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The effects of pre-pregnancy body mass index and gestational weight gain on neonatal birth weight in Taiwan

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The aim of this retrospective study was to explore the effects of pre-pregnancy body mass index and gestational weight gain on neonatal birth weight in Taiwan. Study subjects included two hundred and sixty three women who delivered their babies at two local hospitals in southern Taiwan. Initial data included maternity records on age, parity, socio-economic status, body mass index (BMI), pregnancy weight gain, neonatal gender, and neonatal birth weight. The mean age of 263 women was 29.99 years (range 19 - 42). The mean BMI was 21.19 kg/m^2 (range 16.22 - 32.05), and the mean pregnancy weight gain was 13.98 kg (range 3 - 33.5). The mean neonatal birth weight was 3192.57 gm (range 2120 - 4390). Mothers whose BMI was 24 - 27 had significantly higher neonatal birth weight than those mothers with a BMI > 27 and < 18.5) (F = 5.816, p = 0.001). After dividing the weight gain during pregnancy into four groups based on the recommendation of the Department of Health in Taiwan, our results show differences between maternal weight gain and neonatal body weight (F = 9.49, p < 0.001). Pregnant women with a weight gain less than 10 kg resulted in deliveries of neonates with lower birth weight (113.94, 237.62 and 332.58 gm) than those mothers who gained 10 - 14, 14 – 16 kg, and more than 16kg. Multiple regression models control for other maternal and neonatal characteristics were able to document, weight gain as being more strongly associated with neonatal birth weight than pre-pregnancy body mass index. Neonatal birth weight was not correlated with maternal working status, socio-economical status and was not differentiated between primipara and multipara status. Conclusively, pre-pregnancy BMI and prenatal weight gain are related to neonatal birth weight. These results suggest that the pre-pregnancy BMI and prenatal weight gain should be among the most important concerns for providers offering prenatal services. Hopefully these findings will serve as a useful reference for prenatal nurses and will reinforce health insurance departments' efforts to ensure quality prenatal care.

Key words: Body mass index, pregnancy weight gain, neonatal birth weight.

INTRODUCTION

Evidence-based research on the prevention and management of appropriate weight gain during pregnancy are critical for health care providers (Stotland et al., 2005; Chen et al., 2010). Neonatal birth weight is a most important pregnancy outcome that is determined by several criteria such as, maternal age, parity, pre-pregnancy BMI, weight gain during pregnancy, gestational age, and neonatal gender (Achadi et al., 1995; Thorsdottir and Birgisdottir, 1998; Chen et al., 2010). BMI can be calculated by taking the weight in kilograms divided by the square of height in meters (kg/m^2). This formula, documented in recent guidelines published by the Institute of Medicine (IOM) (Institute of

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Table 1. Comparison of the recommended gestational weight gain of Institute of Medicine and Department of * Health.

	Institute of Medicine*		Department of Health**	
	BMI (kg/m^2)	Weight Gain (kg)	BMI (kg/m^2)	Weight Gain (kg)
Underweight	< 18.5	12.7 – 18.2	<18.5	14 - 16
Normal	18.5 – 24.9	11.4 – 15.9	18.5-24	10 - 14
Overweight	25.0 – 29.9	6.8 – 11.4	24-27	10 - 14
Obese	≥ 30.0	5 - 9.1	> 27	At least 7 - 10

BMI = Body Mass Index.* Adapted from US Department of Health and Human Services; **Adapted from Taiwan Department of Health.

Medicine [IOM], 2009) has been widely used in recommending weight gain during pregnancy (in the United States. In Taiwan, the categories of BMI and weight gain during pregnancy are not the same as the recommendations in this most recent IOM report (2009). The different recommendations for weight gain of pregnant women between the United States and Taiwan is shown in Table 1.

Studies show that the greater the maternal weight gain, the higher the neonatal birth weight (Thorsdottir and Birgisdottir, 1998; Chen et al., 2010; Abrams and Selvin, 1995). Additional studies demonstrate a relationship between weight gain during pregnancy and BMI. For example, obese women tend to gain less weight during pregnancy (Graves et al., 2006; Maddah, 2005; Achadi et al., 1995; Copper et al., 1995; Chen et al., 2010; Weisman et al., 2010). In contrast, Maddah's study (2005) of pregnancy weight gain in 704 Iran women documented women with the lowest pre-pregnancy BMI (< 19.6) group had a mean weight gain of 11.39 kg, which was higher than other groups (BMI = 19.6 - 26, 9.88 kg; BMI > 26, 9.11 kg). The trend of neonatal birth weight demonstrates a positive correlation with n pre-pregnancy BMI and weight gain. The findings show that women with underweight pre-pregnancy BMI and weight gain less than IOM recommendation have an increased in the prevalence of low neonatal birth weight (Maddah, 2005; Graves et al., 2006; Frederick et al., 2008). Moreover, maternal obesity and inappropriate weight gain during pregnancy increases the prevalence of macrosomia (Chen et al., 2010, Frederick et al., 2008), the rate of cesarean section (Kumari, 2001; Fraser, 2006; Graves et al., 2006) and childhood obesity (Heinzer, 2005). Additional factors effecting neonatal birth weight include maternal age, parity and gender (Thorsdottir and Birgisdottir, 1998; Abrams and Selvin, 1995; Frederick et al., 2008), and male newborns weight more than female (Abrams and Selvin, 1995; Achadi et al., 1995; Frederick et al., 2008).

In Taiwan, there are ten free prenatal care clinics supported by the National Health Insurance. The pre-pregnancy BMI and weight gain will serve as a useful reference for prenatal services. Yet, there has been limited research on the gestational weight gain related to neonatal birth weight outcome from women accessing care from these services. The purpose of this retrospective study is to determine whether a women's BMI and the maternal weight gain effects neonatal birth weight.

MATERIALS AND METHODS

This retrospective study was conducted between July 2006 and May 2007, in two local hospitals in southern Taiwan. The criteria of subjects were over 18 years of age and delivered a full term and healthy infant without complications.

Data quality

After obtaining informed consent, information for this study on maternal age, parity, pre-pregnancy weight and height, education level, and working status were obtained by interview with a structured data sheets. The patient identifiers (that is, name) were de-linked from data being collected and that participation in the study did not impact their ability to receive care. Socioeconomic status (SES) based on education and occupation divided into three categories, high SES, middle SES, and low SES. The number of days of gestation was calculated using women's recall of the date of their last menstrual period and the date of birth. Categories of pre-pregnancy body mass index (BMI) were < 18.5 (under weight), 18.5 - 24 (normal), 24 - 27 (overweight), and > 27(obese). Weight gain during pregnancy was calculated as weight at the end of pregnancy minus weight before pregnancy. Categories of weight gain during pregnancy (kg) were stratified by the recommendation of the Taiwan Department of Health (DOH, 2002), > 16, 14 - 16, 10 - 14, and 7 - 10 kg. Infant characteristics, neonatal birth weight and sex, were abstracted from delivery records. The study was approved by Hospital Ethics Committee.

Data analyses

Data analyses were carried out by using the Statistical Package for Social Science (SPSS 12.0 for Windows Program). Student's *t* test and analysis of variance (ANOVA) were used to assess the association between neonatal birth weight and characteristics of maternal and newborn. To assess the effects of pre-pregnancy body mass index and gestational weight gain on neonatal birth weight, the neonatal birth weight was set as dependent variable. After controlling the confounding variables, we used hierarchical regression to assess the relationship between BMI and neonatal birth weight, weight gain and neonatal birth weight. $P < 0.05$ was considered as the level of significance.

Table 2. Association between pre-pregnancy BMI and weight gain in pregnancy.

Weight gain (kg)	BMI < 18.5 n (%)	18.5 - 24 n (%)	24 - 27 n (%)	> 27 n (%)	Total* n (%)
< 10	6 (2.3)	25 (9.5)	2 (0.8)	8 (3.0)	41 (15.6)
10 – 14	15 (5.7)	76 (28.9)	7 (2.7)	8 (3.0)	106 (40.3)
14 – 16	7 (2.7)	30 (11.4)	5 (1.9)	0 (0)	42 (16.0)
> 16	6 (2.3)	58 (22.1)	8 (3.0)	2 (0.8)	74 (28.1)
Total n (%)	34 (12.9)	189 (71.9)	22 (8.4)	18(6.8)	263 (100)

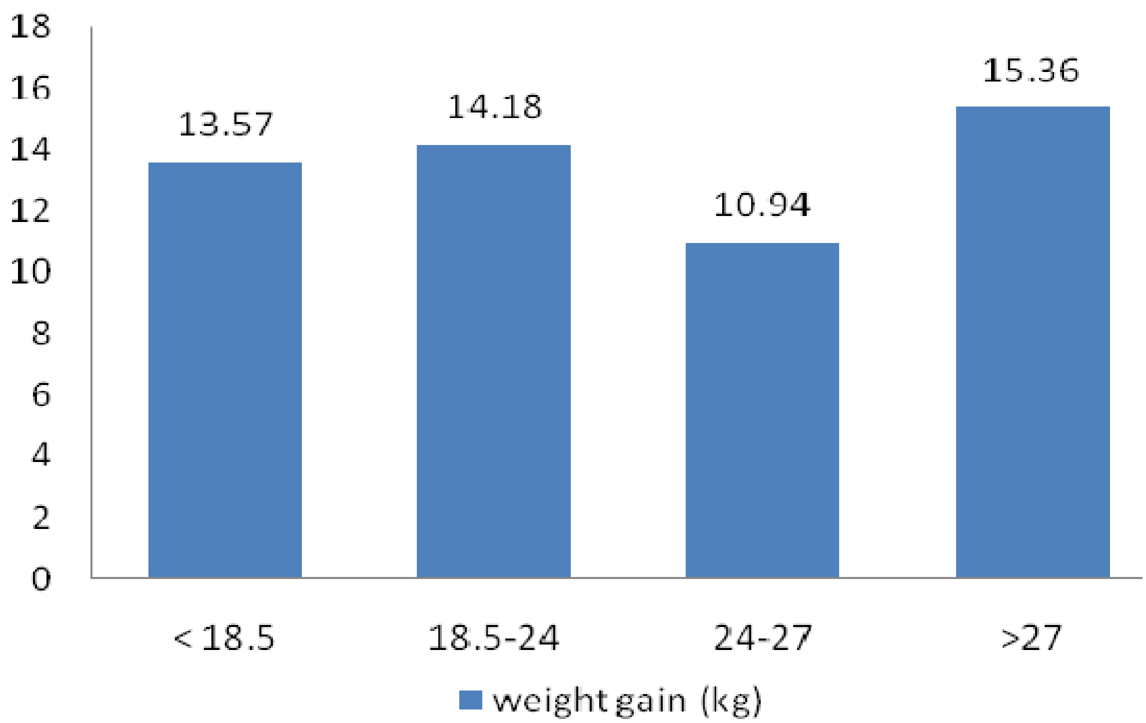

Figure 1. The mean weight gain among four BMI groups.

RESULTS

Two hundred and sixty three women were included in this study. 60% of women were primipara, and 40% were multipara. To illustrate the relationship between the BMI and weight gain, we divided the study group by pregnancy weight gain and BMI according to those categories used by the Taiwan DOH. This data was entered into a 4 × 4 table. Overall, 71.9% (n = 189) of women had normal BMI, 12.9% (n = 34) were underweight, 8.4% (n = 22) were overweight, and 6.8% (n = 18) were obese. There were 37.3% (n = 98) of women gained weight within the cut-point recommended data by Taiwan DOH, and 18.3% women weight gain below and 44.4% above the recommended data by DOH (Table 2). The weight gain in the underweight group was 13.57 kg, normal group was 14.18 kg, obese group was 10.94 kg, and overweight group was 15.36 kg (Figure 1). One-way ANOVA was used to assess the effect of four groups on weight gain. There was a significant difference in weight gain among these four BMI groups ($F = 3.59$, $p = 0.014$). The mean weight gain in the overweight group was higher than other groups. However, the weight gain was lower for the obese group than for the other three groups.

The socio-demographic and characteristics of the women and newborns were compared by using t- test and analysis of variance to test the difference between the means of newborn birth weight (Table 3). There were no significant differences on mother's working status, social economic status, parity, type of labor and type of neonatal sex. The correlation of BMI and weight gain during pregnancy was not significant ($r = -0.117$,

Table 3. Neonatal birth weight (gm) by maternal and neonatal characteristics.

Characteristic	Mean	SD	t/F	P
Age			-2.34	0.02
(1) ≤30	3146.32	369.14	(2) > (1)	
(2) > 30	3254.92	375.92		
Mother's work			0.48	0.63
Housewife	3208.03	417.95		
Working	3184.66	352.37		
SES			2.35	0.10
High	3270.38	378.04		
Middle	3178.41	380.31		
Low	3115.00	330.99		
Parity			-0.002	1.00
Primipara	3192.54	381.75		
Multipara	3192.62	366.95		
Labor type			-0.52	0.61
NSD	3202.04	372.14		
C/S	3177.38	381.44		
			-1.87	0.06
Neonatal sex				
Male	3234.27	380.16		
Female	3147.91	366.06		
BMI			5.82	.001
(1) < 18.5	2983.97	252.18		
(2) 18.5 - 24	3214.19	387.75	(2) > (1)	
(3) 24 – 27	3372.27	307.68	(3) > (1), (4)	
(4) > 27	3140.00	360.07		
Total weight gain			9.49	0<.001
(1) < 10	3015.12	365.91		
(2) 10 – 14	3129.07	323.66		
(3) 14 – 16	3252.74	333.59	(3) > (1)	
(4) > 16	3347.70	410.74	(4) > (1), (2)	

Note. t = computed value of t test, F = computed value of ANOVA test.

p = 0.059), nor was the correlation of BMI with neonatal birth weight (r = 0.118, p = 0.056). However, after dividing BMI into four DOH weight groups and comparing the mean neonatal birth weight in these four BMI groups, the findings indicate that mothers with an overweight BMI (24 - 27) had significantly higher neonatal birth weight than obese mothers with a BMI > 27 and underweight mother with a BMI < 18.5 (F = 5.816, p = 0.001). Weight gain during pregnancy was highly correlated with neonatal birth weight (r = 0.334, p < 0.001). After dividing the weight gain during pregnancy into four groups, the results showed there were significant differences between maternal weight gain and their neonatal body weight (F = 9.486, p < 0.001). Women with a pregnancy weight gain less than10 kg resulted in mean neonatal birth weight 113.94 gm lower than weight gain with 10 – 14 kg (p = 0.085), 237.62 gm lower than weight gain with 14 – 16 kg (p = 0.003), and 332.58 gm lower than weight gain over 16 kg (p < 0.001). To explore the strength of the relationship between BMI and neonatal birth weight, two sets of independent variables were entered in steps and carried out by analysis of covariance, with variables

Table 4. Hierarchical multiple regression: BMI estimates neonatal birth weight (n = 263).

Predictor	Intercept	B	Beta	Adjusted R^2	F change
Step I	-1332.74			0.173	11.94***
Gestational age (d)		13.48***	0.22		
Neonatal sex (male)		76.27	0.10		
Maternal age (y)		12.69*	0.14		
Multipara *		25.10	0.03		
Weight gain (kg)		27.20***	0.33		
Step II	-1599.43			0.194	7.65**
Gestational age (d)		12.73***	0.21		
Neonatal sex (male)		80.35	0.11		
Maternal age (y)		13.96 **	0.15		
Multipara *		4.93	0.01		
Weight gain (kg)		28.51***	0.35		
BMI		19.94**	0.16		

* p < 0.05, ** p < 0.01,*** p < 0.001. * Reference group is primipara * .

retained in sequential blocks. The first block included gestational age, neonatal sex, maternal age, parity, and weight gain. The second block was BMI. The outcome variable was neonatal birth weight. Step one of the regression model accounted for a statistically significant proportion of the variance in the neonatal birth weight (adjusted R^2 = 17.3%, $p < 0.001$). The beta coefficients in this step showed that gestational age, maternal age, and weight gain significantly explained the variance. BMI was also statistically significant and accounted for an additional 2.4% of the variance in the neonatal birth weight (Table 4).

To explore the strength of the relationship between weight gain and neonatal birth weight, two sets of independent variables were entered in steps, with variables retained in sequential blocks. The first block included gestational age, neonatal sex, maternal age, parity, and BMI. The second block was weight gain. The outcome variable was neonatal birth weight. Step one of the regression model accounted for a statistically significant proportion of the variance in the neonatal birth weight (adjusted R^2 = 7.5%, $p < 0.001$). The beta coefficients in this step showed that gestational age, neonatal sex, maternal age, and BMI significantly explained the variance. In the step 2, weight gain was also statistically significant and accounted for an additional 11.9% of the variance in the neonatal birth weight (Table 5).

DISCUSSION

The effects of maternal pre-pregnancy BMI and weight gain during pregnancy on birth outcomes have been discussed in numerous studies. Studies indicate that the maternal indicators of pre-pregnancy body mass index (BMI) and weight gain in pregnancy were important predictors of neonatal birth weight (Abrams and Selvin, 1995; Maddah, 2005; Thorsdottir and Birgisdottir, 1998; Chen et al., 2010; Frederick et al., 2008). In this study, we found the mean BMI was coincident with the recommendation of Taiwan DOH (2002) (t = -0.36, p = 0.72). Although, previous studies (Maddah, 2005; Copper et al., 1995; Achadi et al., 1995) have shown that greater pre-pregnancy BMI results in lower weight gain during pregnancy, our findings is not consistence with these findings. After stratifying BMI into four groups and analyzing the weight gain among these groups, this study determined the mean weight gain in the underweight group was less than the weight gain recommended by the DOH. The three remaining BMI groups gained more weight than that recommended by the DOH. The women in this study gained more weight during pregnancy than that which has been documented in other studies (e.g., Maddah, 2005). For adequate prenatal nutrition education, more detail investigation to assess the pattern of trimester weight gain is needed.

In conducting regression analyses, we found that weight gain was more strongly associated with neonatal birth weight than pre-pregnancy body mass index. These findings are consistent with some reports of gestational weight gain and neonatal birth weight (Edwards et al., 1996; Chen et al., 2010). In our study, the obese group had lower neonatal birth weight than the overweight group. Although this outcome is inconsistent with Kumari's study (2001), it could be explained that pregnant women in Kumari's study with BMI > 40 had an increase incidence of gestational diabetes which is associated with

Table 5. Hierarchical multiple regression: weight gain estimates neonatal birth weight (n = 263).

Predictor	Intercept	B	Beta	Adjusted R^2	F change
Step I	-1186.63			0.075	5.265***
Gestational age (d)		13.17***	0.22		
Neonatal sex (male)		94.15*	0.13		
Maternal age (y)		12.81*	0.14		
Multipara *		-19.87	-0.03		
BMI		15.31*	0.12		
Step II	-1599.43			0.194	38.675***
Gestational age (d)		12.73***	0.21		
Neonatal sex (male)		80.35	0.11		
Maternal age (y)		13.96**	0.15		
Multipara *		4.93	0.01		
BMI		19.94**	0.16		
Weight gain (kg)		28.51***	0.35		

* $p < .05$, ** $p < .01$,*** $p < .001$. * Reference group is primipara.

an increase incidence of marosomia.

Studies have shown that male newborns weight more than female (Abrams and Selvin, 1995; Achadi et al., 1995; Frederick et al., 2008) and maternal weight gain, maternal age, and parity of mother are associated with neonatal birth weight (Achadi et al., 1995). Hierarchical multiple regression models in our study show the gestational age and weight gain of women during pregnancy are the most important predictor of neonatal birth weight. Maternal age and BMI are also positive predictors of neonatal birth weight; however, the gender of newborns and parity of mother were not associated with neonatal birth weight based on our multiple regression analysis.

In order to improve maternal and newborn health, numerous studies recommend that women maintain a normal BMI range and an adequate to weight gain during pregnancy. (Achadi et al., 1995; Copper et al., 1995; IOM, 2009). There are few studies that examine the relationship among BMI, weight gain and neonatal birth weight in Taiwan. Additional studies are needed to assess other variables that can impact neonatal birth weight such as, complications in pregnancy, the rate of preterm delivery and other lifestyle factors such as smoking.

This study supports findings suggest appropriate pregnancy weight gain as a more important predictor of neonatal birth weight than pre-pregnancy body mass. Based on our findings, we conclude that prenatal counseling of women regarding an appropriate weight gain in relation to their pre-pregnancy BMI must be considered an important part of prenatal visits. Accordingly, attention needs to be paid to nutrition consulting offered by health providers during prenatal visits.

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