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Fetal Growth and Pregnancy Outcome Following Bariatric Surgery: A Retrospective, Observational Cohort Study

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Abstract

Background Obese women face multiple fetal and maternal complications during pregnancy. This study investigates the effects of bariatric surgery (BS) on fetal and maternal pregnancy outcomes, particularly focusing on Doppler US during the perinatal period.

Methods A quantitative, retrospective observational cohort study (January 2015- June 2022) was performed in the ultrasonography obstetrics and gynecology department at King Khalid University Hospital. Pregnant women (50) from Riyadh, Saudi Arabia, who have undergone bariatric surgery, served as the research population. The participants were closely monitored throughout the pregnancy and delivery during regular prenatal care appointments. Serial ultrasounds assessed fetal growth parameters such as head circumference, femoral length, abdominal circumference, and estimated fetal weight. Their first visit established the baseline data, whereas vital signs, anthropometric measures, and fetoplacental circulation Doppler US scans were observed during later routine examinations. The data were compared with normal prenatal development to assess maternal and fetal outcomes.

Results A better fetal growth was noticed in the "<2 years after the BS" pregnancy group as compared to the " >2 years after the BS" pregnancy group during a gestational age of 13-26 weeks. A higher estimated fetal weight (716.65 g), head scan (24.88 cm), abdominal circumference (25.29 cm), and femoral length (25 cm) were noted in the "<2 years after the BS" pregnancy group. Contrarily, the ">2 years after the BS" pregnancy group demonstrated lower estimated fetal weight (537.47 g), head scan (23.31 cm), abdominal circumference (23.29 cm), and femoral length (23.06 cm).

Conclusion The study establishes BS as a risk factor for fetal growth in pregnant women. Overall, BS affected fetal nutrition, particularly in women who became pregnant after two years of BS. Therefore, the pregnancy-related high-risk category should be extended up to five years after the BS.

Keywords: Bariatric surgery, pregnancy outcome, fetal growth

Background

Obese women could suffer from infertility, spontaneous pregnancy loss, and an increased risk of congenital defects. Obese pregnant women face 50% higher health risks (hypertension, macrosomia, gestational diabetes, pre-eclampsia, unsuccessful labor induction, and an emergency cesarean section) than normal-weight pregnant women [1, 2]. Obesity (BMI ≥30 kg/m2) is a global issue that affects women's fertility, and influences birth weight and patterns of prenatal development [3]. Bariatric surgery

(BS) could positively and negatively affect pregnancy outcomes. BS might alleviate newborn critical care, gestational diabetes, cesarean sections, and hypertension. On the other hand, it could elevate the risk of small-for-gestational-age (SGA) newborns through continued weight loss after the treatment [3, 4]. Bariatric surgery (BS) is an effective long-term weight strategy for extremely obese women, which alleviates obesity-related comorbidities through sustained weight loss. The postoperative BS effects on neonates, fertility, and pregnancy are rising as often reproductive women undergo BS [5, 6]. International guidelines advise post-bariatric females to postpone (12 to 24 months) conception to ensure fetal and maternal health [7]. These recommendations are based on various studies presenting an elevated risk of impaired fetal growth and fetal loss in pregnancies conceived within a year after BS. For example, Costa et al. [8] retrospectively studied pregnancies with a BS history. They reported preconception deficiencies in these women, which were aggravated during pregnancy. Most of these women had micronutrient (iron, vitamin D, zinc, and vitamin B12) deficiencies. However, they concluded that pregnancy after BS is generally well-tolerated and safe, but requires close monitoring [8]. Johansson et al. [9] demonstrated a significant ratio of SGA infants born after 1.8 years of BS. Balestrin et al. [5] compared BS and non-BS obese pregnant women in Brazil in 2019 to study gestational outcomes and revealed that the prevalence of negative conditions was lower in non-BS females. Contrarily, the SGA deliveries were higher in the post-bariatric group, which might have been caused by compromised fetal growth.

Maric et al. [10] conducted a sizable retrospective cohort study and noticed significantly lower birthweight in women with previous bariatric surgery in comparison to non-bariatric but comparable BMI pregnancies. This UK-based study also compared fetoplacental Doppler and fetal biometry in both groups. The results demonstrated that women with BS history presented smaller abdominal circumference (AC), femur length (FL), and estimated fetal weight (EFW) in fetuses during gestation and delivery. Post-bariatric group's lower glucose levels contributed to these fetal variations, thus establishing a potential connection between fetal growth and maternal glucose metabolism. Moreover, 17 observational studies' meta-analyses compared post-BS and non-BS pregnancies in women [11]. The group with BS history presented a lower ratio of big neonates, preeclampsia, and gestational diabetes mellitus. Contrarily, the BS group was characterized by elevated risk of small neonates, maternal anemia, preterm birth, and admission for neonatal intensive care. Abenhaim et al. [12] adopted a retrospective cohort design and found comparable pregnancy outcomes in BS females and women with morbid obesity. They noticed a lower incidence of premature membrane rupture, hypertensive disorders, chorioamnionitis, instrumental delivery, cesarean birth, and postpartum hemorrhage and infection in the BS group. Moreover, the BS group also experienced higher rates of restricted fetal growth, labor induction, venous thromboembolism, and blood transfusion. A smaller sample (18 patients) cross-sectional study at Latifa Hospital in Dubai in 2018 investigated pregnancy after bariatric surgery (PABS). The participants previously underwent sleeve gastrectomy and had a 0.45% PABS rate. Most of these participants were multiparous and gave birth on their own. They had an average duration of 5.3 months between surgery and pregnancy. Anemia was the most common prenatal complication whereas delivery outcomes of lower segment cesarean section (LSCS) and vaginal birth were identical. They concluded that PABS is a high-risk pregnancy requiring specialized cooperative treatment [13]. Roos et al. [14] analyzed a dataset from the Swedish National Healthcare Service to compare BS effects on prenatal outcomes with non-BS women. They revealed that women with a BS history, particularly with BMI <35, had a higher risk of preterm delivery, SGA, and spontaneous preterm birth. Contrarily, these women presented a lower chance of large gestational age (LGA) delivery. These studies highlight the potential risks of PABS. Micronutrient deficiencies after BS necessitate proper supplementation and careful monitoring. Moreover, preterm delivery and anemia-related complications demand close monitoring and specialized care throughout pregnancy.

The literature still lacks the applicability of Doppler ultrasonography in pregnancy-outcome identification after the BS. A few studies have reported only non-significant differences among fetoplacental Doppler indices of normal-weight females and those who underwent BS [9, 10]. They suggested repeated ultrasound tests (every four weeks) to assess fetal growth in the third trimester of women who did not gain much weight during pregnancy and were pregnant within two years of BS [18, 19]. The lack of studies in the Gulf Cooperation Council (GCC) further complicates the situation, whereas the number of reproductive-age women adopting BS is continuously rising. Hence, intrauterine adaptation after BS necessitates further investigation regarding potential impacts on fetal development and growth [15]. The current study utilizes Doppler tests (umbilical artery, uterine, and middle cerebral artery Doppler) to correlate previous maternal BS, fetal development parameters, and birth weight [16, 17]. The pre-gravid weight is also a critical factor for fetal and maternal health [8, 5]. Therefore, the study examined fetal development and neonatal outcomes in pregnant Saudi Arabian women after the BS. The parameters included prenatal Doppler examinations and fetal measurements (head size, estimated fetal weight, abdominal circumference, and femur length). Moreover, fetal and maternal outcomes such as birthweight, cesarean section, and preterm birth rates were also assessed for a detailed knowledge of BS impacts on pregnancy outcomes.

Methods

A quantitative retrospective observational cohort study was conducted (January 2015 and June 2022) in the King Khalid University Hospital's (KKUH) ultrasonography OB/GYN department in Riyadh, Saudi Arabia. The study population included pregnant women with a BS (bariatric surgery) history. Medical records of 50 pregnant patients with prior BS treatment were used to gather relevant information. Multiple channels (specialized BS clinics, high-risk pregnancy clinics, antenatal clinics, and referrals from healthcare professionals) were used to collect pregnant women’s data. The inclusion criteria included pregnant women (18- 50 years) with BS history, whereas pregnant women with multiple pregnancies or chronic diseases were excluded. The participants were monitored throughout their pregnancies until delivery. The information was used to statistically estimate a precise sample size.

Study protocol

Data was collected from the medical records regarding pregnant women's routine scans, visits, prenatal care, and pre-existing comorbidities throughout the pregnancy. Pregnant women with a BS history who regularly attended follow-up visits at predetermined intervals (every 6-8 weeks) were particularly focused. Clinical evaluations such as vital signs, BMI, and weight were recorded as well. Simultaneously, serial ultrasound examinations assessed fetal growth, Doppler parameters (ductus venosus, umbilical artery, and middle cerebral artery (MCA)), and fetal anomalies/ growth deviations. Moreover, maternal complications (gestational diabetes, preeclampsia, and gestational hypertension) were documented as well. However, the absence of intervention/ randomization procedures, placebo controls, treatments, and masking/ blinding techniques is the main limitation of this study. Customized CRFs were designed for systematic data collection regarding variables of interest. CRFs contained demographic information, medical history, pregnancy outcomes, fetal growth parameters, Doppler study results, and maternal complications. Data were recorded onto electronic CRFs (Google Forms).

Electronic Data Capture (EDC) System

REDCap, an electronic data capture system, was employed to enhance data management efficiency. Trained research staff entered the data collected on the CRFs' hard copy into the EDC system. EDC system provided a secure platform for data entry, analysis, and storage. Data quality and adherence were regularly monitored to ensure data integrity and validity. Participants' personal information was coded and de-identified to maintain confidentiality and ensure anonymity. Ethical guidelines were followed during the study, and it was approved by the Institutional Review Board (IRB)/ Research Ethics Committee (REC) of King Saud University.

Research Biases

The study was conducted only in the ultrasound OB/GYN department at KKUH, which could limit the data's generalizability. The participants could differ from excluded individuals in health and socioeconomic status. Data from the medical record could be partially accurate or incomplete. Ultrasound examinations might be subjective and could vary with sonographers. Maternal health and lifestyle-related self-reported data might be subject to recall bias. Potential confounders (gestational age, maternal age, and BMI) could affect the BS and pregnancy outcome relationship. Moreover, maternal nutrition, pre-existing comorbidities, and healthcare access could also impact pregnancy outcomes.

Statistical Analysis

SPSS (ver. 22) was used to statistically analyze (descriptive and comparative) the data. Descriptive statistics (frequencies, means, medians, and standard deviations) facilitated the characterization of the study population and outcomes. Comparative analysis helped in comparing outcomes between pregnant women with a BS history and standard measurements. T-tests established significant differences among the studied parameters at $p<0.05$. Regression analysis was performed to adjust for potential confounding factors, including BMI, maternal age, and gestational age.

Results

All of the post-BS pregnant participants of this cohort study underwent laparoscopic sleeve gastrectomy (LSG) in Saudi Arabia. They had a mean age of 33.2 years (22 to 44). 21 participants conceived in < 2 years post-BS, whereas the other 26 women conceived after 2 years or more post-BS. 10 of the participants delivered outside KKUH, whereas 4 were still pregnant at the end of the research period. A total of 37 deliveries were documented, with 7 preterm (<37 weeks) deliveries (Table 1).

Table 1 Maternal characteristics of the studied sample

	Participants		
Age (of participants)	<30	12	26%
	30-39	30	64%
	>39	5	10%
Nationality	Saudi	45	96%
	Not Saudi	2	4%

Timing from surgery (of included)	<2years >=2years	21 26	45% 55%
1^{st} pregnancy after bariatric surgery	33		
2^{nd} pregnancy after bariatric surgery	24		
Gestational age at the time of delivery	<37 weeks	7	<2 years =5 >2years =2
	>=37 weeks	30	<2years =18 >2years =12

Table 2 presents the frequency and percentage of the mode of delivery. Out of a total of 35 cases, 18 (51.4%) deliveries occurred through cesarean section (CS) whereas 17 cases (48.6%) were of spontaneous vaginal deliveries (SVD) (Fig. 1). Thus, an even distribution was noticed among modes of delivery (CS vs SVD).

Table 2 Modes of deliveries

Mode of Delivery	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
CS	18	51.4	51.4	51.4
SVD	17	48.6	48.6	100
Total	35	100	100	

Based on pregnancies' time intervals, data depicted significantly different estimated fetal weights, femoral length, and abdominal circumference between both groups. However, head circumference did not vary significantly (Table 3). The group that conceived after two or more years of BS had an average estimated fetal weight of 537.47 g with a standard deviation of 203.719. Contrarily, the group that conceived in less than two years of BS demonstrated a higher average estimated fetal weight of 716.65 g with a standard deviation of 264.916 (Table 3). The fetal weights in both groups presented some variability. A slightly higher standard deviation among 2^{nd} group indicates more data spread in comparison to the first group (Fig. 2).

Table 3 Estimated fetal weight among studied groups

	Duration from surgery to pregnancy	**N**	**Mean**	**Std. Deviation**	**Std. Error**
Estimated Fetal Weight	More than two years	17	537.47 g	203.719	49.409
	Less than two years	17	716.65 g	264.916	64.252

EFW significantly varied between the two groups according to the independent samples T-test. EFW was significantly higher in the "<2 years" group than in the other group (>2 years). The significance value of 0.034 (<0.05) depicts significantly different EFW in both groups, revealing that it is unlikely to have occurred by chance. Thus, the differences between both groups are reliable and did not emerge as a random variation (Table 4).

Table 4 Independent samples t-test of estimated fetal weight (EFW)

		Levene's Test for Equality Variances		oft-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
EFW	Equal variances assumed	3.442	.073	-2.211	32	.034	-179.176	81.053	-344.275	-14.077
	Equal variances not assumed			-2.211	30.020	.035	-179.176	81.053	-344.704	-13.649

The scan of head circumference compared with the gestational age-confirming scan revealed that it was lower in the ">2 years" group, with a mean value of 23.31 cm and a standard deviation of 1.991. The mean value of head circumference was noted as 24.88 cm with a standard deviation of 2.446 in the "<2 years" group. A slightly higher standard deviation in the "<2 years" group indicates more data spread as compared to the other group (>2 years) (Table 5, Fig. 3).

Table 5 Fetal head circumference in both studied groups

	Duration From Surgery to Pregnancy	N	Mean	Std. Deviation	Std. Error Mean
Head Circumference	More than two years	16	23.31 cm	1.991	0.498
	Less than two years	16	24.88 cm	2.446	0.612

Data on head circumference did not significantly differentiate between the two groups. The independent samples T-test demonstrated a significance of 0.057, which is more than 0.05, depicting non-significant differences in head circumference between the>2 years of BS and <2 years of BS groups. It suggests that the observed differences between both groups could have occurred by chance due to random variations (Table 6).

Table 6 Independent samples t-test of head circumference in both groups

		Levene's Testt for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Head Circumference	Equal variances assumed	2.229	.146	-1.982	30	.057	-1.563	.788	-3.173	.048
	Equal variances not assumed			-1.982	28.811	.057	-1.563	.788	-3.175	.050

The “>2 years of BS” group had an average abdominal circumference of 23.29 cm with a standard deviation of 3.037, whereas the “<2 years of BS” group presented an average abdominal circumference of 25.29 cm with a standard deviation of 3.021. The independent samples T-test generated a significance value of 0.048, revealing a significantly varied abdominal circumference between both groups. The group with “<2 years of BS” had a higher average abdominal circumference (25.29 cm) than the other “>2 years of BS” (23.29 cm). Standard deviations (3.037 cm and 3.021 cm) of both groups demonstrate similarly variable abdominal circumferences in both groups (Table 7, Fig. 4).

Table 7 Abdominal circumference in both groups

	Duration From Surgery to Pregnancy	N	Mean	Std. Deviation	Std. Error Mean
Abdominal Circumference	More than two years	17	23.29	3.037	.736
	Less than two years	17	25.29	3.021	.635

The independent samples T-test revealed a significance value of 0.048, indicating significantly different abdominal circumferences in both groups, “<2 years of BS” and “>2 years of BS”. Thus, abdominal circumference differences are reliable and are unlikely to have occurred by chance/randomly (Table 8).

Table 8 Independent samples t-test of abdominal circumference in both groups

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper

Abdominal Circumference	Equal variances assumed	0.049	0.826	-2.057	32	.048	-2.000	.972	-3.980	-.020
	Equal variances not assumed			-2.057	31.316	.048	-2.000	.972	-3.982	-.018

The average femoral length was noted as 23.06 cm with a standard deviation of 2.512 cm in the ">2 years of BS" group. The other group, "<2 years of BS", had an average femoral length of 25 cm with a standard deviation of 2.318 cm. Similar standard deviations (2.512 and 2.318 cm) in both groups depict the same variability of femoral length in both groups (Table 9, Fig. 5).

Table 9 Femoral length in both groups

	Duration From Surgery to Pregnancy	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Femoral Length	More than two years	17	23.06	2.512	.609
	Less than two years	17	25.00	2.318	.562

Femoral length significantly differentiated between both groups, with a significance value of 0.026. The significance value of 0.026 represents reliable differences, and that it's by chance/random occurrence is unlikely (Table 10). Collectively, the study revealed a significantly higher EFW, AC, and Femoral length in the "<2 years of BS" group during a gestational age of 13-26 weeks.

Table 10 Independent samples t-test of femoral length in both groups

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Femoral Length	Equal variances assumed	.318	.577	-2.342	32	.026	-1.941	.829	-3.630	-.253
	Equal variances not assumed			-2.342	31.797	.026	-1.941	.829	-3.630	-.252

Discussion

The study investigates the effects of bariatric surgery (BS) on post-surgery pregnancy. BS is an efficient obesity treatment yielding significant weight loss and improved metabolic health. It potentially alleviates various adverse outcomes, including pregnancy-induced hypertension among fetuses and obese mothers, and gestational diabetes [20, 21]. However, it can exert various complications (potential surgical, maternal-fetal nutrition, and modified glucose metabolism) during pregnancy. Therefore, the elaboration of published guidelines is necessary to devise an accurate protocol for obstetricians for high-risk patients [22, 23]. Falcone et al. [20] performed a retrospective cohort investigation to analyze BS-related challenges and reported that it could mitigate certain pregnancy complications, such as pregnancy-induced hypertension and gestational diabetes, while concurrently causing anemia, micronutrient deficiencies, and SGA infants. Like previous studies, they also suggested careful pregnancy monitoring and management after BS, particularly focusing on regular glucose monitoring and nutritional supplementation.

During this study, serial ultrasound examinations assessed fetal growth parameters such as head circumference, femoral length, abdominal circumference, and estimated fetal weight. The pregnancy in women who conceived in <2 years after BS significantly varied from those who conceived >2 years after BS (the recommended post-BS interval) [24]. Better fetal growth was noticed in <2 years after the BS pregnancy group. This finding contradicts other investigations suggesting an elevated risk of SFGA fetus if conceived in <2 years after BS [10, 25]. EFW, AC, and FL were also significantly differentiated in both groups. It could be attributed to strict supervision and assessment of pregnancies within <2 years of BS as high-risk patients [16]. These patients often adopt regular follow-ups and improved nutrition for better fetal growth. Contrarily, reduced fetal growth was noted in the other pregnancy group (>2 years after BS). This might be because they were generally not considered high-risk patients. Therefore, the designation of high-risk patients should be re-evaluated for pregnancies after >2 years of BS to avoid adverse impacts on fetal growth. It could be due to the body's incomplete physiological adaptation to absorb nutrients in >2 years after the BS group. However, the lack of BMI data at conception and throughout pregnancy restricts the confirmation regarding progressive weight loss effects on fetal growth post-BS.

Fetoplacental blood flow in pregnant women with BS history might only change minutely and is less likely to be detected by Doppler methods. Moreover, BS impacts considerably vary among individuals [10, 16]. Wong et al. [26] explored umbilical artery Doppler velocimetry (UADV) to predict adverse perinatal outcomes in diabetic pregnant women. The UADV method, presenting limited prediction ability, cannot serve as the only reliable approach. Therefore, they emphasized the integration of a comprehensive fetal monitoring approach in diabetic pregnancies consisting of UADV and clinical assessments. Shub and Lappas [27] monitored pregnancies in diabetic women *via* fetal well-being and aneuploidy screening and demonstrated higher diabetes prevalence and related risks among pregnant women. Data regarding intrauterine response to BS are limited. BS can initiate acute changes and physiological responses in the body, such as vitamin deficiencies and hormonal disruptions [28]. Feichtinger et al. [29] studied birth anthropometry intrauterine fetal growth variations after mothers' gastric bypass surgery. They noted a significant rise in SGA newborns in the gastric bypass group. A substantial decline in fetal growth percentiles was also noted from the start of the second trimester to the completion of the third trimester. Moreover, placental and birth weights were significantly lower in the gastric bypass group than in the control group. Thus, investigations of related adaptations and underlying mechanisms are crucial to assess their effects on fetal development and growth.

Most of the studies are pointed toward women with a BMI of 40 or higher, whereas the women with lower BMIs remain largely ignored. Therefore, retrospective cohort studies should be prioritized to monitor females throughout their pregnancies into the postpartum period. It could generate comprehensive data on long-term and short-term child health outcomes. Furthermore, comparative investigations of different BS types could help in identifying beneficial procedures for pregnancy-considering women [15]. Women with different BMIs should be focused on as well to assess their impact on pregnancy outcomes. These studies should involve women from diverse racial and ethnic backgrounds to evaluate potential variations in pregnancy outcomes. The in-depth assessment of these aspects could yield a better understanding of BS effects on pregnancy outcomes, thus facilitating the development of more informed care guidelines for post-BS pregnancy. The current study presents BS as a fetal growth risk factor. The women who conceived within two years of BS require special care and nutrition and should be treated as high-risk patients. Similarly, the women who conceived after two years of BS also faced certain risks. Therefore, pregnant women should be treated as high-risk patients for at least five years after the BS. However, the study lacked Doppler MCA, ductus venosus (DV), newborn weight, and patients' BMI data due to certain unavoidable factors, which should be considered in future investigations.

Conclusion

The study establishes BS as a risk factor for fetal growth in pregnant women. The group conceiving within two years of BS had significantly higher EFW, AC, and FL during gestational age (13–26 weeks) than women who conceived after two years of BS. The head circumference difference was not noticeable in both groups. Overall, BS affected mothers' potential for fetal nutrition, particularly in women who became pregnant after two years of BS. Individuals with a BS history should be re-evaluated to be treated as high-risk patients. The pregnant women within two years of BS were classified as high-risk patients and received special care and attention. Contrarily, the women who became pregnant after two years of BS were not considered high-risk patients, which led to reduced fetal development. Therefore, the guidelines must be updated to include women in the high-risk category up to five years after BS. It could facilitate close monitoring and specialized care to alleviate fetal problems. Moreover, Doppler ultrasonography data collection of MCA and DV is recommended in future studies to accurately assess fetal-maternal circulation in patients with a BS history.

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