

Research Article

Association between Maternal Body Mass Index and Neonatal Apgar Scores: A Multicenter Study

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Abstract

Objective: To determine the association between maternal body mass index (BMI) and neonatal Apgar scores in two tertiary referral hospitals in Indonesia between 2023 and 2024.

Methods: This cross-sectional study analyzed the medical records of 200 women who delivered at Dr. Hasan Sadikin Hospital, Bandung, and Prof. Dr. Margono Soekarjo Hospital, Purwokerto, from August 2023 to July 2024. Participants were classified based on maternal BMI. The associations between BMI, mode of delivery, and Apgar scores were analyzed using chi-square tests and logistic regression.

Results: Maternal BMI, mode of delivery, age, parity, gestational age, and comorbidities showed no significant association with Apgar scores ($p > 0.05$). Birth weight was the only significant predictor; infants with low birth weight were associated with Apgar scores <7 (OR 0.219; 95% CI: 0.118–0.407). Regarding mode of delivery, 69.2% of obese mothers underwent cesarean section compared to 52.3% of normoweight mothers. Obese mothers were significantly more likely to have a cesarean delivery, although this did not correlate with lower Apgar scores.

Conclusion: Maternal obesity is associated with a higher chance of cesarean delivery but does not significantly affect neonatal Apgar scores. Infant birth weight remains the strongest predictor of Apgar scores in this group.

Keywords: Apgar score; maternal body mass index; mode of delivery; neonatal outcomes; obesity

Asosiasi Antara Indeks Massa Tubuh dan Skor Apgar pada Kehamilan: Studi Multisenter

Abstrak

Tujuan: Penelitian ini bertujuan untuk mengetahui asosiasi antara indeks massa tubuh (IMT) dan skor *Apgar* dengan obesitas pada kehamilan di Rumah Sakit Margono dan Rumah Sakit Hasan Sadikin selama tahun 2023 – 2024.

Metode: Penelitian ini merupakan studi observasional analitik dengan pendekatan potong lintang. Data diperoleh dari rekam medis 200 ibu bersalin periode Agustus 2023 – Juli 2024 di RSUP Dr. Hasan Sadikin Bandung dan RS Prof. Dr. Margono Soekarjo Purwokerto. Subjek diklasifikasikan berdasarkan Indeks Massa Tubuh (IMT). Hubungan antara IMT dengan metode persalinan dan skor *Apgar* dianalisis menggunakan uji *chi-square* dan regresi logistik.

Hasil: Hasil penelitian menunjukkan bahwa dari seluruh variabel, hanya berat lahir bayi yang berpengaruh signifikan terhadap skor *Apgar*. Bayi dengan berat lahir rendah berisiko lebih tinggi mendapat skor *Apgar* rendah ($p < 0,05$) OR 0,219 (CI 95% 0,118–0,407). Tidak ditemukan hubungan signifikan antara IMT maupun metode persalinan dengan skor *Apgar* ($p > 0,05$). Persalinan *seksio sesarea* terjadi pada 52,3% ibu dengan IMT *normoweight* dan 69,2% pada kelompok obesitas.

Kesimpulan: Obesitas pada ibu hamil meningkatkan risiko persalinan dengan *seksio sesarea*. Berat lahir bayi merupakan prediktor skor *Apgar* yang signifikan.

Kata Kunci : Indeks massa tubuh maternal; luaran neonatal; mode persalinan; obesitas; skor Apgar

Introduction

Obesity is defined as an abnormal or excessive accumulation of fat, globally, regionally, or as ectopic lipid deposition, that poses a significant health risk. In 2022, approximately one in eight individuals worldwide was living with obesity.¹ Globally, the prevalence of obesity increased from 31 million people (2%) in 1990 to 160 million people (8%) in 2022.¹ In Indonesia, data from the Basic Health Research (*Riset Kesehatan Dasar*) show that about 30% of adults are overweight or obese, with a continuous increase over the past decade.¹

Obesity during pregnancy poses one of the biggest challenges in obstetrics due to its negative impact on maternal and fetal health. Reports show a growing number of women enter pregnancy with excess weight. In the United Kingdom, approximately half of women of reproductive age are overweight or obese, with over 15% classified as obese at the beginning of pregnancy. Similarly, studies at Dr. Cipto Mangunkusumo National General Hospital in Jakarta reported that approximately 15% to 20% of pregnant women were obese from 2014 to 2019.²

Obesity is diagnosed by measuring body weight and height to determine the body mass index (BMI). The World Health Organization (WHO) categorizes women into four groups based on BMI: underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥30.0 kg/m²). However, differences in body composition among populations, such as higher body fat percentages in Asian populations compared to Europeans at the same BMI, emphasize the need for adjusted thresholds. In the Asia–Pacific region, the cutoff for obesity is defined as a BMI of ≥25 kg/m².³

Obesity is associated with molecular changes that impact various physiological processes, including adipocyte dysfunction, insulin resistance, chronic inflammation,

and epigenetic alterations.⁴ Excessive energy intake over time causes adipocyte hypertrophy and hyperplasia beyond the tissue's capacity, leading to cellular stress and the release of proinflammatory cytokines such as TNF- α and IL-6. This condition disrupts adipose hormone secretion (increasing leptin and resistin while decreasing adiponectin), impairs GLUT4 expression, and worsens insulin resistance.⁵ Additionally, obesity is characterized by low-grade systemic inflammation, increased infiltration of proinflammatory M1 macrophages, and higher CRP levels. During pregnancy, this maternal inflammation and endothelial dysfunction—marked by an imbalance of vasodilators and vasoconstrictors caused by oxidative stress—can impair tissue perfusion. As a result, this may lead to placental insufficiency and fetal hypoxia, potentially affecting neonatal health.⁶⁻⁹

The Apgar score is a quick clinical assessment used to evaluate a newborn's condition one minute after birth and to determine if immediate resuscitation is necessary. The assessment includes five components: skin color, heart rate, reflex irritability, muscle tone, and respiration, each scored zero, one, or two. Apgar scores are routinely recorded at one and five minutes after birth. A low Apgar score at five minutes is linked to a 20- to 100-fold higher relative risk of cerebral palsy compared with infants who score seven to ten.¹⁰

Although many studies have investigated the relationship between maternal BMI and neonatal outcomes, findings regarding Apgar scores are inconsistent. Some studies show lower Apgar scores in infants born to mothers with obesity, while others find no significant link after adjusting for factors like delivery mode, gestational age, and birth weight. Moreover, most existing studies were conducted in single centers or in populations with different ethnic and socioeconomic backgrounds, which limits how well their

findings apply to the Indonesian context.

In Indonesia, evidence about the association between maternal obesity and Apgar scores is limited, especially from multicenter studies involving tertiary referral hospitals with diverse patient populations. Variations in referral practices, obstetric procedures, and maternal risk factors across centers may affect neonatal outcomes and contribute to differences in previous findings. Therefore, this multicenter study at two leading referral hospitals aims to examine the relationship between maternal BMI and Apgar scores, addressing gaps in the existing literature and offering context-specific evidence relevant to obstetric care in Indonesia.

Methods

The research design employed an analytical observational quantitative approach with a cross-sectional design, carried out within a specific time frame to examine the relationship between the independent variable (body mass index) and the dependent variable (Apgar score). The study took place at Dr. Hasan Sadikin General Hospital in West Java and Prof. Dr. Margono Soekardjo Hospital in Central Java, Indonesia. The research period was from August 2023 to July 2024, lasting six months. The population included pregnant women at all gestational ages. A total sampling method was used during 2023–2024, involving 100 participants from each hospital, totaling 200 participants. Inclusion criteria consisted of all pregnant women who delivered at the two hospitals within this period. Exclusion criteria included pregnant women with incomplete medical records related to body mass index or Apgar score.

The research process started with submitting an application for permission and obtaining approval from the Health Research Ethics Committee at Dr. Hasan Sadikin General Hospital and Prof. Dr. Margono

Soekardjo Hospital. Data was collected retrospectively from medical records of patients who delivered at both hospitals from August 2023 to July 2024. The data included maternal body mass index before or in early pregnancy (less than twelve weeks), the infant's Apgar score at the fifth minute, and other variables such as maternal age and history of comorbid diseases.

Patients treated at RSMS generally had higher body mass index, greater parity, and more metabolic comorbidities, which were linked to increased rates of cesarean delivery and higher neonatal birth weights. Conversely, patients at RSHS more often experienced preterm delivery and gave birth to low birth weight infants, indicating a higher complexity of obstetric cases handled at this tertiary referral center.

Data analysis in this study was conducted quantitatively using the Statistical Package for the Social Sciences version 26.0. Univariate analysis described basic sample characteristics, such as maternal age, parity, pregnancy complications, infant birth weight, mode of delivery, maternal body mass index before or early in pregnancy, and infant Apgar score at five minutes. Bivariate analysis examined the association between maternal body mass index and infant Apgar score using the Chi-Square test. Multivariate analysis employed multiple logistic regression to identify the most influential factors on infant Apgar score after controlling for confounding variables, with results presented as Odds Ratios and confidence intervals.

Results

There were 200 patients included in the study, categorized as shown in Table 1. The most common body mass index category was normoweight, accounting for 54.5%, while the obesity category included only 26 patients, representing 13%. Regarding the mode of delivery, cesarean section was

the most frequently performed, occurring in 58.0% of mothers, whereas spontaneous vaginal delivery was observed in 20.5%. An assessment of neonatal condition based on the Apgar score revealed that the majority of neonates, 69.5%, had scores above 7 (good category), while 30.5% had scores below 7, indicating an initial clinical condition that

may require special attention.

The distribution of parity revealed that multiparous women made up the largest group at 39.5%. Most mothers delivered preterm, before 37 weeks gestation, representing 57.5%, while 37.0% delivered at term between 37 and 42 weeks. Regarding comorbidities, 43.0% of mothers had

Table 1 Population Characteristics

Parameter	Frequency	Percentage
Body Mass Index		
Underweight (<18,5 Kg/m ²)	17	8.5
Normoweight (18,5 - 24,9 Kg/m ²)	109	54.5
Overweight (25,0 - 29,9 Kg/m ²)	48	24.0
Obese (> 30 Kg/m ²)	26	13.0
Mode of Delivery		
Spontaneous	41	20.5
Induction	34	17.0
Operative delivery	9	4.5
Caesarean Section	116	58.0
APGAR Score		
Adequate (>7)	139	69.5
Low (<7)	61	30.5
Parity		
Primipara	68	34.0
Multipara	79	39.5
Grandmultipara	53	26.5
Gestational Age		
Preterm	115	57.5
Anterm	74	37.0
Posterm	11	5.5
Comorbidities		
None	79	39.5
Hypertension	86	43.0
Anemia	16	8.0
Diabetes Mellitus	7	3.5
Heart Failure	12	6.0
Birth Weight		
Low (<2.000 gr)	107	53.5
Normal (2.500 - 4.000 gr)	54	27.0
Macrosomia (>4.000 gr)	39	19.5

Table 2 Chi-square Analysis Results

Variable	P-value	Interpretation
Body Mass Index/Obesity	0.521	Not significant
Mode of Delivery	0.137	Not significant
Maternal Age	0.049	Not significant
Parity	0.139	Not significant
Gestational Age	0.457	Not significant
Comorbidities	0.283	Not significant
Birth Weight	0.000	Significant. The lower the birth weight, the higher the risk of a low Apgar score

Table 3 Logistic Regression Analysis Results

Variable	B	Sig.	Exp(B)	CI 95%	Interpretation
Body Mass Index/Obesity	0,138	0,513	1,148	0.758-1.739	Not significant
Mode of Delivery	0,148	0,297	1,160	0.878-1.531	Not significant
Maternal Age	-0,029	0,219	0,971	0.927-1.017	Not significant
Parity	-0,288	0,204	0,750	0.481-1.169	Not significant
Gestational Age	-0,064	0,824	0,938	0.534-1.649	Not significant
Comorbidities	0,189	0,246	1,208	0.878-1.663	Not significant
Birth Weight	-1,518	<0,001	0,219	0.118-0.407	Significant. The lower the birth weight, the higher the risk of a low Apgar score

hypertension, 8.0% had anemia, 6.0% had a history of heart failure, and 3.5% had diabetes mellitus. Overall, 39.5% of subjects had no comorbidities.

Based on birth weight, most infants (53.5 percent) were classified as having low birth weight (less than 2,000 grams), while 27.0 percent had normal birth weight (2,500–4,000 grams), and 19.5 percent were classified as macrosomic (greater than 4,000 grams). These findings indicate a high prevalence of intrauterine growth restriction and preterm birth within the study population.

The data were normally distributed; therefore, Chi-square analysis was performed. As shown in table 2, there is no significant association ($p > 0.05$) between maternal body mass index and Apgar scores, as well as between maternal body mass index and mode of delivery. In contrast, birth weight was significantly associated with Apgar scores (p

< 0.05).

Logistic regression analysis was conducted including all variables. It showed that, among the seven variables examined, only birth weight significantly impacted Apgar scores ($p < 0.05$). The Exp(B) value for birth weight, as shown in Table 2, indicates that infants with low birth weight are about 78% more likely to have a low Apgar score compared to infants with normal or high birth weight. Other variables such as Body Mass Index, mode of delivery, maternal age, parity, gestational age, and comorbidities did not demonstrate significant associations with Apgar scores in this study.

Discussion

Maternal Body Mass Index (BMI) is a significant maternal factor that can affect perinatal outcomes, including neonatal Apgar

scores. Both low and high maternal BMI may result in impaired fetal growth, metabolic imbalances, and obstetric complications, which can ultimately influence neonatal vitality at birth. Several studies have shown associations between maternal obesity and lower Apgar scores. A meta-analysis by Keag et al. (2015) found that pregnant women with a BMI of 25 kilograms per square meter or higher have a higher risk of delivering infants with a five-minute Apgar score below 7 than women with normal BMI. The risk increases with the degree of obesity, likely due to impaired placental perfusion, a higher risk of preeclampsia, and fetal macrosomia, all of which may disrupt the newborn's physiological adaptation after birth.^{11,12}

However, these findings differ from the study by Aisyah et al. (2024) at Dr. Hasan Sadikin General Hospital, which indicated that although obesity increased the risk of cesarean delivery, there was no significant association between maternal BMI and neonatal Apgar scores.¹³ Similar results were observed by Pradipta et al. (2023), who noted that birth weight had a stronger effect on Apgar scores than maternal factors like BMI or mode of delivery.¹⁴ The absence of a significant connection between maternal obesity and neonatal Apgar scores in this study may be due to the nature of the Apgar score as an immediate postnatal assessment that mainly reflects neonatal cardiopulmonary adaptation rather than intrauterine metabolic conditions. Enhanced intrapartum management, prompt obstetric interventions, and effective neonatal resuscitation may reduce the impact of maternal obesity on early neonatal outcomes.¹²

In addition to BMI, other factors known to influence Apgar scores include the mode of delivery. Infants delivered by cesarean section, especially in emergency situations or without optimal preparation, face a higher risk of low Apgar scores compared to those delivered vaginally. Gestational age is also

crucial, as preterm infants (less than 37 weeks) are at greater risk of asphyxia and delayed organ development, leading to lower Apgar scores.

Birth weight is a significant predictor of Apgar score, with low-birth-weight infants having a three- to fourfold increased risk of respiratory and perfusion problems that can lower their scores. Birth weight directly influences Apgar scores because it indicates fetal maturity and physiological reserves at birth. Infants with low birth weight, especially those related to prematurity or intrauterine growth restriction, tend to have immature respiratory and cardiovascular systems, reduced muscle tone, and limited metabolic adaptation, all of which contribute to lower Apgar scores. On the other hand, adequate birth weight is associated with better lung development, stronger respiratory effort, and more effective neonatal adaptation in the immediate postnatal period.¹⁵

Other maternal factors such as maternal age, parity, and comorbidities are also important to consider. Extremely young or advanced maternal age, as well as very low or high parity (primipara or grand multipara), are associated with higher pregnancy risks that can affect fetal well-being. Comorbidities like hypertension, gestational diabetes, and anemia may cause impaired fetal oxygenation and intrauterine stress, which can be seen in lower Apgar scores.¹⁶ In this study, only birth weight showed a significant relationship with Apgar scores; maternal BMI, delivery mode, gestational age, maternal age, parity, and other comorbidities did not. This supports the idea that while BMI is an important risk factor, its impact on Apgar scores might be mediated by more direct factors affecting neonatal health at birth, such as birth weight and organ maturity.

Maternal outcomes show that higher maternal BMI is associated with increased risk of gestational diabetes mellitus (GDM), hypertensive disorders during pregnancy,

cesarean delivery, preterm birth, and postpartum hemorrhage. The rate of GDM is higher among overweight and obese women, likely due to insulin resistance often seen in these BMI groups. Hypertensive disorders, including gestational hypertension and preeclampsia, are more common in the obese group, aligning with evidence that shows a strong connection between obesity and hypertension.¹⁷ Cesarean delivery rates are notably higher in obese women, possibly because of more obstetric complications and challenges with vaginal delivery. Additionally, the greater occurrence of preterm birth among overweight and obese women suggests that increased maternal BMI may play a role in preterm delivery, potentially through conditions such as hypertension or diabetes.¹⁸

Five-minute Apgar scores tend to be lower in infants born to overweight and obese mothers, indicating possible immediate postnatal health issues. Additionally, admission rates to the neonatal intensive care unit are considerably higher in this group, reflecting an increased need for medical interventions due to complications such as respiratory distress and metabolic disorders.¹⁹ The rate of stillbirth is also higher among obese mothers, emphasizing the serious risks associated with extreme maternal BMI. These findings are consistent with previous studies that associate obesity with adverse fetal outcomes, potentially through placental dysfunction and maternal health conditions.¹⁸

A meta-analysis by Santos et al. demonstrated that maternal overweight and obesity account for 23.9 percent of pregnancy complications, while other studies show significantly higher risks of fetal, neonatal, and infant mortality associated with extreme maternal BMI. Further research also reports that maternal obesity increases the risk of low Apgar scores at one and five minutes, as well as severe neonatal hypoxia.¹⁷

The underlying causes connecting

maternal obesity and pregnancy complications involve a complex network of metabolic dysregulation and ongoing low-grade systemic inflammation. In obese pregnant women, the normal insulin resistance of pregnancy becomes excessive, leading to high blood sugar and elevated lipids.²⁰ Excess fat tissue acts as an active endocrine organ, releasing large amounts of proinflammatory cytokines (such as tumor necrosis factor alpha and interleukin-6) and dysfunctional adipokines, which create a sustained proinflammatory environment throughout the body. This dysfunctional metabolic state collectively increases the production of reactive oxygen species, leading to oxidative stress.²¹

Oxidativestressandchronicinflammation damage the vascular endothelium, leading to endothelial dysfunction. This pathological process, worsened by lipotoxicity from free fatty acid buildup, directly impairs placental function; trophoblast invasion and spiral artery remodeling are disrupted, resulting in placental hypoperfusion and ischemia. These changes form the basis of pregnancy vascular complications like preeclampsia.²² Furthermore, a nutrient-rich and proinflammatory intrauterine environment directly impacts fetal development, increasing the risk of metabolic disorders through fetal programming. Long-term exposure modifies fetal epigenetic pathways, significantly predisposing individuals to metabolic syndrome, obesity, and cardiovascular disease in adulthood.²³

Conclusion

This study indicates that maternal body mass index is not independently linked to Apgar scores in a tertiary referral hospital setting. Instead, neonatal outcomes seem to be more strongly affected by birth weight and gestational age, implying that the influence of maternal obesity on Apgar scores is mostly

indirect. Clinically, these results highlight the importance of preventing low birth weight and preterm birth among obese pregnant women. However, the lack of data on gestational weight gain and lifestyle factors is a limitation that future research should address.

References

1. Antonakou A, Papoutsis D, Tzavara C. Maternal obesity and its association with the mode of delivery and the neonatal outcome in induced labour: Implications for midwifery practice. *Eur J Midwifery*. 2018;12(2):1-4.
2. Indarti J, Susilo SA, Hyawicaksono P, Berguna JSN, Tyagitha GA, Ikhsan M. Maternal and Perinatal Outcome of Maternal Obesity at RSCM in 2014-2019. *Obstet Gynecol Int*. 2021;2021(1):1-6.
3. World Health Organization. *The Asia-Pacific Perspective: Redefining Obesity and Its Treatment*. World Health Organization; 2000.
4. Blüher M. Adipose tissue dysfunction in obesity. *Exp Clin Endocrinol Diabetes*. 2009;117(6):241–250.
5. Lustig RH, Collier D, Kassotis C, Roepke TA, Kim MJ, Blanc E, et al. Obesity I: overview and molecular and biochemical mechanisms. *Biochem Pharmacol*. 2022;199(115016):1-10.
6. Ellulu MS, Patimah I, Khaza'ai H, Rahmat A, Abed Y. Obesity & inflammation: The linking mechanism & the complications. *Archives of Medical Science*. 2017;13(4):851–863.
7. Fahed G, Aoun L, Zerdan MB, Allam S, Bouferraa Y, et al. Metabolic syndrome: updates on pathophysiology and management in 2021. *Int J Mol Sci*. 2022;23(2):786-790.
8. Fink NR, Chawes B, Bønnelykke K, Thorsen J, Stokholm J, Rasmussen MA, et al. Levels of Systemic Low-grade Inflammation in Pregnant Mothers and Their Offspring are Correlated. *Sci Rep*. 2019;9(1):3043-3050.
9. Kajikawa M, Higashi Y. Obesity and endothelial function. *Biomedicines*. 2022;10(3):512-522.
10. Kelly AC, Powell TL, Jansson T. Placental function in maternal obesity. *Clin Sci*. 2020;134(8):961–984.
11. Watterberg KL, Aucott S, Benitz WE, Cummings JJ, Eichenwald EC, Goldsmith J, et al. The apgar score. *Pediatrics*. 2015;136(4):819–822.
12. Keag, O.E., Norman, J.E., & Stock, S.J. Association between maternal body mass index and obstetric and neonatal outcomes: a systematic review and meta-analysis. *PLoS Medicine*. 2015;12(8):1-10.
13. Aisyah, S., Sulthany, A.I., & Rosdiana, D. Hubungan Anemia pada Ibu Hamil dengan Skor APGAR di RSUD dr. Hasan Sadikin. *eJurnal Kedokteran Indonesia (eJKI)*. 2024;12(1):1-6.
14. Pradipta, Y.A., Wulandari, D., & Ramadhani, R. Hubungan Indeks Massa Tubuh dengan Kejadian Seksio Sesarea dan Skor APGAR. *Jurnal Obstetri dan Ginekologi Indonesia*. 2023;47(2):67–74.
15. Yuliana, A., et al. Hubungan Metode Persalinan terhadap Skor APGAR Bayi Baru Lahir di RSUD Dr. Moewardi. *Jurnal Kedokteran UNS*. 2021;9(1):42–49.
16. Situmorang, A.M., et al. Berat Lahir sebagai Prediktor Skor APGAR di RSUD Haji Medan. *Jurnal Keperawatan dan Kesehatan Masyarakat*. 2022;11(2):115–120.
17. Santos S, Voegtline KM, Bastos V, et al. Pre-pregnancy obesity and maternal-fetal outcomes: a systematic review and meta-analysis. *BJOG: An International Journal of Obstetrics & Gynaecology*. 2019;126(9):1093-1105.
18. Aune D, Saugstad OD, Henriksen T, et al. Maternal body mass index and the

- risk of fetal and infant death: a systematic review and meta-analysis of prospective studies. *JAMA*. 2014;311(15):1536-1546.
19. Black M, Soloman C, Norman JE. Maternal obesity and preterm birth: a systematic review and meta-analysis. *Obes Rev*. 2013;14(12):984-996
 20. Catalano PM, Hauguel-De Mouzon S. Maternal obesity and the transmission of obesity from mother to offspring. *Annu Rev Nutr*. 2011;31(1):1-21.
 21. Schwartz B, Moni M, Obeid J, et al. Maternal obesity-induced inflammation and placental dysfunction: a key to fetal programming. *Nutrients*. 2019;11(1):162.
 22. Redman CW, Sargent IL, Staff AC. Placental stress and preeclampsia: a revised view. *Pregnancy Hypertens*. 2014;4(2):160-165.
 23. Roberts JM, Pearson G, Cutler J, et al. The pathogenesis of preeclampsia: an insightful look at the role of oxidative stress. *Clin Chem*. 2011;57(2):181-192.