

ORIGINAL ARTICLE

Relationships between pregnancy outcomes, biochemical markers and pre-pregnancy body mass index

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Objective: We examined the relationships between pre-pregnancy maternal body mass index (BMI), pregnancy outcomes and biochemical markers.

Design: This study was conducted as a cross-sectional analysis.

Subjects: Korean women in their second and third trimesters of pregnancy were recruited at two hospitals in the metropolitan Seoul area. Pre-pregnancy BMI was categorized in four groups according to the Asia-Pacific standard.

Measurements: Fasting blood samples were obtained and analyzed for serum levels of homocysteine, folate and high-sensitivity C-reactive protein (hs-CRP). Concentrations of fetal fibronectin were assessed in the cervix and vagina, and cervical length was measured.

Results: Obese subjects had a lower education level and a lower income level than subjects of normal weight. The level of maternal stress was positively associated with pre-pregnancy BMI. Normal weight subjects were more likely to eat breakfast and consume meals of appropriate size than the rest of our sample. In overweight and obese subjects, weight gain during pregnancy was significantly lower than in the underweight and normal subjects. High pre-pregnancy maternal BMI increased the risks of preterm delivery (odds ratio (OR) = 2.85, confidence interval (CI) = 1.20–6.74), low-birth-weight (LBW) infants (overweight subjects: OR = 5.07, CI = 1.76–14.63; obese subjects: OR = 4.49, CI = 1.54–13.13) and macrosomia. In obese subjects, the average serum folate level was significantly lower than in the underweight subjects. In obese subjects, the average serum hs-CRP level was significantly higher than in the rest of our sample.

Conclusion: Pregnancy outcomes are influenced by pre-pregnancy BMI. These findings suggest that women can minimize their risks of preterm delivery, LBW and macrosomia by maintaining normal pre-pregnancy BMI.

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Keywords: pre-pregnancy BMI; preterm delivery; low birth weight; macrosomia

Introduction

Women with low pre-pregnancy body mass index (BMI) ($<19.8 \text{ kg m}^{-2}$) experience high risk of delivering low-birth-weight (LBW) newborns, whereas women with high pre-pregnancy BMI ($>29.0 \text{ kg m}^{-2}$) experience increased risk of macrosomia.¹ LBW increases the risks of infant mortality and impaired development.² In Korea, the number

of LBW infants increased from 18 532 in 1993 to 22 725 in 2008.³

A preterm birth is defined as delivery before 37 completed weeks gestation.⁴ Preterm infants experience significant perinatal mortality.⁵ The number of preterm infants born in Korea, increased from 40 114 in 1996 to 62 869 in 2008.³ Studies suggest increased risks of preterm delivery for underweight women, whereas obese women experience significantly lower rates of preterm delivery.^{6,7}

Several biochemical markers are considered to be associated with LBW and preterm delivery. Elevated total homocysteine concentrations in plasma or serum are associated with preeclampsia, intrauterine growth retardation, perinatal death, preterm birth and LBW.^{8–10} Low-serum folate is significantly correlated with increased risks of neural

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tube defects, preterm birth and LBW.¹¹ Elevated levels of C-reactive protein (CRP) are associated with increased risks of preterm delivery and increasing BMI of mother.¹² Finally, the levels of fetal fibronectin (fFN) in the cervix and vagina measured between 22 and 37 weeks gestation are considered potential markers of preterm delivery¹³ and short cervical length is associated with an increased risk of preterm delivery.¹⁴

The available data on pregnancy outcomes associated with pre-pregnancy maternal BMI are inconsistent. Some studies^{6,7} report increased risk of preterm delivery among underweight women, whereas others¹⁵ report increased risk of preterm delivery among obese women. Previous studies have only rarely investigated the relationships between biochemical markers such as homocysteine, folate, high sensitivity CRP, fFN or cervical length and pre-pregnancy BMI. In this study, we examined the relationships between pre-pregnancy maternal BMI, pregnancy outcomes and biochemical markers.

Subjects and methods

Subjects

Subjects were recruited at MizMedi Hospital and Ewha Womans University Hospital, Seoul, Korea between April 2006 and April 2009. A total of 830 pregnant women in their second and third trimesters (19–39 weeks) participated in this study. After excluding subjects with incomplete height and weight records, 608 subjects were included in this analyses. General and obstetric characteristics, anthropometric measurements, and information regarding health habits and nutrient intake were obtained through interviews using a standardized questionnaire. The general and obstetric questions addressed age, educational level, income level, occupation status, number of family members, gestational period at baseline, total number of pregnancies and morning sickness. Weight gain during pregnancy was calculated by subtracting the pre-pregnancy weight from weight just before delivery. Pre-pregnancy BMI was calculated using self reported height and pre-pregnancy weight. We collected information on health habits, including smoking, alcohol drinking, coffee drinking, stress, weight reduction attempts, physical activity and exercise status. The stress levels of the subjects were measured using a questionnaire developed by Holmes *et al.*¹⁶ and classified as low (scores <12) or high (scores ≥12) out of a possible total score of 41.¹⁷ The subjects' dietary habits were assessed by assessing meal frequency, frequency of eating breakfast, regularity of mealtimes, amount consumed at each meal and frequency of eating out. Data regarding weight before delivery, gestational age, neonate weight and neonate height were collected from hospital records after delivery. Pre-pregnancy BMI was categorized in four groups according to the Asia-Pacific standard: the underweight group

(<18.5 kg m⁻²), normal weight group (18.5–22.9 kg m⁻²), overweight group (23.0–24.9 kg m⁻²) and obese group (≥25 kg m⁻²).¹⁸

Methods

Fasting blood samples were obtained from subjects during the second and third trimesters (19–39 weeks) of pregnancy, and the serum levels of homocysteine, folate and hs-CRP were measured. The samples were collected into a serum separating tube (plain tube). Serum were separated by centrifugation at 3000 r.p.m. for 15 min and stored at -70 °C until analysis. Serum homocysteine concentration levels was determined by fluorescent polarization immunoanalysis using an automatic analyzer (Hitachi 7180, Daiichi, Japan) with a Liquid Stable 2-Part Homocysteine Reagent Kit (Catch, Bothell, WA, USA). The upper limit of homocysteine reference values was taken as 15.0 μmol l⁻¹.¹⁹ Serum folate levels were measured by radioimmunoassay²⁰ with a vitamin B12/folate dual radioassay kit (MP Biomedicals, Huntsville, AL, USA). The normal range for this assay is 3–16 ng ml⁻¹.²¹ Serum hs-CRP levels were measured by a latex immunoturbidimetric assay²² that uses latex particles with monoclonal anti-CRP antibody, and performed on automatic analyzers (Hitachi 7080). The interassay and intraassay coefficients of variation were both <10%.²³ Concentrations of fFN in vaginal secretions were measured by enzyme-linked immunosorbent assay²⁴ using a human fFN PTD check (Adeza Biomedical, Sunnyvale, CA, USA), with concentrations greater than or equal to 50 ng ml⁻¹ considered as positive. Cervical length was measured by 3D ultrasonography (Accuvix XQ, Seoul, Korea). Cervical length was measured by tracing from the internal os to the external os in cervix cannal. The cutoff value for cervical length is 25 mm. This is cutoff value of below the tenth percentile at 24 weeks of gestation for prediction of preterm delivery.²⁵

Statistical analyses

Statistical analyses were performed with SPSS for Windows, version 17.0. The statistical differences among the four groups were analyzed by ANOVA with *post-hoc* analysis via Tukey's test. The values are presented as mean ± s.d. The χ^2 test was used to identify significant differences between groups. The risks of preterm delivery, LBW and macrosomia are presented as adjusted odds ratios (ORs) with the 95% confidence interval (CI) computed by binary logistic analysis. Results were considered significant when $P < 0.05$.

Results

The results of general and obstetric maternal characteristics according to pre-pregnancy BMI are reported in Table 1. The maternal age was significantly lower in the underweight

Table 1 General and obstetric characteristics of mothers according to pre-pregnancy BMI

	Pre-pregnancy BMI				P-value
	Underweight (n = 111)	Normal weight (n = 363)	Overweight (n = 67)	Obese (n = 67)	
Gestational period at baseline (week)	27.8 ± 4.6 ^a	26.3 ± 4.2	26.1 ± 3.7	27.3 ± 5.0	0.060 ^b
Age (years)	30.7 ± 3.6 ^a	32.3 ± 4.0 ^b	32.8 ± 3.7 ^b	32.9 ± 3.8 ^b	<0.001
<i>Educational years</i>					
≤12	17 (17.0) ^c	56 (17.3)	16 (25.8)	30 (50.8)	<0.001 ^d
>12	83 (83.0)	268 (82.7)	46 (74.2)	29 (49.2)	
<i>Monthly income level (\$)</i>					
≤1800	14 (14.1)	41 (12.8)	11 (17.7)	19 (32.8)	0.002
>1800	85 (85.9)	279 (87.2)	51 (82.3)	39 (67.2)	
<i>Employment status</i>					
Yes	33 (32.4)	126 (39.7)	28 (45.2)	11 (20.0)	0.014
No	69 (67.6)	191 (60.3)	34 (54.8)	44 (80.0)	
Number of family members (person)	2.7 ± 1.0	2.7 ± 0.9	3.0 ± 1.1	3.0 ± 1.3	0.076
Total number of pregnancies	1.9 ± 1.1 ^a	2.2 ± 1.2 ^{ab}	2.0 ± 1.0 ^{ab}	2.4 ± 1.3 ^b	0.025
<i>Morning sickness</i>					
Yes	45 (50.0)	119 (40.8)	36 (62.1)	21 (42.0)	0.018
No	45 (50.0)	173 (59.2)	22 (37.9)	29 (58.0)	

Abbreviation: BMI, body mass index. BMI (kg m^{-2}) categories according to the Asia-Pacific standard: underweight (<18.5), normal weight (18.5–22.9), overweight (23.0–24.9), obese (≥ 25). ^aMean ± s.d. ^bP-value by analysis of variance. ^cN (%). ^dP-value by χ^2 -test. Values followed by different alphabets within the same row are significantly different at $P < 0.05$ by Tukey's test.

Table 2 Maternal anthropometric characteristics according to pre-pregnancy BMI

	Pre-pregnancy BMI				P-value
	Underweight (n = 111)	Normal weight (n = 363)	Overweight (n = 67)	Obese (n = 67)	
Height (cm)	162.8 ± 4.6 ^b	161.3 ± 4.7 ^{ab}	161.0 ± 4.2 ^a	160.1 ± 4.8 ^a	0.002 ^b
Pre-pregnancy weight (kg)	46.8 ± 3.2 ^a	53.2 ± 4.1 ^b	61.7 ± 3.6 ^c	71.1 ± 8.1 ^d	<0.001
Pre-pregnancy BMI (kg m^{-2})	17.6 ± 0.7 ^a	20.4 ± 1.2 ^b	23.8 ± 0.5 ^c	27.7 ± 2.5 ^d	<0.001
Body weight at delivery (kg)	60.5 ± 6.0 ^a	66.9 ± 6.5 ^b	73.4 ± 6.2 ^c	81.7 ± 9.3 ^d	<0.001

Abbreviation: BMI, body mass index. BMI (kg m^{-2}) categories according to the Asia-Pacific standard: see Table 1. ^aMean ± s.d. ^bP-value by analysis of variance. Values followed by different alphabets within the same row are significantly different at $P < 0.05$ by Tukey test.

group than the other groups ($P < 0.001$). The percentage of subjects with less than 12 years of education was significantly higher in the obese group than in the other groups. The percentage of subjects with monthly income below \$1800 was significantly higher in the obese group than in the other groups. Furthermore, the obese group had a higher rate of unemployment than the other groups ($P < 0.05$). Therefore, the obese group had an overall lower education level ($P < 0.001$), lower income level and higher rate of unemployment ($P < 0.05$).

The risk of obesity increased with increasing total number of pregnancies. The percentage of women experiencing morning sickness was significantly higher in the overweight group than in the other groups ($P < 0.05$).

The results of maternal anthropometric characteristics according to pre-pregnancy BMI are reported in Table 2. Maternal height in the underweight group was significantly ($P < 0.05$) taller than the overweight and obese groups.

Pre-pregnancy weights and BMIs were significantly (< 0.001) different among the groups.

The results of maternal health-related habits with regard to pre-pregnancy BMI are reported in Table 3. Most of the pregnant women quit smoking and drinking alcohol when they recognized their pregnancy. No significant differences were found in frequency of coffee consumption among the groups. The frequency of pre-pregnancy weight reduction attempts was significantly high in the obese group ($P < 0.05$) than in the other groups. The percentages of subjects who reported high stress levels were significantly higher in the overweight and obese groups than in the underweight and normal weight groups ($P < 0.001$).

The results of maternal dietary habits according to pre-pregnancy BMI are reported in Table 4. The normal weight group showed higher frequencies of breakfast consumption and proper meal size than the other groups ($P < 0.05$). No significant differences were found in meal frequency,

Table 3 Maternal health-related habits according to pre-pregnancy BMI

	Pre-pregnancy BMI				P-value ^a
	Underweight (n = 111)	Normal weight (n = 363)	Overweight (n = 67)	Obese (n = 67)	
<i>Smoking</i>					
Non-smoker	88 (86.3) ^b	287 (91.1)	56 (90.3)	48 (82.8)	0.197
Ex-smoker	14 (13.7)	28 (8.9)	6 (9.7)	10 (17.2)	
Current smoker	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
<i>Alcohol drinking</i>					
Non-drinker	67 (65.7)	202 (63.9)	34 (54.0)	34 (58.6)	0.698
Ex-drinker	35 (34.3)	113 (35.8)	29 (46.0)	24 (41.4)	
Current drinker	0 (0.0)	1 (0.3)	0 (0.0)	0 (0.0)	
<i>Frequency of coffee drinking</i>					
No	42 (41.6)	133 (41.4)	25 (40.3)	19 (32.2)	0.553
1–2 per week	35 (34.7)	87 (27.1)	16 (25.8)	15 (25.4)	
3–4 per week	15 (14.9)	70 (21.8)	14 (22.6)	16 (27.1)	
> 5 per week	9 (8.9)	31 (9.7)	7 (11.3)	9 (15.3)	
<i>Stress^c</i>					
Low	84 (83.2)	269 (83.5)	40 (64.5)	38 (64.4)	<0.001
High	17 (16.8)	53 (16.5)	22 (35.5)	21 (35.6)	
<i>Pre-pregnancy weight reduction attempt</i>					
Yes	7 (8.0)	69 (23.8)	18 (31.0)	23 (46.9)	<0.001
No	80 (92.0)	221 (76.2)	40 (69.0)	26 (53.1)	
<i>Weight reduction attempt during pregnancy</i>					
Yes	4 (4.6)	9 (3.1)	3 (5.2)	3 (6.0)	0.714
No	83 (95.4)	277 (96.9)	55 (94.8)	47 (94.0)	
<i>Physical activity^d</i>					
Light	62 (69.7)	185 (65.4)	39 (67.2)	33 (68.8)	0.641
Moderate	21 (23.6)	88 (31.1)	18 (31.0)	13 (27.1)	
Heavy	6 (6.7)	10 (3.5)	1 (1.7)	2 (4.2)	
<i>Regular exercise</i>					
≥ 3 times per week	16 (18.0)	64 (22.5)	9 (15.8)	15 (31.3)	0.206
< 2 times per week	73 (82.0)	221 (77.5)	48 (84.2)	33 (68.8)	

Abbreviation: BMI, body mass index. BMI (kg m^{-2}) categories according to the Asia-Pacific standard: see Table 1. ^aP-value by χ^2 -test. ^bN (%). ^clow < 12, high ≥ 12. ^dLight: walk and stand a day less than 2 h, office job and housework; moderate: walk and stand a day for 2–4 h, marketer and teacher; heavy: walk and stand a day for 4–6 h, construction industry and tennis.

regularity of mealtimes or frequency of eating out among the groups.

The pregnancy outcomes of mothers and neonates for all pre-pregnancy BMI categories are reported in Table 5. In the overweight and obese groups, the amount of weight gained during pregnancy was significantly ($P < 0.001$) less than the underweight and normal weight groups. In the overweight and obese groups, gestational age was significantly shorter than in the underweight and normal weight groups ($P < 0.001$). The percentage of women delivering preterm was significantly higher in the overweight and obese groups ($P < 0.006$) than in the underweight and normal weight groups. The frequencies of LBW (< 2.5 kg) and macrosomia (≥ 4 kg) were significantly higher in the overweight and obese groups ($P < 0.001$) than in the other groups. The neonates born to obese mothers were significantly shorter (cm) than those born to mothers of normal weight ($P < 0.02$).

In the normal group (mean birth weight; 3.29 kg), birth weight was significantly ($P < 0.001$) higher than in the preterm group (mean 2.13 kg), and the gestational age of LBW neonates (33.29 weeks) was significantly ($P < 0.001$) shorter than in the normal (38.80 weeks) and macrosomic (39.71 weeks) neonates (data not shown).

The results of biochemical markers and cervical length according to pre-pregnancy BMI category are reported in Table 6. In the obese group, serum folate levels were significantly lower than in the underweight group ($P < 0.05$). In the obese group, serum hs-CRP levels were significantly higher than in the other groups ($P < 0.001$), but serum homocysteine levels, cervical lengths and fFN levels did not significantly differ between groups.

The results of ORs and 95% CI for preterm delivery, LBW and macrosomia according to pre-pregnancy BMI are reported in Table 7. The risk of delivering a preterm was

Table 4 Maternal dietary habits according to pre-pregnancy BMI

	Pre-pregnancy BMI				P-value ^a
	Underweight (n = 111)	Normal weight (n = 363)	Overweight (n = 67)	Obese (n = 67)	
<i>Meal frequency (times per day)</i>					
Once	0 (0.0) ^b	1 (0.3)	1 (1.7)	0 (0.0)	0.693
Twice	29 (29.9)	68 (22.0)	17 (28.8)	12 (23.1)	
Three	59 (60.8)	216 (69.9)	37 (62.7)	34 (65.4)	
Four	3 (3.1)	9 (2.9)	1 (1.7)	1 (1.9)	
Irregular	6 (6.2)	15 (4.9)	3 (5.1)	5 (9.6)	
<i>Breakfast frequency (days per week)</i>					
0–1	20 (22.2)	32 (11.0)	11 (19.0)	10 (20.0)	0.013
2–3	11 (12.2)	29 (9.9)	13 (22.4)	3 (6.0)	
4–5	12 (13.3)	64 (21.9)	10 (17.2)	9 (18.0)	
≥6	47 (52.2)	167 (57.2)	24 (41.4)	28 (56.0)	
<i>Regularity of meal time (three meals a day per week)</i>					
> 6	31 (34.4)	103 (35.6)	15 (25.9)	20 (40.8)	0.750
4–5	47 (52.2)	148 (51.2)	36 (62.1)	24 (49.0)	
< 2–3	12 (13.3)	38 (13.1)	7 (12.1)	5 (10.2)	
<i>Amount of meal^c</i>					
Overeat	20 (22.2)	56 (19.2)	11 (19.0)	10 (20.0)	0.048
Proper	68 (75.5)	230 (79.0)	41 (70.6)	36 (72.0)	
A little	2 (2.2)	5 (1.7)	6 (10.3)	4 (8.0)	
<i>Eating out</i>					
≥2 per day	2 (2.2)	12 (4.2)	1 (1.8)	1 (2.1)	0.487
1 per day	12 (13.3)	48 (16.8)	9 (15.8)	4 (8.5)	
> 1 per week	67 (74.4)	174 (60.8)	40 (70.2)	31 (66.0)	
> 1 per month	6 (6.7)	32 (11.2)	5 (8.8)	8 (17.0)	

Abbreviation: BMI, body mass index. BMI (kg m^{-2}) categories according to the Asia-Pacific standard: see Table 1. ^aP-value by χ^2 -test. ^bN (%). ^cAmount of meal size was measured by self report.

Table 5 Pregnancy outcomes of mothers and neonates according to pre-pregnancy BMI

	Pre-pregnancy BMI				P-value
	Underweight (n = 111)	Normal weight (n = 363)	Overweight (n = 67)	Obese (n = 67)	
Maternal weight gain during pregnancy (kg)	13.72 ± 4.52b ^a	13.71 ± 4.83b	11.59 ± 5.04a	10.36 ± 4.83a	<0.001b
<i>Gestational age (weeks)</i>					
< 37	38.60 ± 2.35c	38.29 ± 2.75bc	37.18 ± 3.82ab	36.88 ± 3.73a	<0.001
≥ 37	17 (17.0) ^c	59 (18.4)	18 (31.6)	22 (33.8)	0.006 ^d
Neonates weight (kg)	3.05 ± 0.53	3.09 ± 0.60	2.94 ± 0.84	2.93 ± 0.77	0.170
< 2.5	10 (10.0)	44 (13.9)	16 (28.6)	17 (26.6)	<0.001
2.5–3.99	89 (89.0)	265 (83.6)	37 (66.1)	42 (65.6)	
≥ 4	1 (1.0)	8 (2.5)	3 (5.4)	5 (7.8)	
Length (cm)	48.96 ± 3.08ab	49.09 ± 3.60b	48.34 ± 4.99ab	47.46 ± 5.48a	0.020

Abbreviation: BMI, body mass index. BMI (kg m^{-2}) categories according to the Asia-Pacific standard: see Table 1. ^aMean ± s.d. ^bP-value by analysis of variance. ^cN (%). ^dP-value by χ^2 -test. Values followed by different alphabets within the same row are significantly different at $P < 0.05$ by Tukey test.

increased in the overweight group (OR = 2.85, CI = 1.20–6.74) and the risk of delivering a LBW infant was increased in the overweight (OR = 5.07, CI = 1.76–14.63) and obese groups (OR = 4.49, CI = 1.54–13.13). The risk of delivering a macrosomia was increased with increasing pre-pregnancy BMI (P for trend = 0.010).

Discussion

In this study, obese mothers were characterized by low educational levels and income levels, and were more likely to be unemployed. Another group of researchers²⁶ reported that repeated exposure to the negative environments

Table 6 Biochemical markers and cervical length according to pre-pregnancy BMI

	Pre-pregnancy BMI				P-value
	Underweight (n = 111)	Normal weight (n = 363)	Overweight (n = 67)	Obese (n = 67)	
Homocysteine ($\mu\text{mol l}^{-1}$)	4.98 \pm 1.58 ^a	4.80 \pm 1.65	5.03 \pm 1.90	5.02 \pm 2.06	0.681 ^b
Folate (ng ml^{-1})	12.01 \pm 6.19 ^b	10.36 \pm 5.72 ^{ab}	10.38 \pm 5.21 ^{ab}	8.09 \pm 4.57 ^a	0.008
Hs-CRP (mg dl^{-1})	0.28 \pm 0.65 ^a	0.29 \pm 0.45 ^a	0.33 \pm 0.27 ^a	0.65 \pm 0.80 ^b	0.001
Cervical length (cm)	3.67 \pm 0.87	3.87 \pm 0.79	3.96 \pm 0.84	3.73 \pm 1.01	0.126
<i>Fetal fibronectin</i>					
Negative	50 (96.2) ^d	189 (95.0)	35 (92.1)	31 (88.6)	0.410 ^d
Positive	2 (3.8)	10 (5.0)	3 (7.9)	4 (11.4)	

Abbreviations: BMI, body mass index; Hs-CRP, high sensitivity C-reactive protein. BMI (kg m^{-2}) categories according to the Asia-Pacific standard: see Table 1. ^aMean \pm s.d. ^bP-value by analysis of variance. ^cN (%). ^dP-value by χ^2 -test. Values followed by different alphabets within the same row are significantly different at $p < 0.05$ by Tukey test.

Table 7 ORs and 95% CIs for preterm delivery, LBW and macrosomia according to pre-pregnancy BMI

	Pre-pregnancy BMI				P-value
	Underweight	Normal-weight	Overweight	Obese	
<i>Preterm delivery (< 37 weeks)</i>					
No. of cases per controls	17/83	59/261	18/39	22/43	0.002 ^a
OR (95% CI) ^b	1	0.91 (0.45–1.87)	2.85 (1.20–6.74)	2.29 (0.97–5.42)	
<i>LBW (< 2.5 kg)</i>					
No. of cases per controls	10/89	44/265	16/37	17/42	<0.001
OR (95% CI) ^c	1	1.61 (0.64–4.07)	5.07 (1.76–14.63)	4.49 (1.54–13.13)	
<i>Macrosomia (> 4 kg)</i>					
No. of cases per controls	1/89	8/265	3/37	5/42	0.010
OR (95% CI) ^c	1	1.97 (0.23–16.61)	4.20 (0.36–48.46)	7.82 (0.85–71.51)	

Abbreviations: BMI, body mass index; CI, confidence interval; LBW, low-birth weight; OR, odds ratio. Pre-pregnancy BMI cutoff categories according to the Asia-Pacific standard: 1 = underweight group (< 18.5), 2 = normal-weight group (18.5–22.9), 3 = overweight group (23.0–24.9), 4 = obese group (≥ 25). ^aP-value for linear trend test. ^bORs and 95% CI were analyzed by logistic regression. OR was adjusted for maternal age, stress. ^cModels adjusted for maternal age, pregnancy experiences.

associated with low educational level and poor socioeconomic status leads to worse health outcomes. People of low socioeconomic status may be at increased risk of obesity because of the higher frequencies of unhealthy behaviors.

We found that total number of pregnancies was positively correlated with pre-pregnancy BMI. Other studies^{27,28} also reported an increased maternal body weight with parity and suggested a strong relationship between parity and weight gain in women.

The percentage of mothers who had morning sickness was higher in the overweight group than in the normal weight group. Other researchers have also reported that the risk of morning sickness increases with the increasing body weight.²⁹

In our study, stress levels were significantly higher in the overweight and obese mothers than in the mothers who were underweight or normal weight. A previous study of mothers of African descent³⁰ reported that higher stress levels were associated with greater weight gain. These results

indicate that women who have higher pre-pregnancy BMI may be expected to experience higher levels of pregnancy-related stress.

Women with unhealthy dietary habits are more likely to be obese.³¹ In this study, subjects of normal weight were more likely to eat breakfast and to consume meals of appropriate size than subjects in the other groups; therefore, normal weight subjects exhibited more desirable dietary habits than underweight, overweight or obese subjects.

We found that weight gain during pregnancy in the overweight and obese groups was significantly lower than in the underweight and normal groups. This result is in agreement with a previous study which reported that weight gain during pregnancy decreased with increasing BMI.³² In this study, we found that the average length of neonates delivered by obese mothers was significantly shorter than the average length of neonates delivered by mothers of normal weight, because of the high rates of preterm and LBW delivery in the obese group.

In this study, serum folate levels were significantly lower in the obese group than in the underweight group, and serum hs-CRP levels were significantly higher in the obese group than in the other groups. Other study have demonstrated that pregnant women delivering preterm infants tend to have lower concentration of folate in serum,³³ and that obese women are at increased risk of delivering infants with neural tube defects.³⁴ Dietary folate supplementation (400 mcg daily) is associated with a 35% decrease in the risk of preterm birth among women of childbearing age, especially those who are obese.³⁵ Obese women of childbearing age should be encouraged to take a folate supplement daily and should receive education regarding the prevention of neural tube defects. It is known that serum CRP levels increase with increasing BMI,³⁶ and that an elevated concentration of maternal serum CRP in early pregnancy is associated with an increased risk of preterm delivery.¹⁵

In this study, high pre-pregnancy BMI increased the risk of preterm delivery, LBW delivery and macrosomia. Khashan and Kenny⁶ reported that the risk of preterm delivery was reduced by almost 10% for overweight (RR=0.89, CI=0.83–0.95) and obese women (RR=0.90, CI=0.84–0.97), but was increased in underweight women (RR=1.33, CI=1.16–1.53). Frederick *et al.*¹ reported that the risk of delivering LBW infants in the underweight group was increased by 51 percent (RR=1.51, CI=1.02–2.25) and that increased BMI is related to an increased risk of macrosomia. These results conflict with our own; however, our results indicate that the concentration of serum folate was significantly lower in the obese group and that the concentration of hs-CRP was significantly higher in the obese group. The relationships that we detected between low folate status and preterm delivery³³ and low folate status and LBW infant delivery³⁷ have been reported previously. Elevated concentrations of maternal serum CRP are associated with increased risk of preterm delivery (OR=2.15, CI=0.85–5.42), and the percentage of preterm deliveries are significantly higher in obese mothers than in mothers of normal weight.¹⁵ Therefore, the increased risk of preterm delivery and the risk of delivering a LBW infant in the obese group that we observed may be explained by low-serum folate and high-hs-CRP levels in our results.

In conclusion, pregnancy outcomes are influenced by pre-pregnancy BMI. Maintaining normal pre-pregnancy BMI reduces the risk of delivering preterm, LBW and macrosomic infants. Women of childbearing age should try to access education, such as books or web-based material, about healthy eating and exercising to maintain a normal weight before becoming pregnant or between pregnancies. Therefore women of childbearing age need to attend to their health and well-being before pregnancy for the health of their infant. Also, obese women of childbearing age who plan to have children should be encouraged to take a folate supplement daily.

Conflict of interest

The authors declare no conflict of interest.

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