

Comparison Of Fetal Biometry In Obese Versus Non Obese Nulliparous Pregnant Women

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Abstract

Background: Maternal obesity is a developing worldwide health issue and has been linked to determine an important change on intrauterine fetal growth pattern. The available literature shows contradictory reports, where some show an overgrowth of the fetus (macrosomia), others show limited or disproportionate fetal growth among obese mothers. The objective of the current research was to compare fetal biometric measures between obese and non-obese nulliparous expectant women as well as to determine how the body mass index (BMI) of the mother affects fetal growth.

Aims: To evaluate the relationship between maternal obesity and fetal growth in nulliparous pregnancies.

Methods: The study was an observational, comparative, cross-sectional research involving 90 nulliparous women who had singleton pregnancies and were aged 20-30 weeks of gestation (45 obese (BMI ≥ 30 kg/m²) and 45 non-obese (BMI < 30 kg/m²)) with singleton pregnancies. Qualified sonographers took standardized

ultrasonographic measurements, such as biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) and estimated fetal weight (EFW). The SPSS 29 version was used to analyze data. Independent samples t-tests were used to compare different groups and calculate descriptive statistics. Correlation and multiple regression were done to establish the correlation between maternal BMI, gestational age and fetal biometric measures. The p-value of less than 0.05 was regarded as significant.

Results: Obese and non-obese groups were subjected to descriptive analysis to determine the distribution of fetal biometric parameters as biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femur length (FL), and estimated fetal weight (EFW). The mean values were as below in the group with obesity: BPD = 5.62 \pm 0.66 cm, HC = 21.20 \pm 1.83 cm, AC = 18.48 \pm 1.77 cm, FL = 3.57 \pm 0.71 cm, and EFW = 556.20 \pm 220.19 g. In the non-obese group,

the same means were a little higher: BPD = 5.89 +- 0.79 cm, HC = 21.65 +- 2.69 cm, AC = 19.24 +- 2.76 cm, FL = 4.22 +- 0.69 cm and EFW = 675.11 +- 305.12 g. Descriptive summary shows that all the fetal biometric parameters were greater in the non-obese group, but the level of difference was more eminent in the length of the femur and estimated weight of the fetus.

Conclusion: This research indicates that the larger the maternal BMI among the nulliparous women, the shorter the length of the femur and the lower the estimated fetus weight when the gestational age is controlled. The results indicate that maternal obesity can have a modification in the growth pathways of the fetus and could end up in the possibility of limited or asymmetric development and not necessarily universal macrosomia. These findings highlight the significance of personal fetal growth tracking during pregnancy in obese pregnancies to detect anomalies in normal growths. More extensive, longitudinal and multicentric research to include placenta and metabolite variables is suggested to clarify the mechanisms behind the changes in fetal biometry as a result of obesity.

INTRODUCTION

Correct evaluation of fetal growth helps you track gestational age, growth patterns, and emerging problems. Ultrasound is the main tool. Modern machines improved accuracy, which supports better decisions during pregnancy. Maternal obesity affects fetal growth and affects the quality of ultrasound imaging. Obesity in pregnancy means a BMI higher than 30 before conception. Rates continue to rise in many regions. Obesity increases the risk of gestational diabetes, preeclampsia, thrombosis, and cesarean delivery. It also alters placental function through abnormal glucose and lipid metabolism. This can cause either macrosomia or fetal growth restriction. Both patterns complicate management and increase the need for reliable biometric monitoring. Standard fetal biometry includes biparietal diameter, head circumference, abdominal circumference, and femur length. Abdominal circumference reflects fetal nutrition, head measurements reflect neurodevelopment, and femur length reflects skeletal growth. In obese women, thick adipose tissue weakens ultrasound penetration. This reduces image clarity and increases the chance of measurement error. Studies show mixed results when comparing fetal biometry between obese and non-obese mothers. Nulliparous women face higher risks of prolonged labor, operative delivery, and hypertensive disorders. When obesity and nulliparity coexist, the risk of cesarean section, labor dystocia, shoulder dystocia, and neonatal complications increases. Few studies focus only on nulliparous women, so the impact of obesity on fetal biometry in this group is unclear.

Ultrasound remains the main imaging method, but its accuracy depends on operator skill and machine quality. Incorrect weight estimation can lead to unnecessary inductions or delayed intervention. Reliable measurements help you plan delivery and guide monitoring. Understanding how obesity alters fetal biometry supports better clinical guidelines. It helps you adjust growth charts, increase scan frequency when needed, and avoid misclassification of fetal growth. Macrosomia increases the risks of birth trauma and neonatal metabolic issues. Fetal growth restriction increases perinatal morbidity. Precise biometry helps manage both risks. Obesity also carries psychosocial effects. Many obese women report stigma in healthcare settings. Nulliparous women often

experience more anxiety, so inconsistent measurements can increase stress. Clear understanding and improved practice improve both clinical outcomes and patient experience.

WHO classifies obesity into three classes based on BMI. Higher obesity classes carry higher risks of stillbirth, congenital anomalies, and long-term metabolic problems in children. Imaging becomes harder as BMI increases. Maternal adiposity also influences fetal growth through metabolic and hormonal pathways. Nulliparous women may be more vulnerable because they have no prior pregnancy adaptations. Evidence remains limited on how different obesity classes affect fetal biometry in nulliparous women. The exact influence on biparietal diameter, head circumference, abdominal circumference, and femur length remains uncertain.

This study aims to compare fetal biometry between obese and non-obese nulliparous women. It explores how maternal obesity affects growth estimation and clinical decisions. It also examines whether obesity always alters biometry or whether the effect varies. The goal is to support better growth models and improve antenatal management for pregnancies affected by maternal obesity.

AIM AND OBJECTIVES

To compare the fetal biometric measures of obese and non-obesity nulliparous pregnant women (Biparietal Diameter, Abdominal Circumference, Femur Length, and Head Circumference).

To evaluate the relationship between maternal obesity and fetal growth in nulliparous pregnancies.

METHODOLOGY

This study used an observational comparative cross-sectional approach and was conducted at Sardar Bibi Hospital, Lahore. A total of 90 participants were included, with 45 women in each group. Non-probability purposive sampling was used to recruit women who met the inclusion criteria. The study duration was nine months. Eligible participants were nulliparous pregnant women between 20 and 30 weeks of gestation. Women with BMI above 30 were placed in the obese group and women with BMI below 30 were placed in the non-obese group. Written informed consent was required. Women were excluded if they had multiple pregnancies, were younger than 18 or older than 35, had preexisting medical conditions, pregnancy complications, fetal abnormalities, or were unable to provide consent. All ethical requirements were followed. Privacy, confidentiality, and anonymity were maintained. Participants were informed of their rights and could withdraw at any time. After consent, height and weight were recorded to calculate BMI. Trained sonographers performed transabdominal ultrasound to measure femur length, head circumference, abdominal circumference, and biparietal diameter. Image quality was documented, and maternal comorbidities such as hypertension or gestational diabetes were noted. Data was stored securely.

RESULTS

This study included a total of 90 pregnant women equally distributed into two groups: 45 obese and 45 non-obese participants. The participants were between 18 and 35 years of age, representing the normal reproductive age group. The gestational age ranged from 20 to 30 weeks, corresponding to the mid-to-late second trimester. All participants were nulliparous and had singleton pregnancies.

The inclusion criteria were designed to ensure that both groups were comparable in terms of gestational age and parity, thereby minimizing the influence of confounding factors on fetal growth. Descriptive analysis was performed to determine the distribution of fetal biometric parameters, including biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femur length (FL), and estimated fetal weight (EFW). The mean values for the obese group were as follows: BPD = 5.62 ± 0.66 cm, HC = 21.20 ± 1.83 cm, AC = 18.48 ± 1.77 cm, FL = 3.57 ± 0.71 cm, and EFW = 556.20 ± 220.19 g. In the non-obese group, the corresponding mean values were slightly higher: BPD = 5.89 ± 0.79 cm, HC = 21.65 ± 2.69 cm, AC = 19.24 ± 2.76 cm, FL = 4.22 ± 0.69 cm, and EFW = 675.11 ± 305.12 g. The descriptive summary indicates that all fetal biometric parameters were higher in the non-obese group, with the most pronounced differences observed in femur length and estimated fetal weight.

Independent t-tests were conducted to compare fetal biometric parameters between the obese and non-obese groups. Femur length (FL) and estimated fetal weight (EFW) were significantly greater among the non-obese women ($p < 0.001$ and $p = 0.037$, respectively). However, no statistically significant differences were observed in biparietal diameter (BPD) ($p = 0.084$), head circumference (HC) ($p = 0.355$), or abdominal circumference (AC) ($p = 0.124$).

Correlation analysis revealed a moderate negative relationship between maternal BMI and femur length ($r = -0.345$, $p = 0.001$) and a weak but significant negative relationship between maternal BMI and fetal abdominal circumference ($r = -0.214$, $p = 0.043$), indicating that higher maternal BMI was associated with reduced fetal growth in these parameters. Regression analysis demonstrated that gestational age was the most significant positive predictor of fetal weight ($B = 95.76$, $p < 0.001$), while maternal BMI had a significant negative effect ($B = -10.27$, $p = 0.003$). This implies that an increase of one unit in BMI was associated with an approximate 10 g reduction in fetal weight. Overall, these findings suggest that maternal obesity negatively influences certain fetal biometric measurements, reflecting possible intrauterine growth restriction patterns.

Table 4.1: Comparison of fetal biometric parameters between obese and non-obese pregnant women.

Variable	Obese (Mean \pm SD)	Non-Obese (Mean \pm SD)	t-statistic	p-value
BPD (cm)	5.62 ± 0.66	5.89 ± 0.79	-1.748	0.084
HC (cm)	21.20 ± 1.83	21.65 ± 2.69	-0.930	0.355
AC (cm)	18.48 ± 1.77	19.24 ± 2.76	-1.554	0.124
FL (cm)	3.57 ± 0.71	4.22 ± 0.69	-4.383	<0.001
EFW (g)	556.20 ± 220.19	675.11 ± 305.12	-2.120	0.037

Interpretation:

Femur Length (FL): Significantly higher in non-obese group ($p < 0.001$).
Estimated Fetal Weight (EFW): Significantly higher in non-obese group ($p = 0.037$).
BPD, HC, and AC: No statistically significant differences ($p > 0.05$).

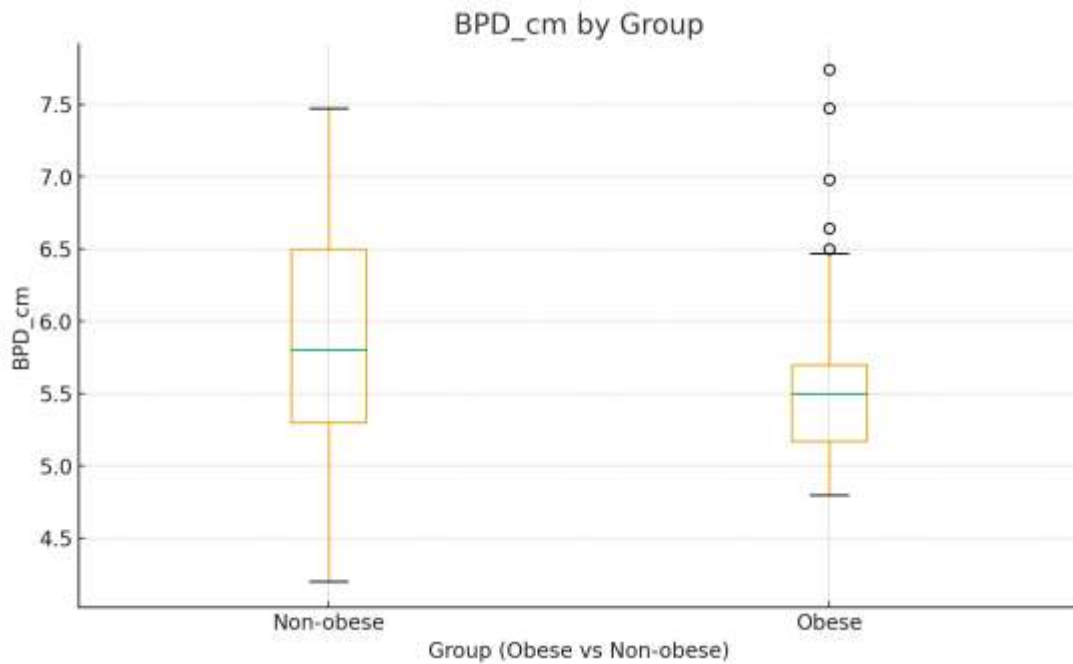


Figure 4.1 : Box plot showing BPD distribution among obese and non obese pregnant women.

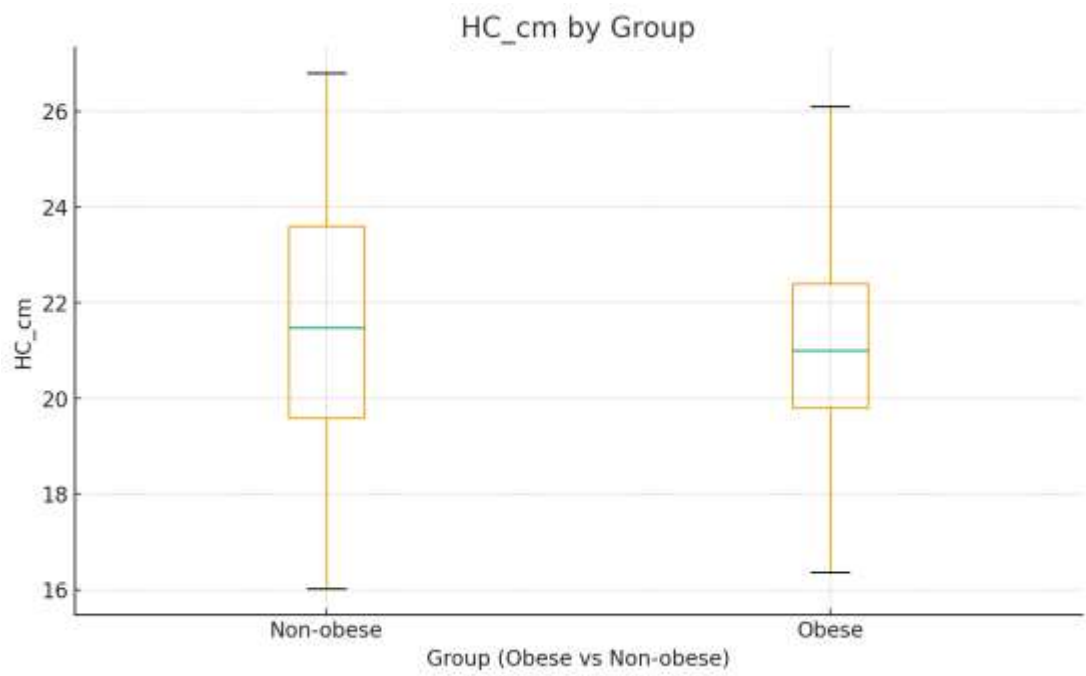


Figure 4.2: Box plot showing HC distribution among obese and non-obese pregnant women.

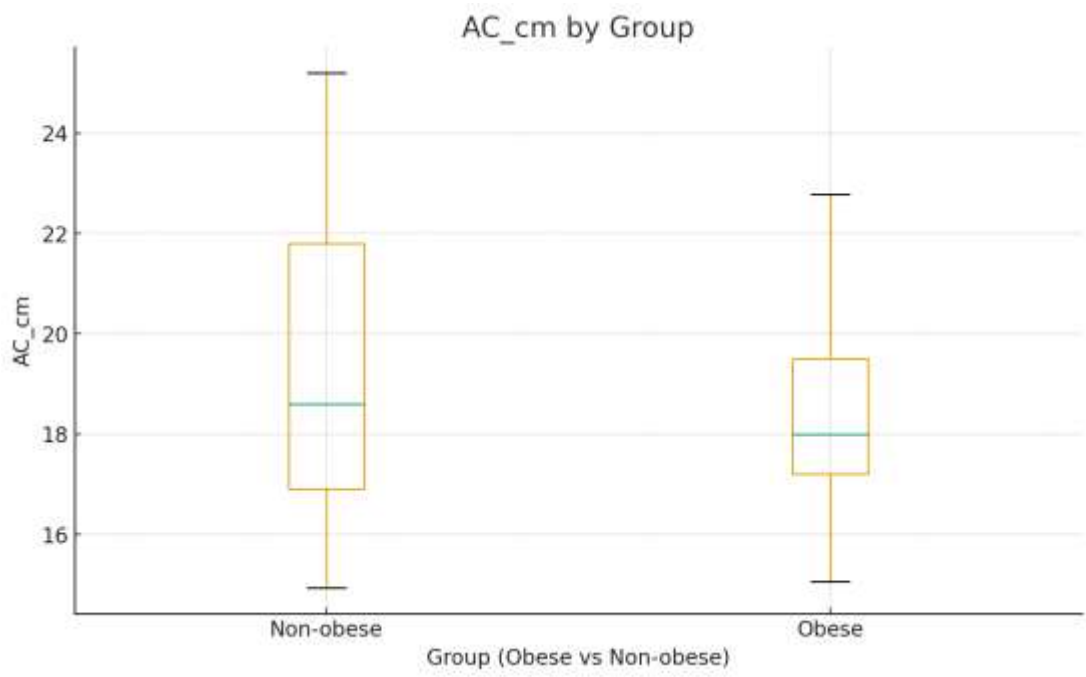


Figure 4.3: Box plot showing AC distribution among obese and non-obese pregnant women

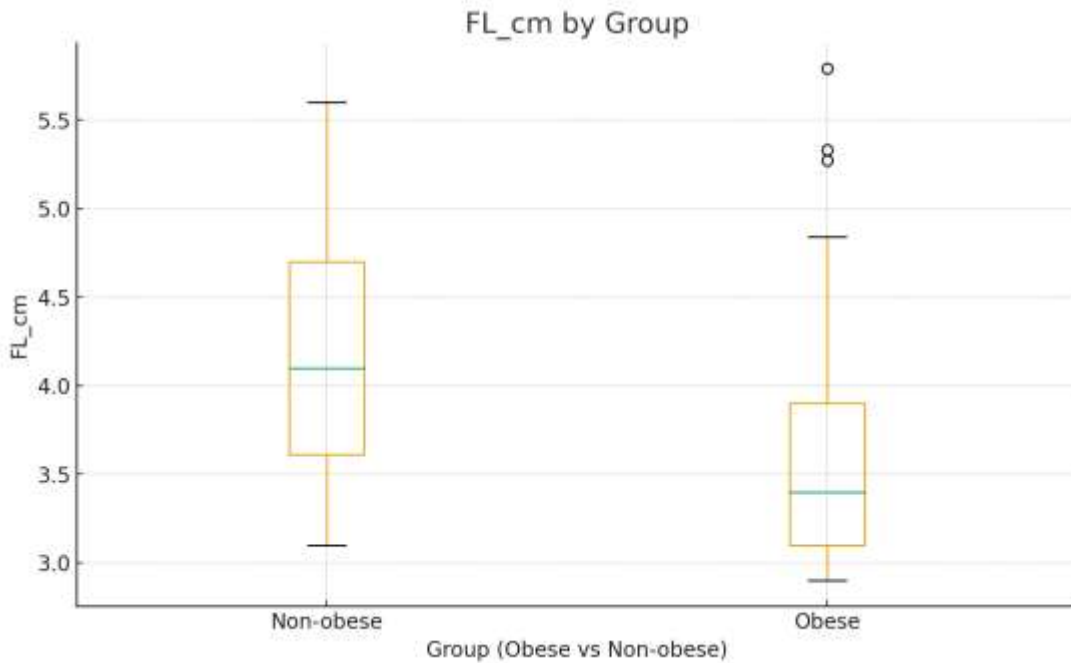


Figure 4.4: Box plot showing FL distribution among obese and non-obese pregnant women

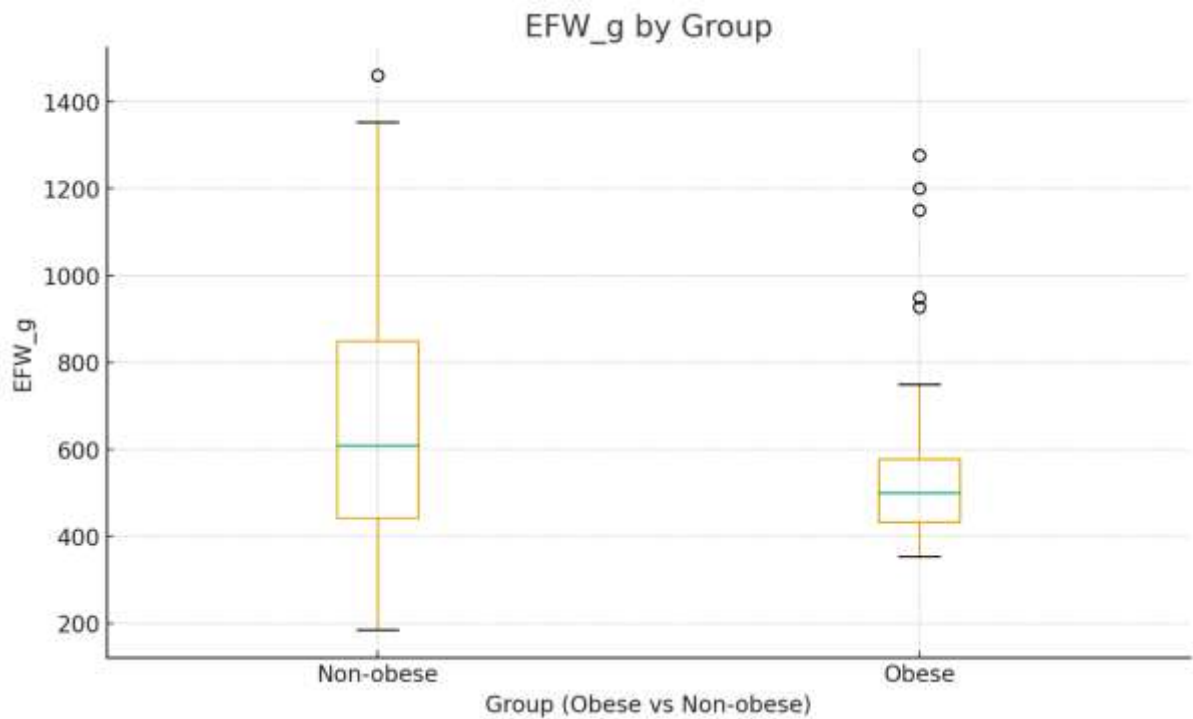


Figure 4.5: Box Plot showing comparison of EFW between obese and non obese pregnant women.

For each fetal parameter:

BPD (cm) → overlap, no significant difference.

HC (cm) → overlap, no significant difference.

AC (cm) → slightly higher in non-obese, not significant.

FL (cm) → visibly higher in non-obese, significant ($p < 0.001$).

EFW (g) → higher in non-obese, significant ($p = 0.037$).

Table 4.2: Correlation between maternal BMI and fetal biometric parameters

Variable	Correlation (r)	p-value
BPD	-0.162	0.127
HC	-0.155	0.144
AC	-0.214	0.043
FL	-0.345	0.001
EFW	-0.192	0.071

Interpretation:

Interpretation:

Femur length (FL) shows a moderate negative correlation with BMI ($r = -0.345, p < 0.001$).

Abdominal circumference (AC) has a weak but significant negative correlation ($r = -0.214, p = 0.043$).

BPD, HC, and EFW show negative but non-significant correlations.

These findings suggest that higher maternal BMI is associated with reduced fetal growth, particularly in femur length and abdominal circumference.

Regression Model

Dependent variable: Estimated Fetal Weight (EFW)

Predictors: Maternal BMI + Gestational Age

Table 4.3: Multiple linear regression analysis predicting estimated fetal weight (EFW)

Predictor	Coefficient (B)	t-value	p-value	95% CI
Constant	-1422.01	-6.57	<0.001	-1852.26, -991.76
BMI	-10.27	-3.01	0.003	-17.05, -3.49
Gestational Age	+95.76	12.34	<0.001	+80.34, +111.19

Model Fit:

$R^2 = 0.65$ (65% of variance in EFW explained by BMI + gestational age)

$F(2,87) = 80.70, p < 0.001 \rightarrow$ Model is highly significant.

Interpretation:

Gestational age is the strongest predictor: for every one-week increase, fetal weight rises by approximately 96 g.

Maternal BMI has a significant negative influence: each unit increase in BMI reduces fetal weight by about 10 g.

Together, both predictors explain a substantial portion of the variation in fetal weight.

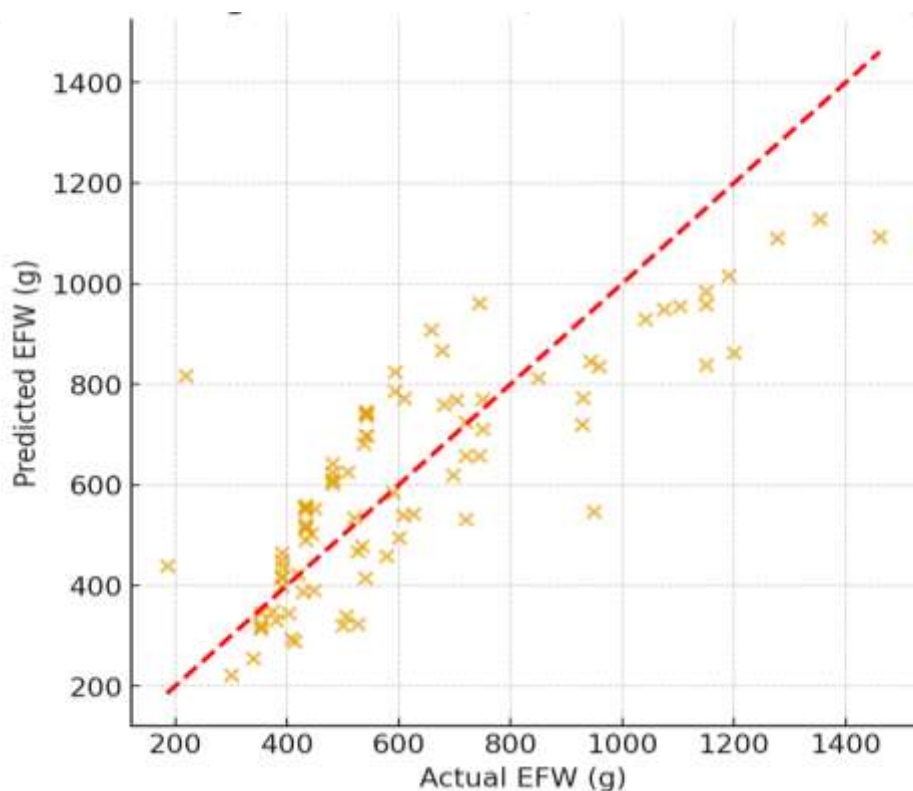


Figure 4.6: Regression plot of the interacting effect of maternal BMI and gestational age on EFW. The plot shows that gestational age is rapidly correlated with an increase in fetal weight whereas high BMI is correlated with a small decrease in fetal weight.

Summary of Findings:

Group Comparison: Non-obese mothers had significantly higher femur length and estimated fetal weight.

Correlation Analysis: Higher maternal BMI was associated with lower fetal femur length and abdominal circumference.

Regression Analysis: After adjusting for gestational age, higher BMI independently predicted lower fetal weight.

Overall, the findings indicate that maternal obesity has a modest but significant negative effect on certain fetal growth parameters, primarily femur length and estimated fetal weight.

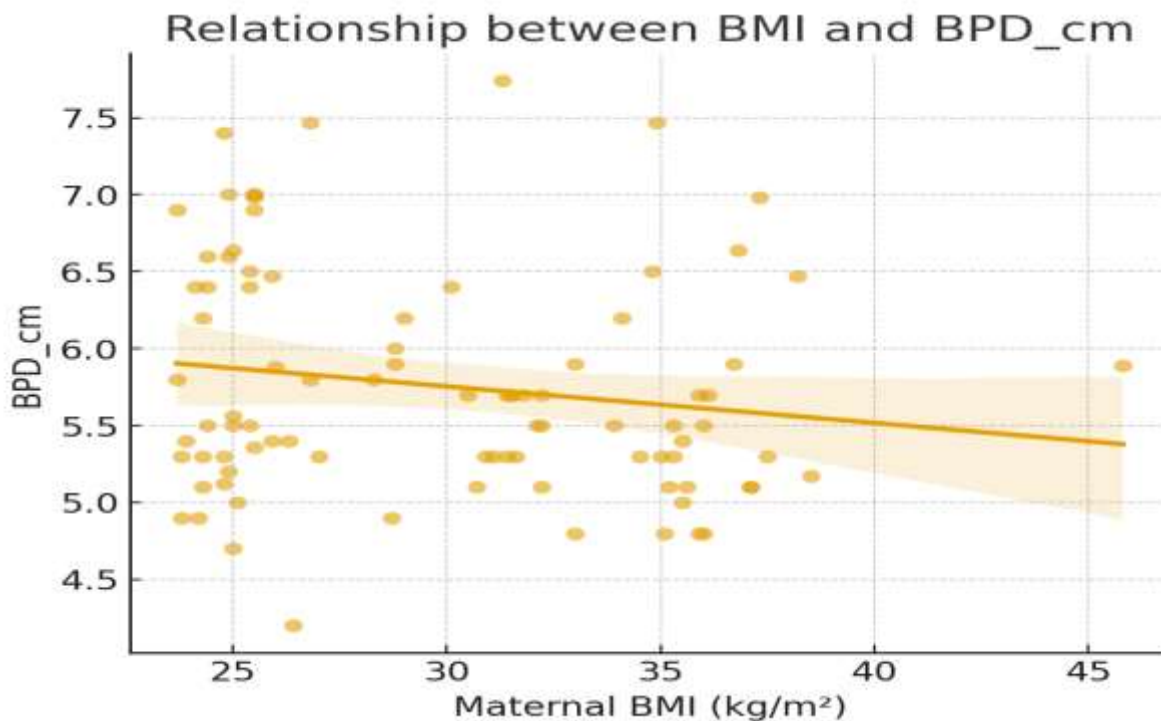


Figure 4.7: Scatter plot of a weak negative relationship between BMI of the mother and Biparietal Diameter (BPD) and no statistically significant correlation ($p > 0.05$).

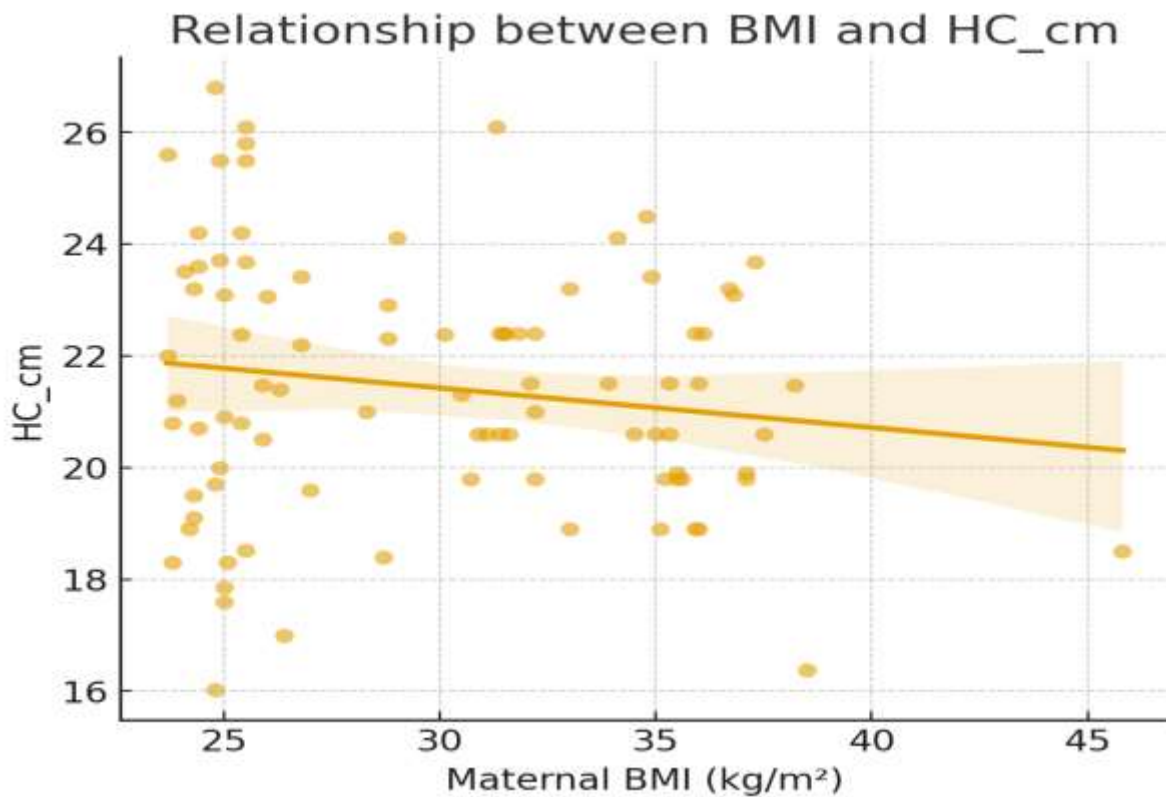


Figure 4.8: Scatter plot of maternal BMI indicating Head Circumference (HC). There is a slight negative slope although there is no significant correlation.

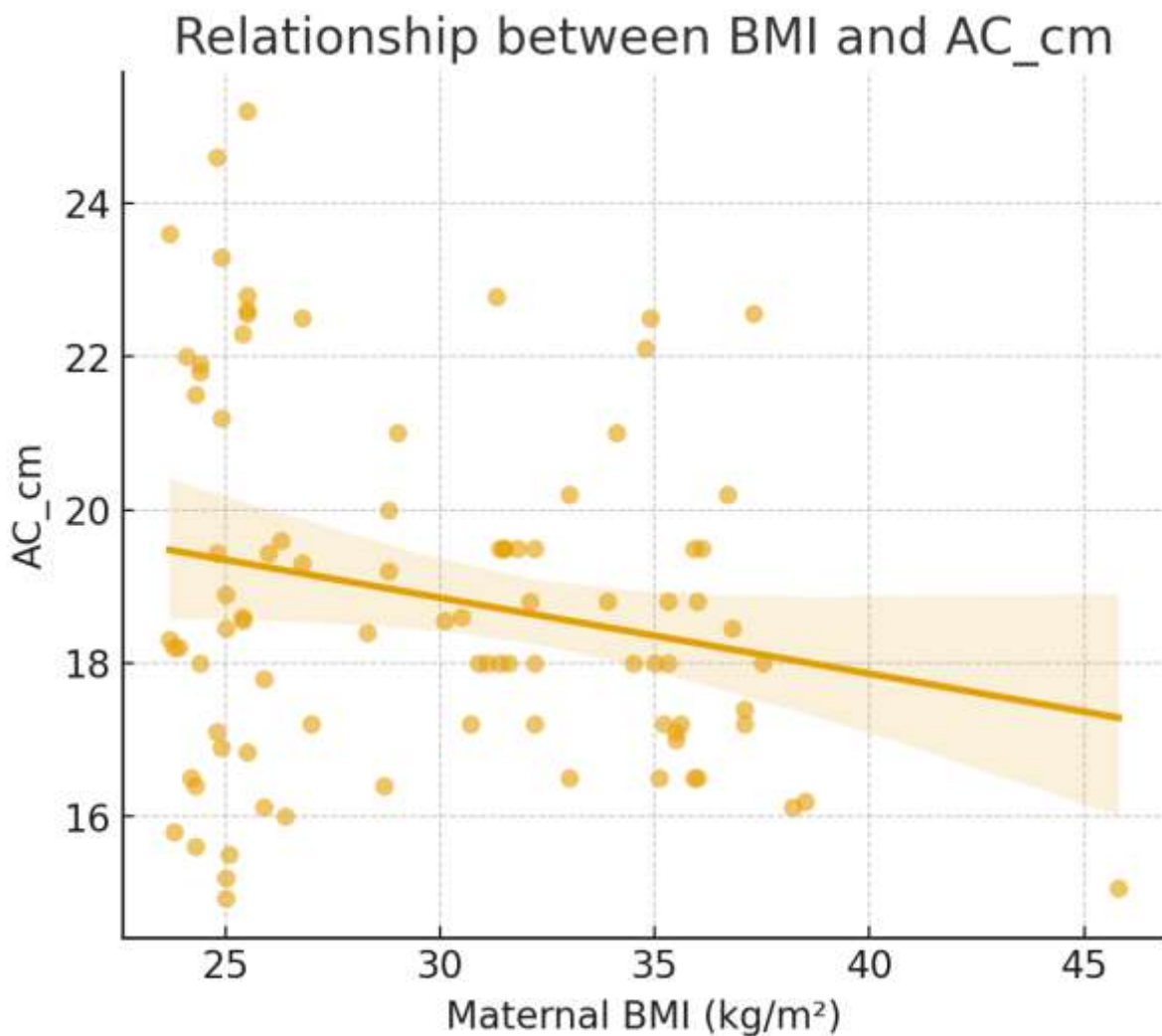


Figure 4.9: The Scatter plot has a weak negative significance relationship between BMI and Abdominal Circumference ($r = -0.214$, $p = 0.043$), which implies that, the greater maternal BMI, the smaller the fetal abdominal circumference.

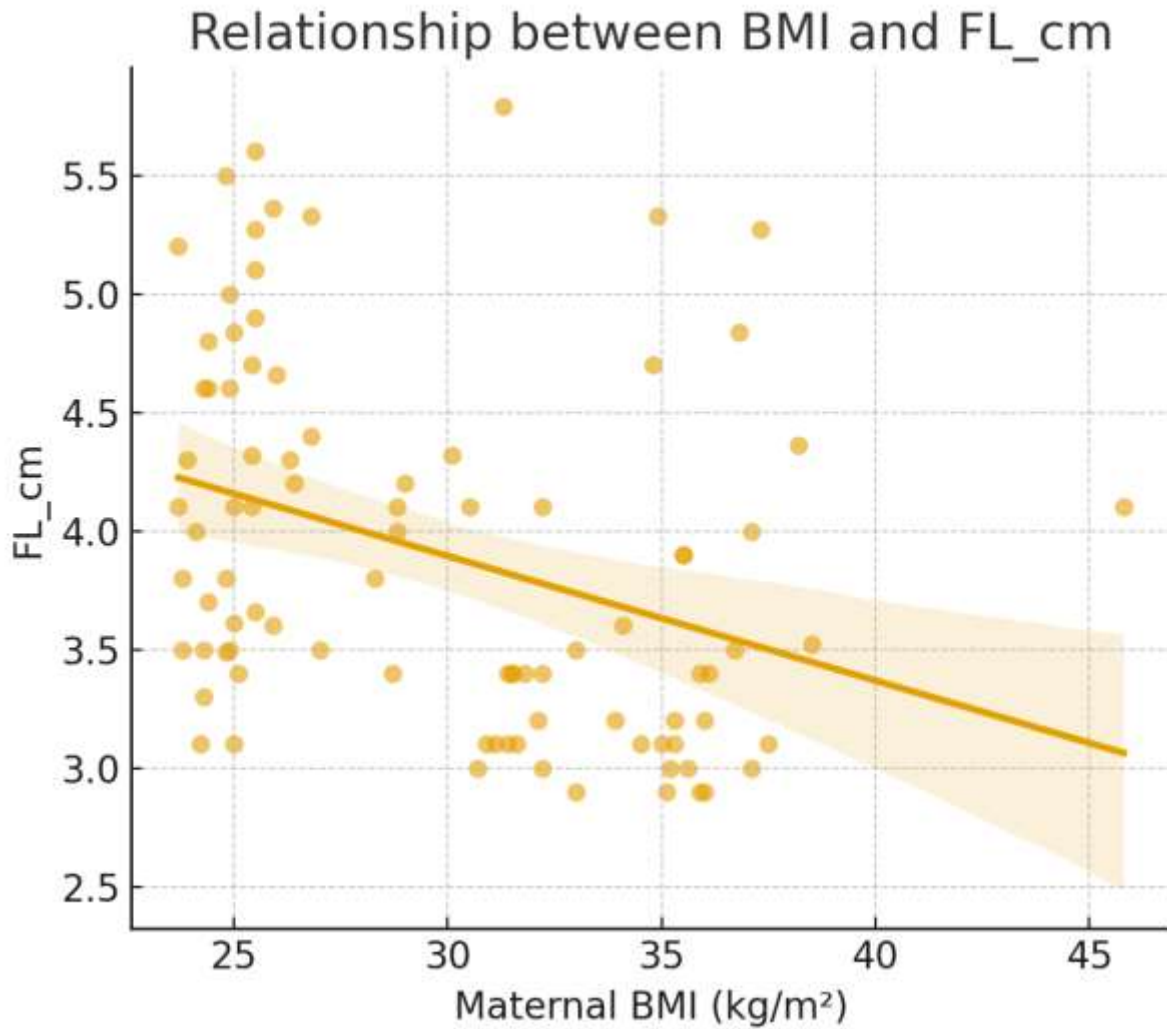


Figure 4.10: Scattered plot illustrating a moderate negative relationship between BMI and Femur Length ($r = -0.345$, $p < 0.001$), with higher BMI of maternal being correlated with lower fetal femur growth.

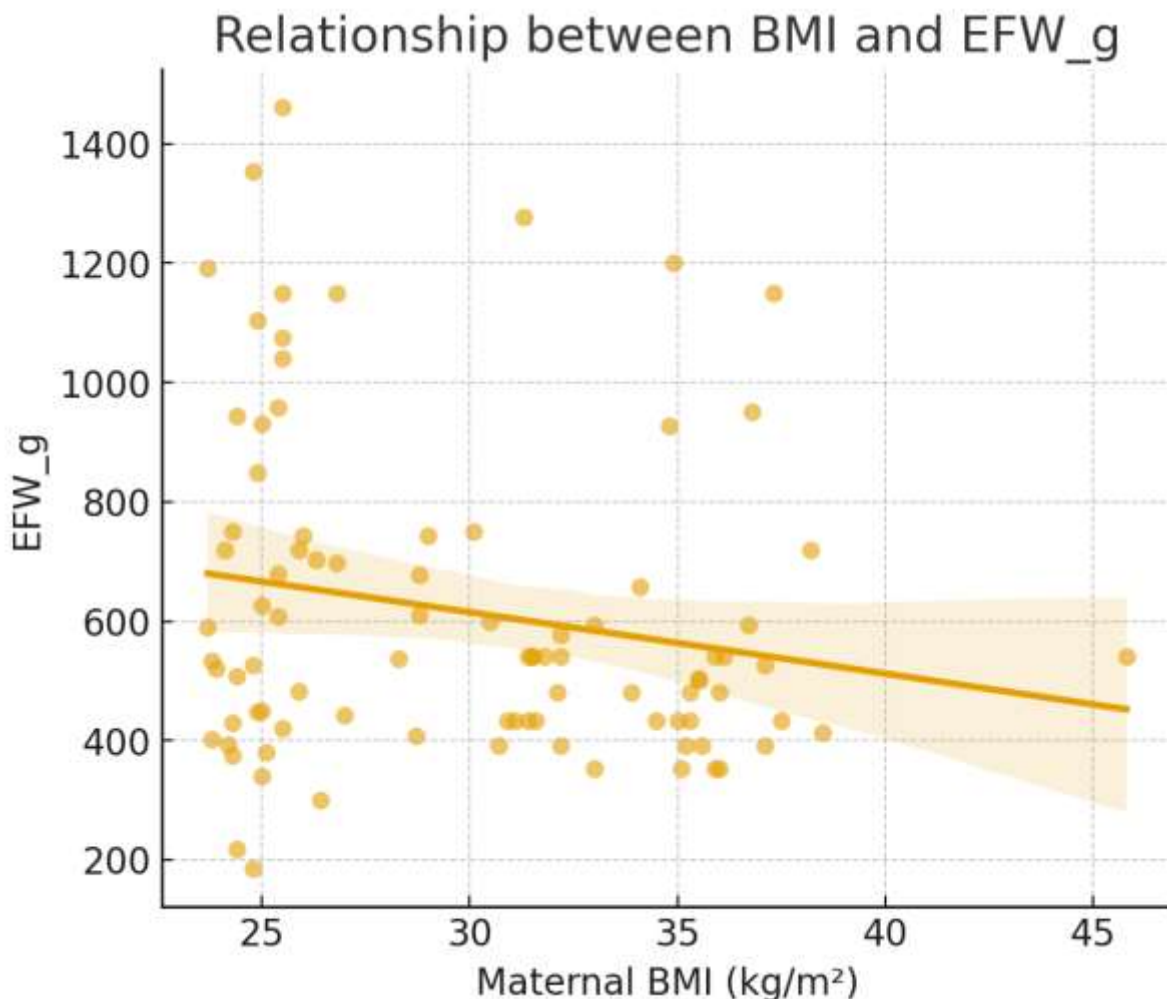


Figure 4.11: Scatter plot showing that BMI and Estimated Fetus weight have a negative yet non significant association ($r = -0.192$, $p = 0.071$), indicating that there is a negative trend that is not statistically significant.

(BMI vs fetal measures) with regression lines:

BPD & HC → slight negative slope, but not statistically significant.

AC → weak negative trend, consistent with significant negative correlation ($p = 0.043$).

FL → clear negative slope, significant ($p < 0.001$).

EFW → slight downward trend, not significant.

These scatter plots visually confirm that higher maternal BMI is linked to lower FL and AC.

DISCUSSION

The study tested how maternal obesity affects fetal biometry in nulliparous women. Femur length and estimated fetal weight showed significant differences between obese and non-obese mothers. BPD, HC, and AC did not show meaningful differences. Higher maternal BMI had a moderate negative correlation with femur length and a weak negative correlation with abdominal circumference. Regression analysis showed that maternal BMI was a strong negative predictor of fetal weight even after adjusting for gestational age. These findings suggest that obesity can restrict some aspects of fetal growth, especially skeletal growth and overall weight. The results only partly match earlier large studies such as Santos et al. Those studies linked obesity with larger fetal size. In contrast, this study found reduced femur length and fetal weight in obese women. Differences in population, diet, ethnicity, and the focus on nulliparous women may explain the variation. Other studies have also reported that obesity can produce mixed fetal growth patterns that depend on placental and metabolic conditions. Large cohort studies often report higher rates of large for gestational age fetuses in obese women. This study showed the opposite trend. Measurement limitations in obese women may also reduce accuracy and influence results. Overall, the findings support the idea that maternal obesity can lead to inconsistent fetal growth outcomes. Some fetuses grow larger, while others show restricted or uneven growth due to placental inefficiency or metabolic issues.

The study highlights that maternal obesity affects fetal growth in complex ways and that nulliparous women may be more vulnerable. Individualized monitoring is important because the effects of obesity vary across pregnancies.

CONCLUSIONS

The present study examined the effects of maternal obesity on fetal biometric measurements in nulliparous pregnant women. The findings revealed that maternal obesity has a measurable impact on certain aspects of fetal development, particularly femur length (FL) and estimated fetal weight (EFW), both of which were significantly lower among obese mothers compared to their non-obese counterparts. Although no significant differences were observed in biparietal diameter (BPD), head circumference (HC), or abdominal circumference (AC), the negative correlations between maternal BMI and both FL and AC suggest that increased maternal adiposity may adversely influence fetal skeletal and soft tissue growth.

Regression analysis further confirmed that maternal BMI was a significant negative predictor of fetal weight, independent of gestational age. These results indicate that higher maternal BMI does not consistently stimulate fetal overgrowth; rather, it may contribute to fetal growth restriction.

The study supports the hypothesis that maternal obesity affects fetal development through mechanisms such as placental dysfunction, impaired uteroplacental perfusion, and altered fetal metabolism—ultimately disrupting the supply of oxygen and nutrients to the fetus. These findings are consistent with those reported by Briese et al. (2018), Morales et al. (2020), and Gaillard et al. (2016), who similarly observed that maternal obesity can lead to abnormal fetal growth patterns due to placental and metabolic dysregulation. It is important to note that fetal alterations associated with maternal obesity may vary: in some cases resulting in macrosomia, while in others manifesting as

limited or asymmetric fetal growth, particularly in nulliparous women where uterine vascular remodeling has not yet occurred.

LIMITATIONS

Despite providing valuable insights into the relationship between maternal obesity and fetal biometry, the current study has several limitations:

Sample Size: Although 90 participants were adequate for statistical analysis, a larger sample size would enhance the external validity and generalizability of the findings.

Single-Center Study: Conducting the research in a single center limits the applicability of results to broader populations; however, this approach ensured consistency in ultrasound methodology and data collection.

Cross-Sectional Design: Since fetal biometry was measured at a single point in gestation, the study could not assess longitudinal growth trends. Future research using a longitudinal design could better capture dynamic changes in fetal development across pregnancy.

RECOMMENDATIONS

Based on the study findings and identified limitations, the following recommendations are proposed:

Expand Sample Size: Future studies should include a larger number of participants to improve the representativeness and generalizability of results across diverse populations and ethnic groups.

Multicenter Collaboration: Conducting multicentric research across different hospitals and regions would yield more comprehensive data and facilitate the comparison of maternal and fetal characteristics across populations.

Longitudinal Study Design: Future investigations should adopt a longitudinal approach, assessing fetal biometry across multiple trimesters to evaluate the progression of growth in relation to maternal obesity.

Clinical Integration: Regular and detailed monitoring of fetal growth in obese pregnant women—especially nulliparous women—should be incorporated into antenatal care protocols to enable early detection and management of potential growth abnormalities.

REFERENCES

- Papageorgiou AT, Ohuma EO, Altman DG, Todros T, Cheikh Ismail L, Lambert A, et al. International standards for fetal growth based on serial ultrasound measurements: the Fetal Growth Longitudinal Study of the INTERGROWTH-21st Project. *Lancet*. 2014;384(9946):869–79.
- Hadlock FP, Harrist RB, Carpenter RJ, Deter RL, Park SK. Sonographic estimation of fetal weight: the value of femur length in addition to head and abdomen measurements. *Radiology*. 1984;150(2):535–40.
- Crane JM, Murphy P, Burrage L, Hutchens D. Maternal and perinatal outcomes of extreme obesity in pregnancy. *J Obstet Gynaecol Can*. 2013;35(7):606–11.

- Heslehurst N, Rankin J, Wilkinson JR, Summerbell CD. A nationally representative study of maternal obesity in England, UK: trends in incidence and demographic inequalities in 619,323 births, 1989–2007. *Int J Obes (Lond)*. 2021;45(5):1129–38.
- Gaillard R. Maternal obesity during pregnancy and cardiovascular development and disease in the offspring. *Eur J Epidemiol*. 2015;30(11):1141–52.
- Salomon LJ, Alfievic Z, Da Silva Costa F, Deter RL, Figueras F, Ghi T, et al. ISUOG Practice Guidelines: Ultrasound assessment of fetal biometry and growth. *Ultrasound Obstet Gynecol*. 2019;53(6):715–23.
- Santos S, Voerman E, Amiano P, Barros H, Beilin LJ, Bergström A, et al. Impact of maternal body mass index and gestational weight gain on pregnancy complications: an individual participant data meta-analysis of European, North American, and Australian cohorts. *BJOG*. 2019;126(8):984–95.
- Flenady V, Wojcieszek AM, Middleton P, Ellwood D, Erwich JJ, Coory M, et al. Stillbirths: recall to action in high-income countries. *Lancet*. 2016;387(10019):691–702.
- Nicolaides KH. Turning the pyramid of prenatal care. *Fetal Diagn Ther*. 2011;29(3):183–96.
- Stirnemann JJ, Villar J, Salomon LJ, Ohuma EO, Ruyan P, Altman DG, et al. International estimated fetal weight standards of the INTERGROWTH-21st Project. *Ultrasound Obstet Gynecol*. 2017;49(4):478–86.
- Blencowe H, Krusevec J, de Onis M, Black RE, An X, Stevens GA, et al. National, regional, and worldwide estimates of low birth weight in 2015, with trends from 2000: a systematic analysis. *Lancet Glob Health*. 2019;7(7):e849–60.
- Kominiarek MA, Chauhan SP. Obesity before, during, and after pregnancy: a review and comparison of five national guidelines. *Am J Perinatol*. 2016;33(5):433–41.
- Poston L, Caleyachetty R, Cnattingius S, Corvalán C, Uauy R, Herring S, et al. Preconceptional and maternal obesity: epidemiology and health consequences. *Lancet Diabetes Endocrinol*. 2016;4(12):1025–36.
- World Health Organization (WHO). *Obesity: preventing and managing the global epidemic. Report of a WHO consultation*. Geneva: World Health Organization; 2000. (WHO Technical Report Series No. 894).
- Catalano PM, Shankar K. Obesity and pregnancy: mechanisms of short-term and long-term adverse consequences for mother and child. *BMJ*. 2017;356:j1.
- Aune D, Saugstad OD, Henriksen T, Tonstad S. Maternal body mass index and the risk of fetal death, stillbirth, and infant death: a systematic review and meta-analysis. *JAMA*. 2014;311(15):1536–46.
- Denison FC, Norwood P, Bhattacharya S, Duffy A, Mahmood T, Morris C, et al. Association between maternal body mass index during pregnancy, short-term morbidity, and increased health service costs: a population-based study. *BJOG*. 2014;121(1):72–81.

- Chauhan SP, Hendrix NW, Magann EF, Morrison JC, Kenney SP, Devoe LD. Limitations of clinical and sonographic estimates of birth weight: experience with 1034 parturients. *Obstet Gynecol.* 1998;91(1):72-7.
- Challier JC, Basu S, Bintein T, Minium J, Hotmire K, Catalano PM, Hauguel-de Mouzon S. Obesity in pregnancy stimulates macrophage accumulation and inflammation in the placenta. *Placenta.* 2008;29(3):274-81.
- Friis CM, Qvigstad E, Paasche Roland MC, Godang K, Voldner N, Bollerslev J, et al. Newborn body fat: associations with maternal metabolic state and placental size. *PLoS One.* 2013;8(2):e57467.
- Cnattingius S, Villamor E, Johansson S, Edstedt Bonamy AK, Persson M, Wikström AK, Granath F. Maternal obesity and risk of preterm delivery. *JAMA.* 2013;309(22):2362-70.
- Marchi J, Berg M, Dencker A, Olander EK, Begley C. Risks associated with obesity in pregnancy, for the mother and baby: a systematic review of reviews. *Obes Rev.* 2015;16(8):621-38.
- Santos S, Voerman E, Amiano P, Barros H, Beilin LJ, Bergström A, et al. Impact of maternal body mass index and gestational weight gain on pregnancy complications: An individual participant data meta-analysis of European, North American and Australian cohorts. *BJOG.* 2019;126(8):984-95.
- Black MH, Sacks DA, Xiang AH, Lawrence JM. The relative contribution of prepregnancy overweight and obesity, gestational weight gain, and IADPSG-defined gestational diabetes mellitus to fetal overgrowth. *Diabetes Care.* 2018;41(1):e44-6.
- Gaillard R, Steegers EA, Franco OH, Hofman A, Jaddoe VW. Maternal weight gain in different periods of pregnancy and childhood cardio-metabolic outcomes: the Generation R Study. *Int J Obes (Lond).* 2016;40(10):1628-36.
- Hinkle SN, Sharma AJ, Schieve LA, Ramakrishnan U, Swan DW, Stein AD. Maternal prepregnancy weight status and associations with child growth and adiposity through age 7 years. *Int J Obes (Lond).* 2016;40(7):1071-8.
- Briese V, Voigt M, Hermanussen M, Wittwer-Backofen U. Morbid obesity: pregnancy risks, birthweight and postpartum weight loss. *Arch Gynecol Obstet.* 2018;297(4):1071-7.
- Blomberg M. Maternal obesity and risk of postpartum hemorrhage. *Obstet Gynecol.* 2018;131(2):289-96.
- Catalano PM, Shankar K. Obesity and pregnancy: mechanisms of short-term and long-term adverse consequences for mother and child. *BMJ.* 2017;356:j1.
- Koyanagi A, Zhang J, Dagvadorj A, Hirayama F, Shibuya K, Souza JP, et al. Macrosomia in 23 developing countries: an analysis of a multicountry, facility-based, cross-sectional survey. *Lancet.* 2013;381(9865):476-83.
- Shields LE, Wiesner S, Klein C, Pelletreau B, Hedriana HL. Use of maternal early warning trigger tool reduces maternal morbidity. *Am J Obstet Gynecol.* 2016;214(4):527.e1-6.
- Voerman E, Santos S, Patro Golab B, Amiano P, Ballester F, Barros H, et al. Maternal body mass index, gestational weight gain, and the risk of overweight in offspring: A systematic review and meta-analysis. *PLoS Med.* 2019;16(6):e1002744.

- Wong T, Barnes RA, Pywell M, Bennett J, Ward LC, Tyack S, et al. Maternal obesity and its effect on fetal biometry: a population-based study. *Aust N Z J Obstet Gynaecol.* 2019;59(2):251-7.
- O'Reilly JR, Reynolds RM. The risk of maternal obesity to the long-term health of the offspring. *Clin Endocrinol (Oxf).* 2013;78(1):9-16.
- Zhou L, Xiao Q, Xie YJ, Wang M, Yang J, Wang S, et al. Maternal obesity, gestational weight gain and birth outcomes: A large cohort study in China. *Nutrients.* 2021;13(12):4399.
- Morales-Roselló J, Khalil A, Morlando M, Papageorghiou A. Changes in fetal Doppler indices and their relationship with maternal body mass index. *Ultrasound Obstet Gynecol.* 2020;55(6):793-801.
- Yu Z, Han S, Zhu J, Sun X, Ji C, Guo X. Pre-pregnancy body mass index in relation to infant birth weight and offspring overweight/obesity: a systematic review and meta-analysis. *PLoS One.* 2013;8(4):e61627.
- Sebire NJ, Jolly M, Harris JP, Wadsworth J, Joffe M, Beard RW, et al. Maternal obesity and pregnancy outcome: A study of 287,213 pregnancies in London. *Int J Obes Relat Metab Disord.* 2001;25(8):1175-82.
- Kominiarek MA, Chauhan SP. Obesity before, during, and after pregnancy: A review and comparison of five national guidelines. *Am J Perinatol.* 2016;33(5):433-41.
- Martin CL, Sotres-Alvarez D, Siega-Riz AM. Maternal dietary patterns during pregnancy are associated with fetal growth. *J Nutr.* 2015;145(6):1289-95.
- Lingwood BE, Henry AM, d'Emden MC, Fullerton AM, Colditz PB, Ward LC. Determinants of body composition in healthy newborn infants. *Pediatr Res.* 2008;63(3):333-9.
- Kirchengast S, Hartmann B. Maternal prepregnancy weight status and pregnancy weight gain as major determinants for newborn weight and size. *Ann Hum Biol.* 2012;39(2):110-5.