

Effect of weight gain during pregnancy on anthropometric measures of the newborn and gestational and neonatal complications: retrospective study on 1,000 Lebanese women admitted at Hôtel-Dieu de France university hospital

Abstract

We hypothesized that an adequate BMI and inappropriate maternal weight gain are responsible for the development of fetal complications. This descriptive and retrospective study was conducted over Lebanese women who delivered at Hôtel-Dieu de France (HDF) from 01/01/2012 to 31/12/2013. Eligible criteria: Lebanese patients ≥ 18 years old, single pregnancy with live birth or fetal death after 20 weeks of gestation, and newborns transferred to HDF within 28 days after birth. A multiple linear regression model was created using the newborn anthropometric measurements (birth weight, birth length and head circumference) as outcomes. 1,000 Lebanese pregnant women were included (mean age: 31.5 ± 4.4 years, mean pre-gestational weight: 62.2 ± 11.0 kg, mean BMI: 23 ± 3.8 kg/cm²). 42% of the women had an adequate weight gain, 30% had a low weight gain and 25% had excessive weight gain (12.7 ± 6.0 kg). Mean birth weight was 3125.0 ± 389 g, 94.7% of the newborns had a normal birth weight, 2.5% had a low birth weight ($< 2,500$ g), and 2.8% macrosomia ($> 4,000$ g). Mean birth length was 49.8 ± 2.1 cm and mean head circumference 34.5 ± 1.3 cm. A significant association was detected between the pre-gestational BMI, maternal weight gain, female sex of the baby and gestational age as predictive factors on one side and all newborn anthropometric measurements as outcome measures on the other side. Gestational diabetes ($B=122.35$, $p=0.023$) and anemia ($B=216.97$, $p=0.03$) were identified as significant predictors of increased birth weight only, and maternal age was an additional predictor for increased birth length ($B=0.04$, $p=0.010$). Birth weight ($B=-191.32$, $p=0.012$) and length ($B=-0.86$, $p=0.043$) significantly decreased in case of cigarette smoking.

Keywords: gestational diabetes, maternal complications, newborn anthropometric measurements, pre-gestational BMI, weight gain

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Georges Abi Tayeh,¹ Tatiana Papazian,² Inaam Hatoum,¹ Christelle Younes,¹ Alexandra Benachi³

¹Department of Gynecology and Obstetrics, Hôtel-Dieu de France University Hospital, Lebanon

²Department of Nutrition, Faculty of Pharmacy, Saint Joseph University, Lebanon

³Department of Gynecology and Obstetrics, Hospital Antoine-Béclère, France

Correspondence: Dr. Georges Abi Tayeh, MD, PhD, Department of Gynecology and Obstetrics, Hôtel-Dieu de France University Hospital, Boulevard Alfred Naccache, Beirut, Lebanon, P.O. Box, 16-6926, Tel +961 | 427 400, Fax +961 | 426 400, Email georges.abitayeh@gmail.com

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Introduction

Food intake during the pre-gestational and pregnancy periods affects fetal growth and has a major impact on the normal course of gestation.¹ Maternal weight before conception is a determinant factor for certain obstetric and neonatal complications,^{2,3} hence starting pregnancy with a normal body mass index (BMI) is of paramount importance.

Pregnant women need to ensure sufficient energy and nutrient intake to meet the physiological changes associated with pregnancy. Indeed, placenta, amniotic fluid and fetal weight represent 30 to 40% of the total weight gain, whereas maternal physiological changes such as plasma volume, growth of the uterus, volume of extracellular fluid as well the maternal fat deposits for breastfeeding account for 60 to 70%.⁴ Besides, maternal weight gain primarily affect birth weight.⁵ Despite the considerable potential for metabolic adaptation, pregnant women with an inadequate BMI or weight gain are more likely to develop gestational complications.¹ Indeed, the pre-gestational underweight increases the risk of premature birth, low birth weight, intrauterine growth retardation and iron deficiency anemia.⁶⁻⁸ Conversely, overweight is responsible for developing gestational

diabetes (GD),^{9,10} macrosomia,^{4,11} fetal prematurity,¹² postpartum hemorrhage (PPH)¹³ and neonatal admission to neonatal unit.¹³ Furthermore, low weight gain during pregnancy is associated with an increased incidence of miscarriage, low birth weight, prematurity and neonatal mortality,¹⁴ while excessive weight gain can result in several gestational complications, particularly GD and fetal macrosomia.¹⁵ Therefore, it is necessary to have an optimal BMI (between 18.5 and 24.9 kg/m²) at conception, and a weight gain compliant with the Institute of Medicine's (IOM) recommendations.¹⁶

Other parameters also play a vital role during pregnancy such as micronutrient deficiencies, smoking and maternal age that may be associated with adverse perinatal consequences.^{17,18} As such, since pregnancy is associated with increased nutritional needs, the daily intake of 27 mg/day of iron and 600 μ g/day of folic acid must be met by eating iron-rich foods (e.g. meat, offal, legumes and leafy vegetables) and other rich in folic acid (leafy vegetables, corn, chickpeas, fermented cheeses and eggs) in addition to supplements.¹⁷ While smoking cessation is vital, women must attend specialized programs targeting both weaning and ensuring optimal gestational weight gain.¹⁹ As for maternal age, pregnancy at advanced age is likely to be compromised by pre-existing and undiagnosed medical

conditions, which explains the increased risk of GD, preeclampsia, placenta previa, placental abruption, premature birth, low infant birth weight, intrauterine fetal death and perinatal mortality.²⁰ In addition, the risk of cesarean delivery is high because of the decrease of the uterus activity and dystocia during labor.²¹ In parallel, pregnancy during adolescence is associated with an increased risk of maternal anemia, infections, eclampsia, delivery by cesarean section and postpartum depression. Infants of adolescent mothers are more likely to be premature with a low birth weight.²²

Thus, it is important to evaluate the effect of pre-gestational BMI on the development of neonatal and obstetric complications in Lebanese pregnant women. In parallel, it is necessary to assess the gestational weight gain compared to recommendations as well as its effect on maternal health and anthropometric measurements of the newborn. Thus, our main hypothesis was that an adequate BMI and an inappropriate maternal weight gain are responsible for the development of fetal complications. Our secondary objectives were:

- 1) To study the relationship between maternal age at conception and development of gestational complications
- 2) To study the effect of maternal anemia on birth weight
- 3) To study the effect of smoking during pregnancy on the alteration of the newborn's anthropometric measurements.

Methods

Study design and population

This was a descriptive and retrospective study conducted over 1,000 Lebanese women who delivered at Hôtel-Dieu de France (HDF). The study was based on the data recorded by the American University of Beirut Medical Center (AUBMC), as part of the National Collaborative Perinatal Neonatal Network. Eligible participants were chosen in a non-probabilistic and accidental way according to the following inclusion criteria: Lebanese patients aged over 18 years old, single pregnancy with live birth or fetal death after 20 weeks of gestation (stillbirth), and newborns transferred to HDF within 28 days after birth.

Data collection

Data were collected from 01 January 2012 till 31 December 2013 in the department of gynecology and obstetrics of HDF, from the patients' medical record. Also, information were gathered through a face-to-face interview with the patients, using one of the three questionnaires according to pregnancy outcome, namely the normal nursery questionnaire (NNQ), the neonatal intensive care unit questionnaire (NICUQ) and the still birth questionnaire (SQ). Those had three common sections related to socio-demographic data, medical and obstetric history. Besides, the following anthropometric measurements were recorded: maternal weight (kg) before pregnancy and on the day of delivery, her height (cm), newborn's weight (g), birth length (cm) and head circumference (cm).

Ethical considerations

The study was approved by the ethical committee of HDF before initiating the study. All participants were interviewed after signing their written informed consent. Data collection and analysis were performed respecting their autonomy and anonymity. The study was also conducted in compliance with the Declaration of Helsinki of 2000.

Statistical analysis

Sample characteristics were summarized using the mean, the standard deviation (SD) for quantitative variables (age, weight, birth length, pre-gestational BMI), and frequency distributions for qualitative variables such as presence of gestational, neonatal and obstetrical complications. In univariate analysis, frequency distributions were compared between categorical independent variables using the chi-squared test or Fisher's exact test when expected cell counts fell below 5. Using a multiple linear regression analysis, a prediction model was created using anthropometric measurements of the newborn (birth weight, birth length and head circumference) as outcomes. Predictors introduced in the regression were maternal age, maternal pre-gestational BMI, maternal weight gain, cigarette smoking, waterpipe smoking, GD, anemia, antenatal steroids, female sex of the baby and gestational age. Significance level was two-sided and set at 5%. The statistical analysis was carried out using IBM SPSS software for Windows Release, version 20 (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.).

Results

General characteristics of the participants

In total, 1,000 Lebanese pregnant women participated in the study with a mean age of 31.5±4.4 years (range: 19-43 years). They had a mean pre-gestational weight of 62.2± 11.0Kg (range: 35-135kg), and a mean height of 164.1±5.7cm (range: 146-184cm). Also, mean BMI was 23±3.8 Kg/cm² (range: 12.8-46.7 Kg/cm²), where 69.5% of the women had normal pre-gestational BMI versus 6.5% who were underweight, 18% overweight and 6% obese.

Based on the IOM's recommendations,¹⁶ 42% of the women had an adequate weight gain, while 30% had a low weight gain and 25% had excessive weight gain (12.7±6.0kg), with individual records of losing 5 Kg in one patient and gaining 40kg in another one. As for gestational complications, 4.6% of the 1,000 women developed GD, 6.2% urinary infections, 1.3% were reported to be anemic, and 0.4% suffered from PPH. Summary of tobacco use among the pregnant women is displayed in Table 1.

Table 1 Tobacco use in the pregnant women (n=1,000)

Variable	N	%
Smoking cigarettes		
Yes	22	2.2
No	975	97.5
Missing data	3	0.3
Number of cigarettes/day	n=22	Mean±SD=7.2±5.4 Range=1-20
Smoking waterpipe (shisha)		
Yes	8	0.8
No	990	99
Missing data	2	0.2
Number of waterpipes/day	n=8	Mean±SD=1.9±2.0 Range=1-7

Abbreviations: %, percentage; n, number of patients; SD, standard deviation

General characteristics of the newborns

The mean birth weight was 3125.0±389g (range: 1,940-4,530). 94.7% of the newborns had a normal birth weight ranging between 2,500 and 4,000 g, while 2.5% had a low birth weight (<2,500g), and 2.8% macrosomia (>4,000g). The mean birth length was 49.8±2.1cm (range: 39-57), and the mean head circumference was 34.5±1.3cm (range: 31-40). No newborn was premature (before 37th week of amenorrhea), mean gestational age was 38th week of amenorrhea. 90% of the newborns were admitted in nursery while 9.8% were

transferred to the intensive care unit, with 2 (0.2%) cases of stillbirth. As for Apgar score, it was below 7 in 4.4% of the newborns at 1 minute after birth, and in 0.1% at 5 minutes after birth.

Association of maternal anthropometric measurements with maternal and fetal complications

A significant association was detected between the pre-gestational BMI and maternal complications, namely GD, anemia, PPH, and the anthropometric measurements of the newborn (Table 2).

Table 2 Association of pre-gestational BMI with maternal complications and anthropometric measurements of the newborn

Variable	BMI categories				P-value*
	Underweight n(%)	Normal weight n(%)	Overweight n(%)	Obese n(%)	
Gestational diabetes					
Yes	2 (3.2%)	23 (3.4%)	11 (6.1%)	9 (16.1%)	0.001b*
No	61 (96.9%)	655 (96.6%)	168 (93.9%)	47 (83.9%)	
Total	63	678	179	56	
Anemia					
Yes	2 (3.2%)	5 (0.7%)	2 (1.1%)	3 (5.4%)	0.014b*
No	61 (96.8%)	673 (99.3%)	177 (98.9%)	53 (94.6%)	
Total	63	678	179	56	
Postpartum hemorrhage					
Yes	0 (0.0%)	1 (0.1%)	1 (0.6%)	3 (5.4%)	0.018b*
No	62 (100.0%)	677 (99.9%)	178 (99.4%)	53 (94.6%)	
Total	62	678	179	56	
Birth weight					
Low	5 (7.9%)	14 (2.1%)	2 (1.1%)	1 (1.8%)	<0.001b*
Normal	58 (92.1%)	646 (99.9%)	173 (96.6%)	47 (83.9%)	
Macrosomia	0 (0.0%)	16 (2.4%)	4 (2.2%)	8 (14.3%)	
Total	63	677	179	56	
Birth length					
Small	15 (23.0%)	74 (11.0%)	19 (10.6%)	7 (12.5%)	<0.024a*
Normal	48 (76.2%)	602 (89.0%)	160 (89.4%)	49 (87.5%)	
Total	63	676	179	56	
Head circumference					
<35cm	38 (60.3%)	338 (50.1%)	77 (43.0%)	24 (43.0%)	0.072a*
≥35cm	25 (39.7%)	336 (49.9%)	102 (57.0%)	32 (57.0%)	
Total	63	674	179	56	
Apgar score					
<7	5 (7.9%)	29 (4.3%)	5 (2.8%)	4 (7.1%)	0.239b
≥7	58 (92.1%)	647 (95.7%)	174 (97.2%)	52 (92.9%)	
Total	63	676	179	56	

* Statistical significance set at 5%. a: Chi-squared test. b: Fisher's exact.

Abbreviations: %, percentage; BMI, Body mass index; n, number of patients

While gestational gain weight was not significantly associated with GD, anemia and PPH, its association with the anthropometric measurements of the newborn was significant (Table 3). As such, women who excessively gained weight during pregnancy had a tendency to give birth to more newborns with macrosomia (5.7%)

compared to women with an adequate gain weight (2.6%), ($p=0.000$). In parallel, 16.6% of women who insufficiently gained weight gave birth to babies of small length *versus* 12% of cases with adequate weight gain.

Table 3 Association of gestational gain weight with maternal complications and anthropometric measurements of the newborn

Variable	Gestational gain weight categories			P-value*
	Insufficient n(%)	Adequate n(%)	Excessive n(%)	
Gestational diabetes				
Yes	16 (5.0%)	12 (2.8%)	17 (6.9%)	0.044*a
No	287 (95.5%)	409 (97.2%)	228 (93.1%)	
Total	303	421	245	
Anemia				
Yes	1 (0.3%)	6 (1.4%)	4 (1.6%)	0.264a
No	302 (99.7%)	415 (98.6%)	241 (98.4%)	
Total	303	421	245	
Postpartum hemorrhage				
Yes	0 (0.0%)	2 (0.4%)	2 (0.8%)	0.290a
No	303 (100.0%)	419 (99.6%)	242 (99.2%)	
Total	303	421	244	
Birth weight				
Low	16 (5.3%)	5 (1.2%)	1 (0.4%)	<0.001*a
Normal	283 (93.4%)	404 (96.2%)	230 (93.9%)	
Macrosomia	4 (1.3%)	11 (2.6%)	14 (5.7%)	
Total	303	420	245	
Birth length				
Small	50 (16.6%)	50 (12.0%)	15 (6.0%)	0.001*a
Normal	251 (83.4%)	371 (88.0%)	230 (94.0%)	
Total	301	421	245	
Head circumference				
<35cm	171 (57.0%)	208 (49.0%)	97 (40.0%)	<0.001*a
≥35cm	130 (43.0%)	212 (51.0%)	147 (60.0%)	
Total	301	420	237	

* Statistical significance set at 5%. a: Chi-squared test.

Abbreviations: %, percentage; n, number of patients

Association of maternal age at pregnancy with maternal and fetal complications

Women aged 35 years old and above (6.5%, n=40) were at a non-significant higher risk of developing GD as compared to those aged below 35 years (4%, n=16), ($p=0.1$). Similarly, maternal age was not significantly associated with anemia nor PPH.

As for the anthropometric measurements of the newborn, birth weight was significantly associated with maternal age ($p<0.001$), where women aged 35 years old and above (7.3%, n=17) were at higher of giving birth with macrosomia compared to the younger

patients (1.7%). Also, the older patients (3.7%, n=9) were more prone to deliver babies with low birth weight as compared to the younger ones (2%, n=16).

Association of smoking with maternal and fetal complications

Smoking waterpipes or cigarettes was not significantly related to gestational gain weight, birth weight nor length. Nonetheless, results showed that smoking women gave birth to more babies with low birth weight and length, as compared to non-smoking mothers (Table 4).

Table 4 Association of any type of smoking (cigarettes and waterpipe) with maternal and fetal complications

Variable	Yes n(%)	No n(%)	P-value*
Gestational gain weight			
Insufficient	9 (31.0%)	291 (31.0%)	0.732a
Adequate	11 (38.0%)	413 (44.0%)	
Excessive	9 (31.0%)	236 (25.0%)	
Total	29	940	
Birth weight			
Low	1 (3.3%)	23 (2.4%)	0.492b
Normal	28 (93.3%)	915 (94.6%)	
Macrosomia	1 (3.3%)	29 (3.0%)	
Total	30	967	
Birth length			
Small	6 (20.0%)	112 (11.6%)	0.155b
Normal	24 (80.0%)	854 (88.4%)	
Total	30	966	

* Statistical significance set at 5%. a: Chi-squared test. b: Fisher's exact.

Abbreviations: %, percentage; n, number of patients

Results of the multiple linear regressions

A significant association was detected between the pre-gestational BMI, maternal weight gain, female sex of the baby and gestational age as predictive factors on one side and all anthropometric measurements of the newborn as outcome measures on the other side. In particular, birth weight increased significantly with maternal pre-gestational BMI (regression coefficient [B]=18.60, $p<0.001$), maternal weight gain (B=17.10, $p<0.001$), and gestational age (B=114.35, $p<0.001$). The same pattern applies to birth length and head circumference.

Also, gestational diabetes (B=122.35, $p=0.023$) and anemia (B=216.97, $p=0.03$) were also identified as significant predictors of increased birth weight only, and maternal age was an additional predictor for increased birth length (B=0.04, $p=0.010$). In parallel, birth weight (B=-191.32, $p=0.012$) and length (B=-0.86, $p=0.043$) significantly decreased in case of cigarette smoking. Women who smoke cigarettes tend to give birth to newborns with an average lower weight by 191g and lower length by 86 mm as compared to mothers who do not smoke (Table 5).

The regression model showed that almost 19% of variations were due to the explanatory variables included in the model, i.e. maternal age, maternal pre-gestational BMI, maternal weight gain, cigarette smoking, waterpipe smoking, GD, anemia, antenatal steroids, female sex of the baby and gestational age. That is to say that 80% of variations were due to variables not included in the regression model, such as genetic factors and physical activity of the mother.

Table 5 Association of pre-gestational anthropometric measurements and complications of the mother with anthropometric measurements of the newborn

Variables	Birth weight			Birth length			Head circumference		
	B	Standard error	P-value*	B	Standard error	P-value*	B	Standard error	P-value*
Mother's age	3.01	2.61	0.249	0.04	0.02	0.010*	0.02	0.01	0.059
Mother BMI (pre-gestational)	18.6	3	<0.001*	0.04	0.02	0.013*	0.05	0.01	<0.001*
Mother's weight gain	17.1	2.4	<0.001*	0.05	0.01	<0.001*	0.03	0.01	0.001*
Cigarette smoking	-191.32	75.63	0.012*	-0.86	0.42	0.043*	-0.35	0.28	0.218
Waterpipe smoking	65.47	124.32	0.599	-0.13	0.69	0.852	0.34	0.46	0.46
Gestational diabetes	122.35	53.7	0.023*	0.46	0.3	0.128	-0.06	0.2	0.773
Anemia	216.97	101.52	0.033*	0.98	0.57	0.083	0.6	0.38	0.113
Antenatal steroids	-99.25	70.97	0.162	-0.08	0.4	0.842	-0.04	0.26	0.885
Female sex of the baby	-141.56	22.42	<0.001*	-0.66	0.13	<0.001*	-0.58	0.08	<0.001*
Gestational age	114.35	11.74	<0.001*	0.62	0.07	<0.001*	0.15	0.04	0.001*
R2 (adjusted)	0.19	-	-	0.13	-	-	0.09	-	-
Interactions									
Sex of baby and BMI	-	-	0.752	-	-	-	-	-	-
Sex of the baby and weight gain	-	-	0.693	-	-	-	-	-	-
Sex of the baby and gestational age	-	-	0.364	-	-	-	-	-	-
BMI and gestational diabetes	-	-	0.038*	-	-	-	-	-	-
BMI and cigarettes smoking	-	-	0.558	-	-	-	-	-	-
BMI and weight gain	-	-	0.112	-	-	-	-	-	-
BMI and anemia	-	-	0.86	-	-	-	-	-	-
Weight gain and gestational diabetes	-	-	0.284	-	-	-	-	-	-

Also testing all interactions between the 10 predictive factors is not possible as more than 500 interactions will be created. The 8 most scientifically relevant interactions on birth weight model were tested with the interaction between BMI and gestational diabetes being the only significant one (p -value=0.038). The slope difference for this interaction was 24.1 meaning that the effect of BMI on birth weight is higher among women who develop gestational diabetes as compared to women who do not develop it (Table 5).

Discussion

The present study aimed to identify the effect of pre-gestational BMI and gestational gain weight on the development of obstetrical and neonatal complications. The study tested the hypothesis that an adequate BMI and an inappropriate maternal weight gain are responsible for the development of fetal complications. Also, additional hypotheses were that Lebanese pregnant women have inadequate BMI at conception, and that the majority do not comply with the recommendations for weight gain during pregnancy. Also, we assumed that pregnancy at an advanced age affects the birth weight, while maternal anemia and smoking during pregnancy is associated with a low birth weight. Ultimately, our results supported our hypotheses as they showed that a significant association was detected between the pre-gestational BMI, maternal weight gain, female sex of the baby and gestational age as predictive factors on one side and all anthropometric measurements of the newborn as outcome measures on the other side. Gestational diabetes and anemia were also identified as significant predictors of increased birth weight only, and maternal age was an additional predictor for increased birth length. Nonetheless, the results also showed that birth weight and length significantly decreased in case of cigarette smoking.

Our study sample consisted of 1,000 women who delivered at HDF between 2012 and 2013. Their mean age was 31.5 years old, which is similar to previous studies.²³⁻²⁵ The advanced age at pregnancy reflects the evolution of the woman's role in our Lebanese society, especially in the educational and professional levels.²⁶ Also and contrarily to literature, no significant association was noted between maternal age, GD and anemia. A Chinese study reported in 2011 that women aged between 35 and 39 years old had a 2.6-fold increased incidence of GD, versus 3.5 for women aged 40 years and above,²⁷ which is secondary to pre-existing but non-diagnosed medical conditions.²⁰ In parallel, the authors highlighted that young women aged between 15 and 19 years old had a 1.4-fold increased risk of anemia compared to the older ones (25 to 29 years old),²⁷ given that adolescents are in their growth stage. Nevertheless, maternal age was significantly associated to birth weight ($p < 0.001$), in accordance with the Chinese study where young mothers had a 2.3-fold increased risk of delivering low birth weight newborns compared to the 25-29 years age category.²⁷

The rate of maternal underweight was 6.5%, versus 18% for overweight, 6% for obesity, and a normal weight of 67%. While underweight rates were higher than those reported by ObEpi-Roche study (4.9%) conducted in France,¹⁴ overweight and obesity were lower compared to the results of a previous Lebanese study (18.8% and 49.4% respectively).²⁸ The overweight rate was also lower than the findings of other studies conducted in Kuwaiti (29.5%) and Saudi (43.8%) women.²⁹ Similarly, an insufficient weight gain during pregnancy was detected in 30% of the participants, compared to the 19.8% by JL et al. in 2015.³⁰ This finding may reflect the neglecting attitude of young Lebanese women toward their weight for esthetic reasons. In parallel, the rate of excessive weight gain was 25%, and thus lowers to 44.4% as reported by Johnsson et al.,³⁰ which reveals the high socio-economic and educational levels of the pregnant

women who delivered at HDF. At HDF, the women are closely and constantly followed up by their gynecologists who guided them to prevent gestational and neonatal complications. Consequently, our results cannot be generalized over the whole Lebanese population.

Regarding smoking, only 3% of the study women were smokers during their pregnancy, where 2.2% consumed cigarettes and 0.8% waterpipe. Our findings are relatively lower than those reported in pregnant women in Lebanon in 2006 (20%),³¹ and in Jordan (19%).³² A possible explanation for this difference may be the higher number of smoking women in the other studies, and the societal pressure on pregnant women to quit smoking, who therefore are reluctant to confess they are smoking and are consequently incorrectly classified as non-smokers. In this context, Gomez et al. revealed through biochemical analysis, that 28 to 35% of pregnant women made mis-declarations about their smoking status.³³ However, women are nowadays more aware about the adverse effects of active and passive smoking,³⁴ and the importance of smoking cessation, particularly during pregnancy. Moreover, our study did not reveal any significant association between smoking and birth weight ($p=0.492$) contrarily to other studies. Brennan et al. found that 13 to 19% of low birth weight newborns were attributed to smoking before pregnancy,³⁵ Harris et al. reported an increased birth weight of 188 g following smoking cessation during pregnancy.³⁶ We note that our study might have not detected any significant associations of smoking with maternal weight gain ($p > 0.05$), birth length ($p=0.255$), or head circumference ($p=0.749$), given the low number of smoking women in our sample (3%).

In terms of gestational complications, our study showed from one side a significant association between BMI before pregnancy and GD ($p=0.001$), which is compliant with the findings of Deruelle et al.,¹³ where overweight women had 1.7 higher risks of developing GD, versus 3.6 for obese women and 8.6 for those with severe obesity.¹³ Likewise, 4.6% of underweight women and 5.4% of obese participants had anemia, similarly to the rates reported in developing countries (2 to 7%).³⁷ The significant association between maternal weight and anemia in our study ($p=0.003$) was also detected in Pakistan, where anemia was attributed to the nutritional iron deficiency in underweight mothers, and to iron perturbation in obese women.³⁷ Pre-gestational obesity was also found to be significantly increasing the risk of PPH ($p=0.019$). Our finding aligns with those of a cohort study conducted between 1997 and 2008 in Sweden, where obese patients (BMI>40) were at 1.23 higher risks of PPH compared to normal weight women.³⁸ From the other side, weight gain during pregnancy was not associated to GD. Nonetheless, an Algerian prospective study demonstrated that excessive gestational weight gain is more frequent in women with GD (22%) compared to their healthy counterparts (11.3%), and that the risk is 4 times increased in women exceeding the IOM's recommendations of 2009.³⁹ Our non-significant results may be due to the limited number of pregnant women who developed GD.

Concerning the anthropometric measures of the newborn, the present study showed that the majority of newborns (94.4%) had a normal birth weight (2500 to 4000 g), while 2.5% had low birth weight and 3% macrosomia. These rates are lower than those reported by UNICEF in 2006 for Middle Eastern countries (15%),⁴⁰ probably because of the high socio-economic level of the Lebanese participants at HDF. A significant association was also found between pre-gestational BMI and birth weight ($p < 0.001$), with women having a low BMI being at higher risk of delivering a baby of low birth weight, and macrosomia associated to maternal obesity. Comparable results are displayed by a Croatian retrospective study⁴¹ and a prospective study conducted in Morocco, which showed a 4-fold

increase of macrosomia in case of moderate obesity, and 9-fold increase in case of severe obesity. Macrosomia could be attributed to the fetal hyperinsulinism reaction to maternal hyperglycemia, due to the anabolic effect of insulin.⁴² In addition, our study identified a significant association between maternal underweight and small birth length (<48 cm) ($p < 0.034$), as well as small head circumference (<35cm) ($p = 0.049$), contrarily to the literature. In fact, the majority of studies reckon only an association between maternal obesity, large birth length and large head circumference.⁴³ However, the present study did not find any significant association between maternal weight and Apgar score, which is controversially reported in literature.

Study limitations and strengths

Our study has methodology limitations. First, the study results are not representative of the Lebanese population since it was conducted over a sample of wealthy women. Second, anemia was self-reported by the patients without performing any blood assessments. Third, information about iron supplements intake, nutritional status, mode of delivery and newborns' gender are missing along with socio-demographic data. Nonetheless, the anthropometric measurements of the mothers and their newborn are reported. More importantly, and up to our knowledge, our study records the largest number of participants and collected parameters in Lebanon to show the impact of pre-gestational weight and weight gain during pregnancy on the maternal complications and the anthropometric measurements of the newborn.

Conclusion

We observed birth weight increased significantly with maternal pre-gestational BMI, maternal weight gain, GD and gestational age. The same pattern was also found with birth length and head circumference expected for GD which was not identified as a significant predictor. Nonetheless, birth weight decreased significantly in case of smoking and female sex of the baby. Further studies should collect the same parameters in hospitals admitting patients with a different socio-economic status, and investigate as well the blood assessments in order to have a comprehensive view of the Lebanese society.

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Conflicts of interest

None.

Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national guidelines on human experimentation (Lebanese Law) and with the Helsinki Declaration of 1975, as revised in 2008, and has been approved by the institutional committees (ethical committee of Hôtel-Dieu de France and Institutional Review Board of the American University of Beirut Medical Center).

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