medicine, Chang Gung University, Taoyuan, Taiwan
[c] Department of Physical Medicine and Rehabilitation, Cheng Hsin Rehabilitation Medical Center, Taipei, Taiwan

ARTICLE INFO

Article history:
Accepted 29 June 2015

Keywords:
Institute of Medicine
large for gestational age
pregnancy outcomes
small for gestational age
weight gain

ABSTRACT

Objective: To investigate perinatal outcomes according to the 2009 Institute of Medicine (IOM) gestational weight gain (GWG) guidelines.
Materials and methods: A retrospective cohort study was conducted among all term, singleton, live births to women who delivered at the Taipei Chang Gung Memorial Hospital, Taipei, Taiwan between 2009 and 2014. Women were categorized into three groups based on prepregnancy body mass index and GWG relative to the IOM guidelines. Multivariable logistic regression analysis was used to assess the associations between GWG outside the IOM guidelines and adverse perinatal outcomes. Women with GWG within the guidelines served as the reference group.
Results: Of 9301 pregnancies, 2574 (27.7%), 4189 (45.0%), and 2538 (27.3%) women had GWG below, within, and above the IOM guidelines. Women with GWG above the IOM guidelines were at risk for preeclampsia [adjusted odds ratio (OR) 3.0, 95% confidence interval (CI) 1.9–4.7], primary cesarean delivery (adjusted OR 1.4, 95% CI 1.2–1.6) due to dysfunctional labor and cephalopelvic disproportion, large-for-gestational age (adjusted OR 1.8, 95% CI 1.5–2.1), and macrosomic neonates (adjusted OR 2.2, 95% CI 1.6–3.1). Women with GWG below the IOM guidelines were more likely to be diagnosed with gestational diabetes mellitus (adjusted OR 1.5, 95% CI 1.3–1.8) and were at higher risk for placental abruption (adjusted OR 1.7, 95% CI 1.1–2.5), small-for-gestational age (adjusted OR 1.6, 95% CI 1.4–1.9), and low birth weight neonates (adjusted OR 1.9, 95% CI 1.4–2.4).
Conclusion: Women with GWG outside the 2009 IOM guidelines were at risk for adverse maternal and neonatal outcomes.

Introduction

In 2009, the Institute of Medicine (IOM) published revised guidelines for weight gain during pregnancy [1]. Key changes made from the previous 1990 IOM recommendations include: (1) the adoption of the body mass index (BMI) categories developed by the International Obesity Task Force and endorsed by the World Health Organization, thus providing a consistent and universal message to both women and health care providers about weight status; (2) a change in the cut-off points for the prepregnancy BMI category, resulting in a smaller proportion of women classified as underweight and a larger proportion classified as overweight; and (3) a specific and relatively narrow range of weight gain recommended for obese women instead of a lower limit. The recommendation is for underweight, normal weight, overweight, and obese women to gain 12.5–18 kg, 11.5–16 kg, 7–11.5 kg, and 5–9 kg, respectively. The 2009 IOM weight gain guidelines were subsequently endorsed by the Ministry of Health and Welfare, Taiwan, and are incorporated into the Maternal Health Booklet for every pregnant woman in Taiwan.

Nevertheless, there have been only a few studies examining maternal and neonatal outcomes in relation to the 2009 IOM guidelines [2–11]. Most of these studies were performed on the American or European populations [2,6–11] and have mainly

* Corresponding author. Department of Obstetrics and Gynecology, Taipei Chang Gung Memorial Hospital, 199 Dun-hua North Road, Taipei 105, Taiwan.
E-mail address: thh20@cgmh.org.tw (T.-H. Hung).

http://dx.doi.org/10.1016/j.tjog.2015.06.010

focused on the association between weight gain and neonatal birth weight [4–8]. Data on whether adherence to the guidelines is associated with improved maternal and neonatal outcomes in Taiwanese women remain scarce. Therefore, we conducted a retrospective cohort study to investigate the associations between adverse perinatal outcomes and gestational weight gain (GWG) above or below the 2009 IOM guidelines.

Materials and methods

A retrospective cohort study was conducted among all term, singleton, live births to women who delivered at the Taipei Chang Gung Memorial Hospital, Taipei, Taiwan between 2009 and 2014. The study data were obtained from a computerized obstetrics database, which included demographic characteristics, medical and obstetric histories, and information regarding the course of the index pregnancy and perinatal outcomes. The data in this database were collected by trained personnel through daily abstraction from the medical and delivery records and via *postpartum* interviews, if necessary, to collect supplemental information. Audits of these data were routinely performed every 2 weeks at the departmental meetings. The study was approved by the Institutional Review Board of Chang Gung Memorial Hospital.

We analyzed all deliveries after 37 0/7 weeks of gestation ($n = 9972$), excluding pregnancies complicated by multiple gestations ($n = 466$), fetal chromosomal or structural anomalies ($n = 101$), and fetal demise ($n = 46$). Women with chronic hypertension ($n = 28$) and prepregnancy diabetes mellitus ($n = 30$) were also excluded. Overall, a total of 9301 deliveries were selected for the present analysis. Figure 1 depicts the sample selection process.

In this hospital, all pregnant women were measured for the height and self-reported prepregnancy weight was recorded at their first antenatal visit. Height and self-reported prepregnancy weight were used to calculate the prepregnancy BMI [calculated as weight (kg)/height $(m)^2$], which was further categorized into four groups: underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (≥30.0 kg/m^2).

GWG was calculated by subtracting each individual woman's prepregnancy weight from her weight at delivery. Women were categorized into three groups based on prepregnancy BMI and GWG relative to the IOM guidelines: (1) weight gain below, (2) weight within, and (3) weight gain above the IOM guidelines.

Perinatal outcomes were compared between the three groups of women, using GWG within the IOM guidelines as the reference group. We examined the following maternal outcomes: gestational diabetes mellitus (GDM), preeclampsia, premature rupture of membranes, acute chorioamnionitis, induction of labor, placental abruption, placenta accreta, *postpartum* hemorrhage (>500 mL for vaginal delivery and >1000 mL for cesarean delivery), operative vaginal delivery, severe perineal injury (3^{rd} and 4^{th} degree perineal injury), and primary cesarean delivery (defined as a cesarean delivery performed for the first time on a pregnant woman). Neonatal outcomes examined were low birth weight (<2500 g), small-for-gestational age (SGA, defined as a birth weight below the 10^{th} percentile for the mean weight corrected for fetal sex and gestational age), large-for-gestational age (LGA, defined as a birth weight above the 90^{th} percentile for the mean weight corrected for fetal sex and gestational age), macrosomia (>4000 g), 1-minute and 5-minute Apgar score < 7, and neonatal intensive care unit admission.

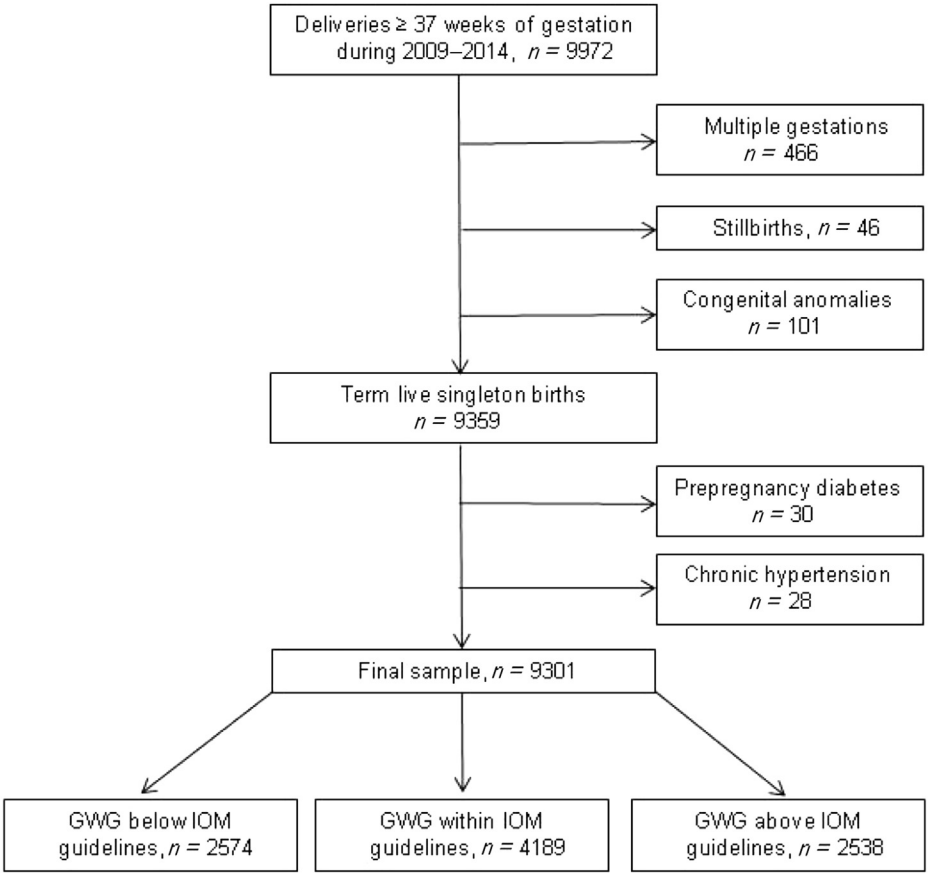

Figure 1. Diagram of patient selection. GWG = gestational weight gain; IOM = Institute of Medicine.

Statistical analyses were performed using SPSS software, version 20.0 (SPSS Inc., Armonk, NY, USA). The categorical variables were calculated as *n* (%) and were compared between the groups using the χ^2 test. A p value < 0.05 was considered to be statistically significant. Multivariable logistic regression analysis was used to control for potential confounding when assessing the associations between adverse perinatal outcomes and GWG above or below the IOM guidelines. Adjusted odds ratios (OR) and 95% confidence intervals (CI) were calculated to describe the relative risk.

Results

Of the 9301 women analyzed in this study, 1312 (14.1%) were underweight, 6995 (72.0%) were of normal weight, 828 (8.9%) were overweight, and 166 (1.8%) were obese based on their prepregnancy BMI category. Of these women, 2574 (27.7%) women had GWG below, 4189 (45.0%) within, and 2538 (27.3%) above the IOM guidelines. As for the relationship between each prepregnancy BMI category and GWG according to the IOM guidelines (Table 1), approximately 44% of women of underweight had weight gain below the IOM guidelines. By contrast, more than half of the overweight or obese women had weight gain in excess of the IOM guidelines.

Table 2 shows the maternal and pregnancy characteristics associated with GWG relative to IOM guidelines. Women older than 34 years at delivery, of underweight, and having genetic amniocentesis were more likely to gain weight below the IOM guidelines. By contrast, characteristics associated with GWG above the IOM guidelines included maternal age of 20–34 years, overweight or obese, primiparity, and having induction of labor.

Table 3 summarizes the association between adverse maternal outcomes and GWG according to IOM guidelines. Compared to women with GWG in concordance with the IOM guidelines, the women who gained less than the IOM guidelines were more likely to be diagnosed with GDM (adjusted OR 1.5, 95% CI 1.3–1.8) and had increased risk for placental abruption (adjusted OR 1.7, 95% CI 1.1–2.5). By contrast, women who had GWG above IOM guidelines were at risk for preeclampsia (adjusted OR 3.0, 95% CI 1.9–4.7) and primary cesarean delivery (adjusted OR 1.4, 95% CI 1.2–1.6) due to dysfunctional labor (adjusted OR 1.3, 95% CI 1.1–1.5) and cephalopelvic disproportion (adjusted OR 1.6, 95% CI 1.2–2.2).

The associations between adverse neonatal outcomes and GWG relative to the IOM guidelines are shown in Table 4. Women with GWG below the IOM guidelines were more likely to have low birth weight (adjusted OR 1.9, 95% CI 1.4–2.4) or SGA neonates (adjusted OR 1.6, 95% CI 1.4–1.9) compared to the women with GWG within the IOM guidelines. By contrast, the risk for a LGA fetus or macrosomia increased two fold in the women who gained more than the IOM guidelines compared to the women who had weight gain within the IOM guidelines.

Table 1
Gestational weight gain according to prepregnancy body mass index category.

Weight gain	Underweight[a] (n = 1312)	Normal weight[b] (n = 6995)	Overweight[c] (n = 828)	Obese[d] (n = 166)
Below IOM guidelines	574 (43.8)	1879 (26.9)	94 (11.4)	27 (16.3)
Within IOM guidelines	612 (46.6)	3243 (46.4)	280 (33.8)	54 (32.5)
Above IOM guidelines	126 (9.6)	1873 (26.8)	454 (54.8)	85 (51.2)

Data presented as *n* (%).
IOM = Institute of Medicine.
[a] Underweight, prepregnancy body mass index (BMI) < 18.5 kg/m^2.
[b] Normal weight, prepregnancy BMI = 18.5–24.9 kg/m^2.
[c] Overweight, prepregnancy BMI = 25.0–29.9 kg/m^2.
[d] Obese, prepregnancy BMI ≥30 kg/m^2.

Table 2
Characteristics of the study population with gestational weight gain relative to Institute of Medicine (IOM) guidelines.

Characteristic	Below IOM guidelines	Within IOM guidelines	Above IOM guidelines	p
Age (y)				
<20	6 (0.2)	8 (0.2)	2 (0.1)	0.333
20–34	1622 (63.0)***	2815 (67.2)	1804 (71.1)**	<0.001
>34	946 (36.8)***	1366 (32.6)	732 (28.8)**	<0.001
Prepregnancy weight category				
Underweight	574 (22.3)***	612 (14.6)	126 (5.0)***	<0.001
Normal weight	1879 (73.0)***	3243 (77.4)	1873 (73.8)**	<0.001
Overweight	94 (3.7)***	280 (6.7)	454 (17.9)***	<0.001
Obese	27 (1.0)	54 (1.3)	85 (3.3)***	<0.001
Primiparity	1309 (50.9)***	2338 (55.8)	1573 (62.0)***	<0.001
Prior induced abortion	763 (29.6)	1241 (29.6)	784 (30.9)	0.500
Prior fetal death	22 (0.9)	38 (0.9)	23 (0.9)	0.972
Prior preterm birth	9 (0.3)	13 (0.3)	5 (0.2)	0.546
Conception by ART	48 (1.9)	53 (1.3)	41 (1.6)	0.137
Genetic amniocentesis	1029 (40.0)*	1560 (37.2)	892 (35.1)	0.002
Smoking during pregnancy	3 (0.1)	10 (0.2)	7 (0.3)	0.386
GBS colonization	379 (14.7)	645 (15.4)	391 (15.4)	0.717
Male fetus	1261 (49.0)*	2164 (51.7)	1325 (52.2)	0.042
Placenta previa	48 (1.9)	98 (2.3)	51 (2.0)	0.380
Epidural analgesia	1283 (49.8)	2128 (52.1)	1326 (52.2)	0.137
Induction of labor	385 (15.0)***	818 (19.5)	624 (24.6)***	<0.001

Data presented as *n* (%).
The p values are based on the Chi-square test; *p < 0.05; **p < 0.01; and ***p < 0.001, compared to women with gestational weight gain within IOM guidelines based on logistic regression analysis.
ART = artificial reproductive technology; GBS = group B streptococci.

Table 3
Adverse maternal outcomes associated with gestational weight gain according to the Institute of Medicine (IOM) guidelines.

Outcome	Below IOM guidelines (n = 2574)	Within IOM guidelines (n = 4189)	Above IOM guidelines (n = 2538)	Below vs. within Adjusted OR (95% CI)	Above vs. within Adjusted OR (95% CI)
Gestational diabetes mellitus	296 (11.5)	342 (8.2)	195 (7.7)	1.5 (1.3–1.8)[a]	0.8 (0.6–0.9)[a]
Preeclampsia	16 (0.6)	31 (0.7)	71 (2.8)	0.9 (0.5–1.7)[a]	3.0 (1.9–4.7)[a]
Premature rupture of membranes	8 (0.3)	13 (0.3)	8 (0.3)	1.0 (0.4–2.5)[a]	0.9 (0.4–2.3)[a]
Chorioamnionitis	12 (0.5)	37 (0.9)	25 (1.0)	0.6 (0.3–1.2)[a]	0.9 (0.5–1.5)[a]
Placental abruption	49 (1.9)	46 (1.1)	24 (0.9)	1.7 (1.1–2.5)[a]	0.9 (0.6–1.5)[a]
Placenta accreta	11 (0.4)	16 (0.4)	14 (0.6)	1.0 (0.5–2.2)[a]	1.7 (0.8–3.5)[a]
Postpartum hemorrhage	43 (1.7)	76 (1.8)	39 (1.5)	0.9 (0.6–1.4)[a]	0.8 (0.6–1.3)[a]
Operative vaginal delivery	67 (2.6)	129 (3.1)	81 (3.2)	0.9 (0.7–1.2)[b]	1.0 (0.8–1.4)[b]
Severe perineal injury	155 (6.0)	253 (6.0)	115 (4.5)	1.1 (0.9–1.4)[c]	0.7 (0.5–0.9)[c]
Primary cesarean delivery	501 (19.5)	996 (23.8)	809 (31.9)	0.8 (0.7–0.9)[d]	1.4 (1.2–1.6)[d]
Dysfunctional labor	157 (6.1)	439 (10.5)	381 (15.0)	0.6 (0.5–0.7)[d]	1.3 (1.1–1.5)[d]
Malpresentation	181 (7.0)	283 (6.8)	166 (6.5)	1.0 (0.8–1.3)[d]	0.9 (0.7–1.1)[d]
Abnormal FHR pattern	79 (3.1)	137 (3.3)	104 (4.1)	1.0 (0.8–1.3)[d]	1.1 (0.9–1.5)[d]
Cephalopelvic disproportion	47 (1.8)	80 (1.9)	100 (3.9)	1.0 (0.7–1.5)[d]	1.6 (1.2-2.2)[d]

Data presented as n (%).
CI = confidence interval; FHR = fetal heart rate; OR = odds ratio.
[a] Adjusted for maternal age at delivery, prepregnancy weight category, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tracts, and fetal sex.
[b] Adjusted for maternal age at delivery, prepregnancy weight category, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tracts, fetal sex, and intrapartum epidural analgesia.
[c] Adjusted for maternal age at delivery, prepregnancy weight category, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tracts, fetal sex, intrapartum epidural analgesia, and operative vaginal delivery.
[d] Adjusted for maternal age at delivery, prepregnancy weight category, parity, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tracts, fetal sex, intrapartum epidural analgesia, and placenta previa.

Table 4
Adverse neonatal outcomes associated with gestational weight gain according to the Institute of Medicine (IOM) guidelines.

Outcome	Below IOM guidelines (n = 2574)	Within IOM guidelines (n = 4189)	Above IOM guidelines (n = 2538)	Below vs. within Adjusted OR (95% CI)[a]	Above vs. within Adjusted OR (95% CI)[a]
Low birth weight	126 (4.9)	107 (2.6)	41 (1.6)	1.9 (1.4–2.4)	0.6 (0.4–0.9)
Small-for-gestational age	278 (10.8)	288 (6.9)	116 (4.6)	1.6 (1.4–1.9)	0.7 (0.5–0.8)
Large-for-gestational age	117 (4.5)	342 (8.2)	356 (14.0)	0.5 (0.4–0.7)	1.8 (1.5–2.1)
Macrosomia	23 (0.9)	63 (1.5)	92 (3.6)	0.6 (0.4–1.0)	2.2 (1.6–3.1)
1-minute AS < 7	18 (0.7)	23 (0.5)	18 (0.7)	1.3 (0.7–2.5)	1.2 (0.7-2.3)
5-minute AS < 7	0	2 (0.0)	2 (0.1)	—	1.6 (0.2–11.8)
NICU admission	37 (1.4)	55 (1.3)	30 (1.2)	1.1 (0.7–1.7)	0.9 (0.5–1.4)

Data presented as n (%).
AS = Apgar score; CI = confidence interval; NICU = neonatal intensive care unit; OR = odds ratio.
[a] Adjusted for maternal age at delivery, prepregnancy weight category, parity, prior induced abortion, prior fetal death, prior preterm birth, conception methods, genetic amniocentesis, smoking during pregnancy, group B streptococcal colonization at the genitorectal tracts, fetal sex, intrapartum epidural analgesia, and placenta previa.

Discussion

Consistent with most prior studies [2–8,10,11], we found significant associations between excessive GWG and increased birth weight (macrosomia) and fetal growth (LGA) and between inadequate GWG and decreased birth weight (low birth weight) and fetal growth (SGA) with respect to the 2009 IOM guidelines. These results underscore the importance of adherence to the weight gain recommendations to optimize neonatal outcomes.

Our previous study showed that a high prepregnancy BMI is associated with the development of preeclampsia [12]. Here, we further demonstrated that women with GWG above the 2009 IOM guidelines had a three-fold increased risk for preeclampsia compared to the women who had GWG within the guidelines, even adjusting for the confounding effects of prepregnancy BMI category. This finding is consistent with most previous studies regarding excessive GWG and the risk for preeclampsia [2,3,9–11]. Although the exact etiology of preeclampsia remains unclear, there is mounting evidence that preeclampsia can manifest as a result of generalized maternal endothelial activation, increased inflammatory state, and metabolic disorders [13,14]. It is possible that excessive GWG causes alterations in lipid concentrations and oxidative stress, subsequently leading to increased maternal inflammatory response and endothelial activation [15,16]. Indeed, a recent meta-analysis found strong evidence that hyperglyceridemia is associated with and precedes the onset of preeclampsia [17]. Nevertheless, in a review of a total of 13 studies on dietary intervention to prevent excessive weight gain during pregnancy, Tanentsapf et al [18] found that dietary intervention significantly reduced total GWG, weight retention at 6 months *postpartum*, and the risk of cesarean delivery, but had no effect on the incidence of preeclampsia. Alternatively, the excessive GWG in women with preeclampsia may be caused by increased fluid retention within the third space, a feature of preeclampsia that is commonly seen in the third trimester. Further studies are needed to clarify the causal relationship between excessive GWG and preeclampsia.

Similar to previous reports [2–4,10,11], we found that women with GWG above the IOM guidelines were more likely to have cesarean delivery. We further demonstrated that this increased risk of cesarean delivery was probably related to increased odds for dysfunctional labor and cephalopelvic disproportion. Both conditions are closely related to increased fetal size (LGA and macrosomia), which is also more common in women with GWG above the IOM guidelines.

In addition to preeclampsia, a high prepregnancy BMI is a well-recognized risk factor for GDM [19] and several previous studies have shown that women with excessive GWG are at increased risk for GDM. However, in this study, we found that women with GWG below the IOM guidelines had a higher rate of GDM than the women with GWG within the guidelines. The explanations for this discrepancy are not clear. It is possible that less total weight gain during pregnancy in women with GDM was due to the result of treatment of GDM, including nutritional therapy, modification of life style, regular monitoring of blood sugar levels, and insulin treatment [20]. Indeed, women who were later diagnosed with GDM were reported to have greater GWG before undergoing the screening test at 24 weeks of gestation compared to the women without GDM [21,22].

Our previous study showed that women with a low prepregnancy BMI were at increased risk for placental abruption [23]. In the present study, we further demonstrated that women with GWG below the IOM guidelines also had a higher risk for placental abruption. Similarly, by analyzing more than one million delivery records, Salihu et al [24] found that women whose GWG was less than the IOM recommendations had a 67% increased likelihood of placental abruption, while those who gained more than the recommended amount of weight had a 30% reduced risk for placental abruption, compared with the women who gained weight within the IOM recommendations. Several animal experiments and observational studies have suggested the potential role of micronutrients such as zinc, β-carotene, and vitamins in pregnancy complications including placental abruption [25,26]. Together, these results suggest that maternal nutrition may contribute to the development of placental abruption.

The strength of this study lies in its ability to include both nulliparous and multiparous women and to adjust for as many confounding factors as possible, as well as the use of patient interview and medical record data rather than relying on vital statistics or birth certificate data; thus, the associations between maternal and neonatal outcomes and GWG with respect to the 2009 IOM guidelines could be objectively investigated.

However, several limitations of our study require attention. First, the prepregnancy weight was self-reported, which is subject to recall error and can lead to under- or overestimation of GWG. Second, this study was limited by its observational and retrospective design. There might be unmeasured confounders that were not have accounted for in this study. Third, this study has a limited sample size of some important but rare pregnancy complications, such as birth injury and neonatal death. Finally, although we have examined the associations between excessive or inadequate GWG and adverse perinatal outcomes, we were not able to confirm the causal relationship. Further studies including information regarding the timing of the diagnosis of preeclampsia and GDM relative to weight gain would help clarify these associations.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

Acknowledgments

This work was partly supported by the Ministry of Science and Technology, Taiwan (103-2314-B-182A-099-MY2) to T.H.H and Chang Gung Memorial Hospital (CMRPG1C0072) to T.T.H.

References

[1] Institute of Medicine and National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines. Weight gain during pregnancy: reexamining the guidelines. Washington (DC): National Academies Press; 2009.
[2] Haugen M, Brantsaeter AL, Winkvist A, Lissner L, Alexander J, Oftedal B, et al. Associations of pre-pregnancy body mass index and gestational weight gain with pregnancy outcome and *postpartum* weight retention: a prospective observational cohort study. BMC Pregnancy Childbirth 2014;14:201.
[3] Li N, Liu E, Guo J, Pan L, Li B, Wang P, et al. Maternal prepregnancy body mass index and gestational weight gain on pregnancy outcomes. PLoS One 2013;8:e82310.
[4] Asvanarunat E. Outcomes of gestational weight gain outside the Institute of Medicine Guidelines. J Med Assoc Thai 2014;97:1119–25.
[5] Wen T, Lv Y. Inadequate gestational weight gain and adverse pregnancy outcomes among normal weight women in China. Int J Clin Exp Med 2015;8:2881–6.
[6] Ferrari N, Mallmann P, Brockmeier K, Struder HK, Graf C. Secular trends in pregnancy weight gain in German women and their influences on foetal outcome: a hospital-based study. BMC Pregnancy Childbirth 2014;14:228.
[7] Chihara I, Hayes DK, Chock LR, Fuddy LJ, Rosenberg DL, Handler AS. Relationship between gestational weight gain and birthweight among clients enrolled in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), Hawaii, 2003–2005. Matern Child Health J 2014;18:1123–31.
[8] Chen A, Xu F, Xie C, Wu T, Vuong AM, Miao M, et al. Gestational weight gain trend and population attributable risks of adverse fetal growth outcomes in Ohio. Paediatr Perinat Epidemiol 2015;29:346–50.
[9] de la Torre L, Flick AA, Istwan N, Rhea D, Cordova Y, Dieguez C, et al. The effect of new *antepartum* weight gain guidelines and prepregnancy body mass index on the development of pregnancy-related hypertension. Am J Perinatol 2011;28:285–92.
[10] Johnson J, Clifton RG, Roberts JM, Myatt L, Hauth JC, Spong CY, et al. Pregnancy outcomes with weight gain above or below the 2009 Institute of Medicine guidelines. Obstet Gynecol 2013;121:969–75.
[11] Truong YN, Yee LM, Caughey AB, Cheng YW. Weight gain in pregnancy: does the Institute of Medicine have it right? Am J Obstet Gynecol 2015;212.362 e1–8.
[12] Lee CJ, Hsieh TT, Chiu TH, Chen KC, Lo LM, Hung TH. Risk factors for preeclampsia in an Asian population. Int J Gynaecol Obstet 2000;70:327–33.
[13] Redman CW, Sargent IL. Placental stress and pre-eclampsia: a revised view. Placenta 2009;30(Suppl. A):S38–42.
[14] Chaiworapongsa T, Chaemsaithong P, Yeo L, Romero R. Pre-eclampsia part 1: current understanding of its pathophysiology. Nat Rev Nephrol 2014;10:466–80.
[15] Hung TH, Burton GJ. Hypoxia and reoxygenation: a possible mechanism for placental oxidative stress in preeclampsia. Taiwan J Obstet Gynecol 2006;45:189–200.
[16] Zavalza-Gómez AB. Obesity and oxidative stress: a direct link to preeclampsia? Arch Gynecol Obstet 2011;283:415–22.
[17] Gallos ID, Sivakumar K, Kilby MD, Coomarasamy A, Thangaratinam S, Vatish M. Pre-eclampsia is associated with, and preceded by, hypertriglyceridaemia: a meta-analysis. BJOG 2013;120:1321–32.
[18] Tanentsapf I, Heitmann BL, Adegboye AR. Systematic review of clinical trials on dietary interventions to prevent excessive weight gain during pregnancy among normal weight, overweight and obese women. BMC Pregnancy Childbirth 2011;11:81.
[19] Torloni MR, Betran AP, Horta BL, Nakamura MU, Atallah AN, Moron AF, et al. Prepregnancy BMI and the risk of gestational diabetes: a systematic review of the literature with meta-analysis. Obes Rev 2009;10:194–203.
[20] Hung TH, Hsieh TT. The effects of implementing the International Association of Diabetes and Pregnancy Study Groups criteria for diagnosing gestational diabetes on maternal and neonatal outcomes. PLoS One 2015;10:e0122261.
[21] Gibson KS, Waters TP, Catalano PM. Maternal weight gain in women who develop gestational diabetes mellitus. Obstet Gynecol 2012;119:560–5.
[22] Carreno CA, Clifton RG, Hauth JC, Myatt L, Roberts JM, Spong CY, et al. Excessive early gestational weight gain and risk of gestational diabetes mellitus in nulliparous women. Obstet Gynecol 2012;119:1227–33.
[23] Hung TH, Hsieh CC, Hsu JJ, Lo LM, Chiu TH, Hsieh TT. Risk factors for placental abruption in an Asian population. Reprod Sci 2007;14:59–65.
[24] Salihu HM, Diamond E, August EM, Rahman S, Mogos MF, Mbah AK. Maternal pregnancy weight gain and the risk of placental abruption. Nutr Rev 2013;71(Suppl. 1):S9–17.
[25] Christian P. Micronutrients and reproductive health issues: an international perspective. J Nutr 2003;133:1969S–73S.
[26] Sharma SC, Bonnar J, Dóstalóva L. Comparison of blood levels of vitamin A, beta-carotene and vitamin E in abruptio placentae with normal pregnancy. Int J Vitam Nutr Res 1986;56:3–9.