Int J Diabetes Dev Ctries (October–December 2016) 36(4):433–438
DOI 10.1007/s13410-015-0443-8

ORIGINAL ARTICLE

A retrospective study of maternal and neonatal outcomes in overweight and obese women with gestational diabetes mellitus

Mingyue Nie[1] · **Weiyuan Zhang**[2] · **Xiaokui Yang**[1]

Received: 23 March 2015 / Accepted: 15 September 2015 / Published online: 24 September 2015

Abstract In pregnant women, obesity is a risk factor for multiple adverse pregnancy outcomes, including gestational diabetes mellitus (GDM), preeclampsia, and preterm birth. The aim of this study was to determine the effects of pre-pregnancy body mass index (BMI) on maternal and neonatal outcomes in women with GDM. A retrospective study of 5010 patients with GDM in 11 provinces in China was performed in 2011. Participants were divided into three groups based on BMI as follows: a normal weight group (BMI 18.5–23.9 kg/m^2), an overweight group (BMI 24–27.9 kg/m^2), and an obese group (BMI ≥28.0 kg/m^2). Maternal baseline characteristics and pregnancy and neonatal outcomes were compared between the groups. Multiple logistic regression analysis was used to explore the relationships between BMI and the risk of adverse outcomes. Of the 5010 GDM patients, 2879 subjects were from north China and 2131 were from south China. Women in the normal weight group gained more weight during pregnancy compared with the overweight and obese GDM patients. Women in the overweight and obese groups had increased odds of hypertension during pregnancy (adjusted odds ratio (AOR)=1.50, 95 % confidence interval (CI)=1.31–1.76 and AOR=2.12, 95 % CI=1.84–3.16). The AORs for macrosomia in the overweight and obese groups were 1.46 (95 % CI=1.16–1.69) and 1.94 (95 % CI=1.31–2.98), respectively. The relative risk of delivering a baby with an Apgar score <7 at 5 min was significantly higher in women who were obese (AOR=2.11, 95 % CI=1.26–2.85) before pregnancy compared with normal weight women. Compared with the normal weight subjects, the incidence of cesarean section and emergency cesarean section among overweight and obese women with GDM was significantly higher (P<0.001). Overall, overweight and obese women with GDM have an increased risk of adverse outcomes, including hypertension during pregnancy, macrosomic infants, infants with low Apgar scores, and the need for an emergency cesarean section. More attention should be paid to GDM women who are obese because they are at risk for multiple adverse outcomes.

Keywords Gestational diabetes mellitus · Obesity · Pregnancy complications · Body mass index

Electronic supplementary material The online version of this article (doi:10.1007/s13410-015-0443-8) contains supplementary material, which is available to authorized users.

✉ Weiyuan Zhang
zhangwy9921@hotmail.com

✉ Xiaokui Yang
xiaokuiyang1@163.com

Mingyue Nie
mingyue881021@163.com

[1] Department of Human Reproductive Medicine, Beijing Obstetrics and Gynecology Hospital, Capital Medical University, Beijing 100026, China

[2] Department of Obstetrics, Beijing Obstetrics and Gynecology Hospital, Capital Medical University, Beijing 100026, China

Introduction

Gestational diabetes mellitus (GDM) is a common metabolic complication during pregnancy. Characterized by glucose intolerance, GDM affects approximately 4.3 % of pregnancies in China [1]. As a major cause of both maternal and neonatal mortality and morbidity, GDM poses a greater risk for macrosomia, cesarean delivery, newborn congenital malformations, and stillbirth. Compared with those who have a normal pregnancy, women with a history of GDM have a significantly higher risk of metabolic syndrome [2]. Furthermore, a history of GDM is a risk factor for type 2 diabetes and

cardiovascular diseases [3], and children born to mothers with prior GDM have a higher risk of overweight and obesity in the future [4].

It has been reported that multiple factors, such as a higher pre-pregnancy body mass index (BMI), abdominal circumference, fasting glycemia in the first trimester of pregnancy, and the presence of polycystic ovary syndrome, are strongly associated with an elevated GDM risk [5]. As a preventable and reversible contributor to GDM, obesity has been one of the most important health problems worldwide. It is reported that overweight is a major threat to a successful pregnancy outcome, leading to preeclampsia, cesarean delivery, cephalopelvic disproportion, and macrosomia [6]. Additionally, gestational weight gain is an important factor in both maternal and infant outcomes. High weight gain (>18 kg) during pregnancy is associated with preeclampsia and cesarean delivery [7]. Many studies have already focused on the association between obesity and GDM. Evidence from Singh et al. suggested that the risk of GDM increased with an increasing BMI across all weight categories. The odds ratio (OR) of incident GDM was 1.08 (95 % confidence interval (CI) 1.08–1.09) for each 1 kg/m^2 increase in BMI and 1.48 (95 % CI 1.45–1.51) for each 5 kg/m^2 increase, indicating that pre-pregnancy BMI plays an important role in GDM risk [8]. Due in large part to the obesity epidemic, GDM is becoming increasingly common worldwide.

Although a few studies have investigated the association between obesity and GDM, the majority of these studies was limited by small sample sizes and may not be applicable to the Chinese population [9, 10]. The objective of the present survey was to investigate the pregnancy outcomes among overweight and obese GDM patients in China.

Materials and methods

This was a hospital-based, retrospective cohort study of women whose pregnancies were complicated by GDM. This study included GDM women who gave birth to a singleton in 11 provinces in China. Data were available from medical records in 2011. Patients were selected from 36 different hospitals in mainland China. One tertiary- or secondary-level hospital was randomly selected in each province. The study was conducted with the permission of the institutional review board at each hospital and was approved by the ethics committees of the medical institutions involved.

All pregnant women with singleton pregnancies diagnosed with GDM in our selected hospitals with a pre-pregnancy BMI≥18.5 kg/m^2 were identified for this retrospective study. The pre-pregnancy BMI was obtained from a self-reported medical record. Exclusion criteria included maternal pre-pregnancy chronic disease, including chronic hypertension, history of diabetes, and multiple gestations. Finally, 5010 GDM women were included in the present analysis.

GDM was defined according to the criteria recommended by the International Association of Diabetes and Pregnancy Study Groups (IADPSG) [11]. GDM was diagnosed when any of the following values were met in the 75-g oral glucose tolerance test (OGTT) performed in gestational week 24–28: fasting blood glucose 5.1 mmol/l, 1-h blood glucose 10.0 mmol/l, or 2-h blood glucose 8.5 mmol/l. The treatments for GDM included dietary consultation and insulin treatment wherever necessary.

We classified women into three groups depending on their pre-pregnancy BMI based on recommendations by the Group of China Obesity Task Force of the Chinese Ministry of Health as follows: normal weight (BMI between 18.5 and 23.9 kg/m^2), overweight (BMI between 24.0 and 27.9 kg/m^2), and obese (BMI≥28.0 kg/m^2).

Baseline characteristics were compared between different groups. Assisted reproductive technology (ART) pregnancies include pregnancies achieved from in vitro fertilization (IVF) or intracytoplasmic sperm injection/embryo transfer (ICSI/ET). We compared the pregnancy outcomes between groups. Gestational hypertension was defined when the systolic blood pressure was ≥140 mmHg or diastolic blood pressure ≥90 mmHg, measured at two different intervals with woman at rest for more than 15 min. Preterm delivery was defined as delivery of a liveborn infant before 37 gestational weeks [12]. Postpartum hemorrhage was defined as blood loss greater than 500 mL in the first 24 h after delivery. Macrosomia was defined as a birth weight of at least 4000 g.

For the statistical analysis, continuous variables were expressed as the means±standard deviation as determined by one-way analysis of variance (ANOVA). The chi-square test, Fisher's exact test, and one-way ANOVA were used to compare variables between different groups. Multivariate logistic regression analysis was performed to estimate the association between pre-pregnancy BMI and adverse outcomes. Adjusted odds ratios (AORs) and 95 % CIs were calculated for all risk factors. Additionally, the outcomes were adjusted for maternal age, parity, gestation weeks, and smoking status. $P<0.05$ was considered significant. All statistical analyses were performed using SPSS version 17.0.

Results

A total of 5010 women with GDM participated in the study. Participants were selected from 36 hospitals in 11 Chinese provinces. We divided the hospitals into two sections based on their location. The rate of obesity was 13.9 % in north China, while it was 7.1 % in south China. The regional distribution of women according to their pre-pregnancy BMI is summarized in Table 1.

Table 1 Regional distribution of pregnant women with GDM in China

Region	Hospital	GDM	Normal weight	Overweight	Obese
North China	22	2879	1985/2879 (68.9 %)	493/2879 (17.1 %)	401/2879 (13.9 %)
South China	17	2131	1717/2131 (80.6 %)	262/2131 (12.3 %)	152/2131 (7.1 %)
Total	39	5010	3702	755	553

The baseline characteristics of the study population are listed in Table 2. A total of 3702 GDM patients had a normal pre-pregnancy BMI, 755 were overweight, and 553 were obese. The mean BMIs in the three groups were 20.9±1.9, 25.9±1.4, and 30.6±2.1 kg/m^2, respectively. There were no significant differences in age, gestational weeks, and alcohol consumption between the different groups. Compared with the overweight and obese women, the normal weight women were more likely to gain more weight during pregnancy (P<0.001). In addition, the percentage of smokers in the normal weight group was higher than that in the other groups (P<0.001).

Table 3 shows the maternal and neonatal outcomes in different groups. The rates of premature rupture of membranes (PROM), preterm labor, placental abruption, postpartum hemorrhage (PPH), and neonatal malformation were not significantly different between the three groups. An increased risk of hypertension during pregnancy (HDP) was observed in overweight and obese GDM patients compared with normal weight patients. The AORs in the overweight and obese groups were 1.50 and 2.12, respectively, compared with the normal weight group. ORs were adjusted for maternal age, gravidity, gestational week, and smoking status. The neonatal outcomes were also different between the groups. Overweight GDM mothers were more likely to deliver a macrosomic infant (AOR=1.46, 95 % CI=1.16–1.69), and the AOR for macrosomia in the obese group was even higher (AOR=1.94, 95 % CI=1.31–2.98). The relative risk of delivering a baby with an Apgar score <7 at 5 min was markedly higher in women who were obese (AOR=2.11, 95 % CI=1.26–2.85) prior to pregnancy.

The modes of pregnancy and delivery in GDM women in the different groups are compared and summarized in Table 4. There were no significant differences between the three groups with regard to the mode of pregnancy, including spontaneous pregnancy and ART pregnancy. However, at delivery, the rate of vaginal delivery was significantly decreased in both the overweight and obese groups. The rate of cesarean delivery was higher in the overweight group than in the normal weight group (65.0 vs. 48.8 %), and the cesarean delivery rate was highest in the obese group (74.5 %). Furthermore, a significantly increased risk of emergency cesarean section was observed in the overweight and obese groups compared with the normal weight group.

Discussion

As previously reported, overweight and obesity at the beginning of pregnancy can lead to adverse pregnancy outcomes, including GDM, gestational hypertension, preeclampsia, induction of labor, prolonged second stage of labor, postpartum hemorrhage, and neonatal macrosomia [13, 14]. Our results suggest that a high pre-pregnancy BMI increased the risk for gestational hypertension, fetal macrosomia, delivering a baby with an Apgar score <7 at 5 min, and cesarean section after adjustment for maternal age, gravidity, gestational age, and smoking status in GDM women. These results demonstrate that obesity is not only a risk factor for GDM but is also a risk factor for adverse pregnancy outcomes induced by GDM.

As one of the most common medical complications of pregnancy, GDM is characterized by glucose intolerance due to an insufficiency of insulin secretion to meet the increased requirements during pregnancy. Previously published studies suggested that insulin secretion and action in GDM were directly affected by adipocyte-derived factors such as leptin and adiponectin [15, 16]. A meta-analysis by Chu et al. involving 20 studies revealed that compared with normal weight pregnant women, overweight, obese, and severely obese women had ORs of developing GDM of 2.14, 3.56, and 8.56,

Table 2 Demographic characteristics in different groups

Variable	Normal weight (n=3702)	Overweight (n=755)	Obese (n=553)	P value
Age (years)	30.5±4.8	31.1±5.7	29.4±4.9	0.201
Pre-pregnancy BMI (kg/m^2)	20.9±1.9	25.9±1.4	30.6±2.1	P<0.001
Weight gain (kg)	14.8±6.1	12.9±4.7	12.2±5.4	P<0.001
Gestational week	37.5±7.3	37.2±4.7	38.6±1.9	0.301
Smoking	0.4 %	0.3 %	0.2 %	P<0.001
Alcohol consumption	0.4 %	0.3 %	0.3 %	0.093

Table 3 Pregnancy and neonatal outcomes in the three groups

Incidence	Normal weight (*n*=3702)	Overweight (*n*=755)		Obese (*n*=553)	
	n (%)	*n* (%)	Adjusted OR (95 % CI)	*n* (%)	Adjusted OR (95 % CI)
Pregnancy outcome					
HDP	312 (8.4 %)	114 (15.1 %)	1.50 (1.31–1.76)#	166 (30.0 %)	2.12 (1.84–3.16)#
PROM	711 (19.2 %)	126 (16.7 %)	1.02 (0.63–1.54)	88 (15.9 %)	0.94 (0.91–1.28)
Preterm labor	270 (7.3 %)	53 (7.0 %)	0.86 (0.49–1.38)	34 (6.1 %)	0.86 (0.48–1.31)
Placental abruption	60 (1.6 %)	12 (1.6 %)	1.12 (0.58–1.40)	9 (1.6 %)	1.04 (0.75–2.89)
PPH	225 (6.1 %)	48 (6.4 %)	0.96 (0.69–1.81)	38 (6.8 %)	1.23 (0.97–1.86)
Newborn outcome					
Macrosomia	349 (9.4 %)	116 (15.4 %)	1.46 (1.16–1.69)#	121 (21.9 %)	1.94 (1.31–2.98)#
5 min Apgar score <7	6 (0.2 %)	3 (0.4 %)	1.17 (0.82–1.65)	4 (0.7 %)	2.11 (1.26–2.85)*
Malformation	32 (0.9 %)	6 (0.8 %)	0.91 (0.72–1.53)	5 (0.9 %)	1.04 (0.42–2.01)

Adjusted for maternal age, gravidity, gestational age, and smoking status

HDP hypertension during pregnancy, *PROM* premature rupture of membranes, *PPH* postpartum hemorrhage

*$P<0.05$; # $P<0.01$

respectively [17]. Furthermore, in another study, Ogonowski et al. demonstrated that with an increasing pre-pregnancy BMI, the risk for GDM increases not only in overweight but also in normal weight women [18]. These findings demonstrated that BMI and GDM are closely related.

Because obesity and GDM are the two risk factors for adverse pregnancy outcomes, we investigated the influence of different BMI categories on pregnancy outcomes in GDM patients. Our results showed that there was an increased risk of gestational hypertension in the overweight (OR=1.50, 95 % CI=1.31–1.76) and obese (OR=2.12, 95 % CI=1.84–3.16) groups compared with the normal weight group, which was in accordance with the conclusion drawn by Zhang et al., who found that the incidence of preeclampsia among obese GDM women was three- and twofold higher than those in normal weight and overweight GDM women, respectively [19]. However, we cannot confirm their findings that the risk of PROM in the obese group was 1.4- and 1.6-fold greater than those in the normal weight and overweight groups, respectively. The reason for this difference maybe that we adjusted for other important covariates to reduce interference in the results. In addition, the weight gain in normal weight women was markedly greater than that in overweight and obese GDM women, which may also have contributed to the difference in the results. Bodnar et al. explained the mechanisms underlying the effects of obesity on preeclampsia risk as an elevated inflammatory response and high triglyceride levels [20]. However, no significant difference in the incidence of preterm labor, placental abruption, PROM, and postpartum hemorrhage was observed between the different groups.

Neonatal outcomes can also be influenced by a high pre-pregnancy BMI. As is already known, women with either GDM or obesity have an increased incidence of macrosomic neonates. Our results confirmed that the incidence was even higher among overweight and obese GDM women compared with normal weight GDM women. According to a retrospective study of 10,468 European children, fetal macrosomia is

Table 4 Pre-pregnancy BMI and the mode of pregnancy and delivery

	Normal weight (*n*=3702)	Overweight (*n*=755)	Obese (*n*=553)	*P* value
Mode of pregnancy				
Spontaneous pregnancy	3608 (97.5 %)	737 (97.6 %)	539 (97.5 %)	
ART pregnancy	94 (2.5 %)	18 (2.4 %)	14 (2.5 %)	0.184
Mode of delivery				
Vaginal delivery	1896 (51.2 %)	256 (33.9 %)	141 (25.3 %)	
Cesarean delivery	1806 (48.8 %)	499 (65.0 %)	412 (74.5 %)	*P*<0.001
Elective	1358 (75.2 %)	321 (64.3 %)	208 (50.5 %)	
Emergency	448 (24.8 %)	178 (35.7 %)	204 (49.5 %)	*P*<0.001

independently associated with the development of overweight/obesity during childhood [21]. Despite this result, we found that the incidence of a low Apgar score was increased in the obese group compared with the other groups, demonstrating an adverse outcome in infants from obese GDM mothers. Gesche et al. also reported that birth weight is related to maternal BMI in obese women and that adherence to gestational weight gain recommendations does not seem to prevent the incidence of increased birth weight [22]. Moreover, increased placental inflammation due to obesity may directly affect neonatal development through alterations in nutrient transport and has a negative impact on the neonatal immune system [23].

We also studied the relationship between pre-pregnancy BMI and the mode of pregnancy and delivery. Women in the overweight and obese groups tended to have a higher rate of ART pregnancies, but this difference was not significant. Generally, obese women experience longer times to conception, even if they are young and cycling regularly. This finding could be attributed to the altered ovarian follicular environment and increased metabolite, C-reactive protein, and androgen activity levels in these women [24]. Based on our survey, the rates of cesarean section in normal weight, overweight, and obese GDM patients were 48.8, 65.0, and 74.5 %, respectively. Compared with normal weight women, the emergency cesarean section rate was 1.4- and 2.0-fold higher in the overweight and obese groups, respectively. Excess abdominal adipose tissue can obstruct the progression of labor mechanically, which in turn blocks fetal circulation and may lead to fetal distress and emergency cesarean section. Cesarean section can increase the risk of maternal and fetal mortality compared with vaginal delivery. All these factors contribute to a worse outcome in obese GDM women.

There are several limitations to this study. First, this is a retrospective study. We collected data on 5010 GDM patients nationwide, but we were limited by what information was available in the medical records. Some clinical data were not included in our survey form, and different results may have been obtained if we had the missing data. Patients who participated in this survey were from tertiary- or secondary-level hospitals, which may have contributed to selection bias. Another limitation is related to the different methods of data capture. The glucose level in GDM patients was not available; thus, the confounding role of this level in each patient could not be assessed.

Conclusions

This study showed a significant association between pre-pregnancy BMI and an increased risk of adverse pregnancy and neonatal outcomes, such as gestational hypertension, fetal macrosomia, and emergency cesarean section, in Chinese women. Weight control should be emphasized prior to pregnancy to achieve a better pregnancy outcome, especially for women with GDM.

Acknowledgments This work was supported by funding from "Health industry special funds for Public Benefit Research Foundation" from the Ministry of Health, People's Republic of China (Grant number 201002013). W. Z. & X. Y. are the recipients of "the Health Excellent Talent Foundation of Beijing" from Beijing Health Bureau (Grant number 2009-2-11 & 2011-3-071).

Conflict of interest The authors declare that they have no competing interests.

References

1. Yang H, Wei Y, Gao X, Xu X, Fan L, He J, et al. Risk factors for gestational diabetes mellitus in Chinese women: a prospective study of 16,286 pregnant women in China. Diabet Med. 2009;26(11):1099–104.
2. Xu Y, Shen S, Sun L, Yang H, Jin B, Cao X. Metabolic syndrome risk after gestational diabetes: a systematic review and meta-analysis. PLoS One. 2014;9(1), e87863.
3. Pintaudi B, Lucisano G, Pellegrini F, D'Ettorre A, Lepore V, De Berardis G, Scardapane M, Di Vieste G, Rossi MC, Sacco M et al. The long-term effects of stillbirth on women with and without gestational diabetes: a population-based cohort study. Diabetologia. 2014.
4. Nilsson C, Carlsson A, Landin-Olsson M. Increased risk for overweight among Swedish children born to mothers with gestational diabetes mellitus. Pediatr Diabetes. 2014;15(1):57–66.
5. Popova PV, Grineva EN, Gerasimov AS, Kravchuk EN, Ryazantseva EM, Shelepova ES. The new combination of risk factors determining a high risk of gestational diabetes mellitus. Minerva Endocrinol, 2014.
6. Phithakwatchara N, Titapant V. The effect of pre-pregnancy weight on delivery outcome and birth weight in potential diabetic patients with normal screening for gestational diabetes mellitus in Siriraj Hospital. J Med Assoc Thai. 2007;90(2):229–36.
7. Tsai IH, Chen CP, Sun FJ, Wu CH, Yeh SL. Associations of the pre-pregnancy body mass index and gestational weight gain with pregnancy outcomes in Taiwanese women. Asia Pac J Clin Nutr. 2012;21(1):82–7.
8. Singh J, Huang CC, Driggers RW, Timofeev J, Amini D, Landy HJ, et al. The impact of pre-pregnancy body mass index on the risk of gestational diabetes. J Matern Fetal Neonatal Med. 2012;25(1):5–10.
9. Martin KE, Grivell RM, Yelland LN, Dodd JM. The influence of maternal BMI and gestational diabetes on pregnancy outcome. Diabetes Res Clin Pract. 2015;108(3):508–13.
10. 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(12), e82310.
11. Li G, Kong L, Li Z, Zhang L, Fan L, Zou L, et al. Prevalence of macrosomia and its risk factors in china: a multicentre survey based on birth data involving 101,723 singleton term infants. Paediatr Perinat Epidemiol. 2014;28(4):345–50.
12. Obendorf DL, Handlinger JH, Mason RW, Clarke KP, Forman AJ, Hooper PT, et al. Trichinella pseudospiralis infection in Tasmanian wildlife. Aust Vet J. 1990;67(3):108–10.
13. Bautista-Castano I, Henriquez-Sanchez P, Aleman-Perez N, Garcia-Salvador JJ, Gonzalez-Quesada A, Garcia-Hernandez JA, et al. Maternal obesity in early pregnancy and risk of adverse outcomes. PLoS One. 2013;8(11), e80410.

14. Somprasit C, Tanprasertkul C, Rattanasiri T, Saksiriwutth P, Wongkum J, Kovavisarach E, et al. High pre-pregnancy body mass index and the risk of poor obstetrics outcomes among Asian women using BMI criteria for Asians by World Health Organization Western Pacific Region (WPRO): a large cohort study. J Med Assoc Thai. 2015;98 Suppl 2:S101–7.
15. Weerakiet S, Lertnarkorn K, Panburana P, Pitakitronakorn S, Vesathada K, Wansumrith S. Can adiponectin predict gestational diabetes? Gynecol Endocrinol. 2006;22(7):362–8.
16. Qiu C, Williams MA, Vadachkoria S, Frederick IO, Luthy DA. Increased maternal plasma leptin in early pregnancy and risk of gestational diabetes mellitus. Obstet Gynecol. 2004;103(3):519–25.
17. Chu SY, Callaghan WM, Kim SY, Schmid CH, Lau J, England LJ, et al. Maternal obesity and risk of gestational diabetes mellitus. Diabetes Care. 2007;30(8):2070–6.
18. Ogonowski J, Miazgowski T, Kuczynska M, Krzyzanowska-Swiniarska B, Celewicz Z. Pregravid body mass index as a predictor of gestational diabetes mellitus. Diabet Med. 2009;26(4):334–8.
19. Zhang Y, Wang ZL, Liu B, Cai J. Pregnancy outcome of overweight and obese Chinese women with gestational diabetes. J Obstet Gynaecol. 2014;34(8):662–5.
20. Bodnar LM, Ness RB, Harger GF, Roberts JM. Inflammation and triglycerides partially mediate the effect of prepregnancy body mass index on the risk of preeclampsia. Am J Epidemiol. 2005;162(12):1198–206.
21. Sparano S, Ahrens W, De Henauw S, Marild S, Molnar D, Moreno LA, et al. Being macrosomic at birth is an independent predictor of overweight in children: results from the IDEFICS study. Matern Child Health J. 2013;17(8):1373–81.
22. Gesche J, Nilas L. Pregnancy outcome according to pre-pregnancy body mass index and gestational weight gain. Int J Gynaecol Obstet. 2015;129(3):240–3.
23. Wilson RM, Messaoudi I. The impact of maternal obesity during pregnancy on offspring immunity. Mol Cell Endocrinol. 2015.
24. Robker RL, Akison LK, Bennett BD, Thrupp PN, Chura LR, Russell DL, et al. Obese women exhibit differences in ovarian metabolites, hormones, and gene expression compared with moderate-weight women. J Clin Endocrinol Metab. 2009;94(5):1533–40.